



(Study Period 5 2010) Exam Period

School	NBE	Subject Area & Catalogue number	CIVE 2010	Paper	1
Course Name	Introduction to Water Engineering				

Length of Exam: 3:00
Official Reading Time: 10 Minutes
Additional Reading Time (included in length of exam): NIL
Total Recommended Reading Time: 10 Minutes

Questions	Time	Total Marks
13 questions	180 mins	100 marks

Instructions to Candidates:

Attempt all 14 questions to the best of your ability.
Write answers in the answer book only (**not** this question paper).
Start each question on a new page.
Clearly number/label every answer.

Student Notes:
2x4DbldSidedHandWrittenNotes AnyCalc

Question 1. [3 marks]

An unloaded pontoon weighs 200 kN and in plan is 12m long and 7m wide. It floats in sea water (density 1025 kg/m^3).

- (a) What is the depth of immersion of the pontoon? [1.5 marks]
(b) What is the distance between the centre of buoyancy (B) and the metacentre (M)? [1.5 marks]

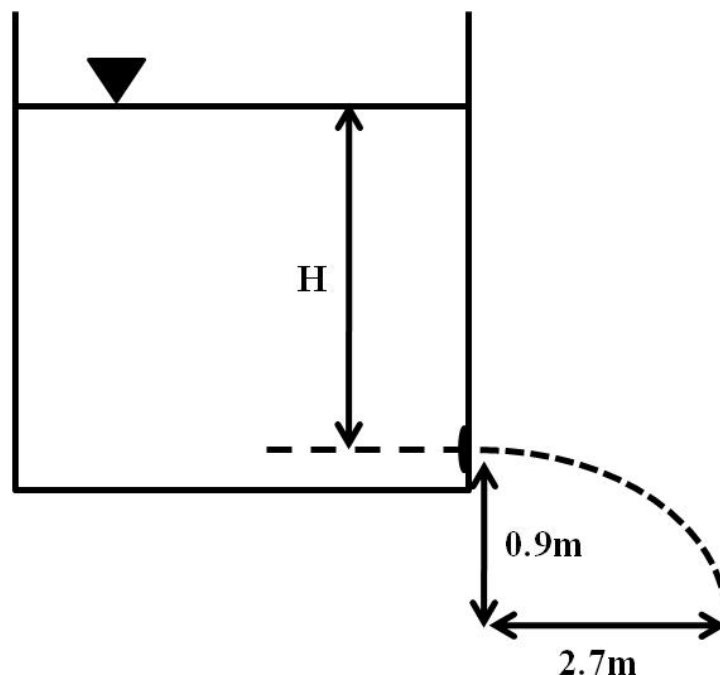
Question 2. [6 marks]

A horizontal pipeline terminates in a nozzle that discharges to the atmosphere. The pipeline has a diameter of 0.8m and operates with a velocity of flow of 2.0m/s.

- (a) What diameter nozzle is required to obtain a jet with a velocity of 7.5m/s? [2 marks]
(b) What is the pressure of the water in the pipeline? [2 marks]
(c) What is the force exerted by the water on the nozzle? [2 marks]

Question 3. [3 marks]

A jet of water discharges from a small orifice. The trajectory of the jet is measured, and is found to travel 2.7m horizontally while dropping vertically through a distance of 0.9m.



- (a) Calculate the speed of the jet. [1.5 marks]
(b) If the driving head H is 2.1m, calculate the coefficient of velocity (C_v) of the orifice. [1.5 marks]

Question 4. [12 marks]

A trapezoidal channel carries a discharge of $24.6 \text{ m}^3/\text{s}$, and has a bottom width of 12.5 m and side slopes of 63.43° (measured above horizontal).

HINT: $\tan(63.43^\circ) = 2$

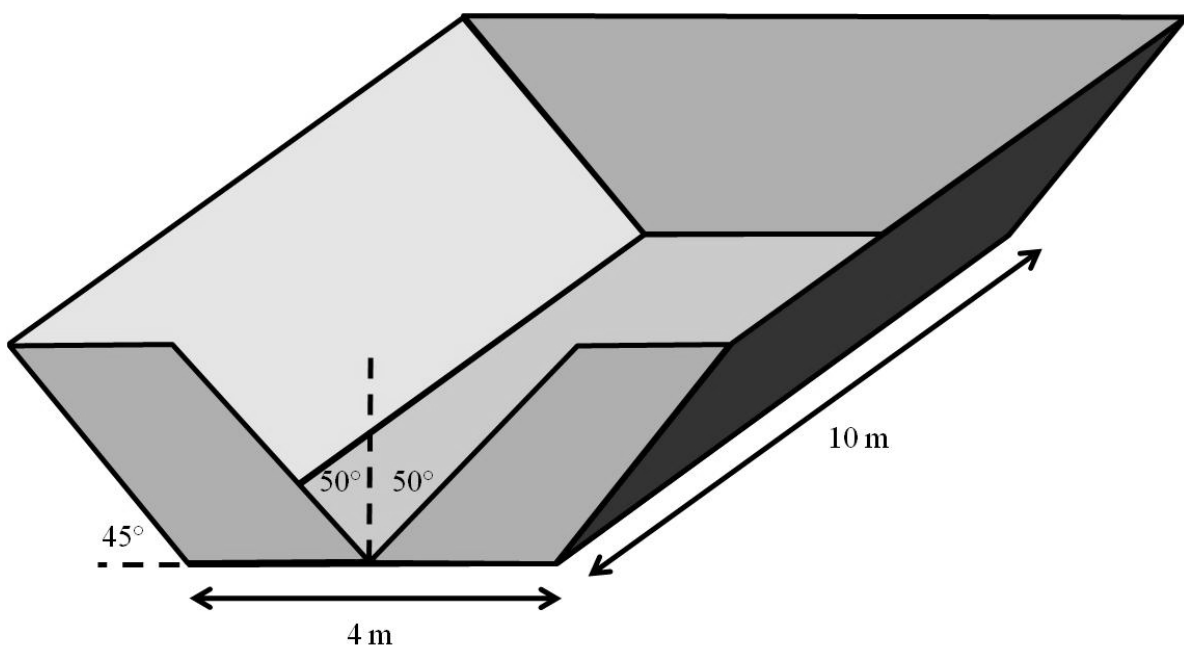
The critical water depth D_C on the channel centerline is known to be between 0.65 and 0.75 m .

Calculate:

- (a) the actual critical water depth on the channel centerline [10 marks]
- (b) the hydraulic mean critical depth D_{MC} and the critical velocity V_C [2 marks]

Question 5. [16 marks]

A tank (shown below) is rectangular in plan with a base 10 m by 4 m . The cross-section of the tank trapezoidal, with the long sides sloping outwards at 45° . The short ends of the tank are vertical. A triangular weir with $\theta/2 = 50^\circ$ is cut out of one of the vertical ends, with the bottom of the V being at base level. The weir has a coefficient of discharge of 0.58 .



- (a) Calculate the inflow rate that would be required to maintain a constant water level in the tank of 1.3 m . [2 marks]
- (b) When the inflow is stopped, use **integration** to calculate the time taken for the water level in the tank to fall from 1.3 m to 0.1 m . [8 marks]
- (c) Repeat part (b) using the **approximate technique**, with 3 slices 0.4 m thick, and calculate the percentage error between this answer and the answer obtained by integration. [6 marks]

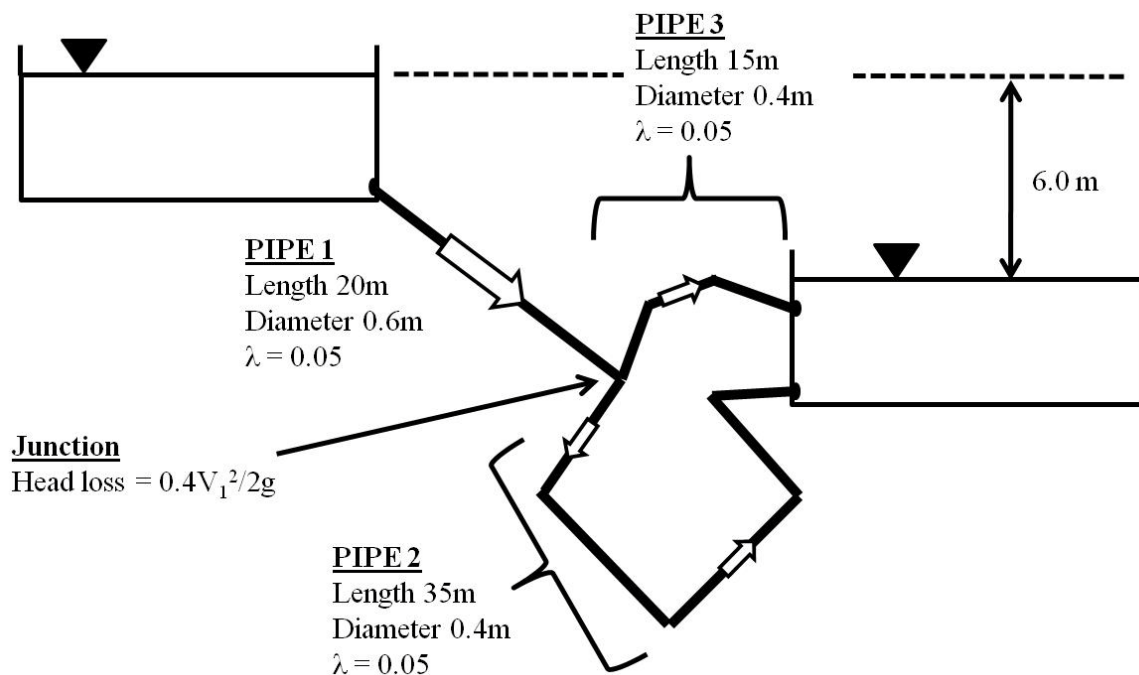
Question 6. [8 marks]

A reservoir must discharge to the atmosphere via a short horizontal pipeline. The entrance to the pipeline is sharp, and the diameter is 0.3m for the first 10m. The pipeline then expands suddenly to 0.45m diameter for the last 10m. For both pipes, $\lambda = 0.06$. If $0.5 \text{ m}^3/\text{s}$ of water must be discharged from the pipeline, determine the height that the water level in the reservoir must be above the centre of the outlet pipe:

- (a) ignoring minor losses [5 marks]
(b) considering both friction and minor losses [3 marks]

Question 7. [10 marks]

Two reservoirs have a difference in surface level of 6.0m as shown schematically below. The pipeline connecting them is initially straight (pipe 1), but then branches into two smaller pipes (pipes 2 and 3). Pipe 2 is long, with 4 tight bends (all with $K = 0.2$). Pipe 3 is shorter, with 2 shallow bends (both with $K = 0.1$). There is a head loss at the junction, as indicated.



The discharge rates in all 3 pipelines are unknown. Your task is to complete the hydraulic analysis up to the point of obtaining 3 equations for the three pipe velocities. You must include friction and minor losses in your analysis. Simplify the equations as much as possible, but you do not have to solve the three equations.

Question 8. [5 marks]

- (a) Explain how it is possible for the flow at a particular cross-section in a channel to occur at two significantly different (alternate) depths of flow for the same discharge. [2.5 marks]
- (b) Describe what is meant by a ‘hydraulic jump’, and explain where, how and why a hydraulic jump forms. [2.5 marks]

Question 9. [6 marks]

Drag force F_D is known to depend on the frontal area A , the velocity V , the fluid density ρ and the coefficient of drag C_{DR} according to the following relationship:

$$F_D \propto C_{DR} \rho A V^2$$

where C_{DR} is dependent on the Reynolds number.

Use dimensional analysis to derive an equation for the drag force F_D (N) on a sphere of diameter D (m), when it is positioned in a fluid flowing with a mean velocity V (m/s), fluid density ρ (kg/m^3) and dynamic viscosity μ (kg/ms). Use the result of your dimensional analysis to confirm the physical relationship defined above.

Question 10. [4 marks]

Water is to be pumped from a sump into a rising main, and there is a choice between two pipe diameters (D): either 150mm or 200mm. There is also a choice of two pumps (A and B). The head-discharge relationship for each pump is as follows:

Pump A

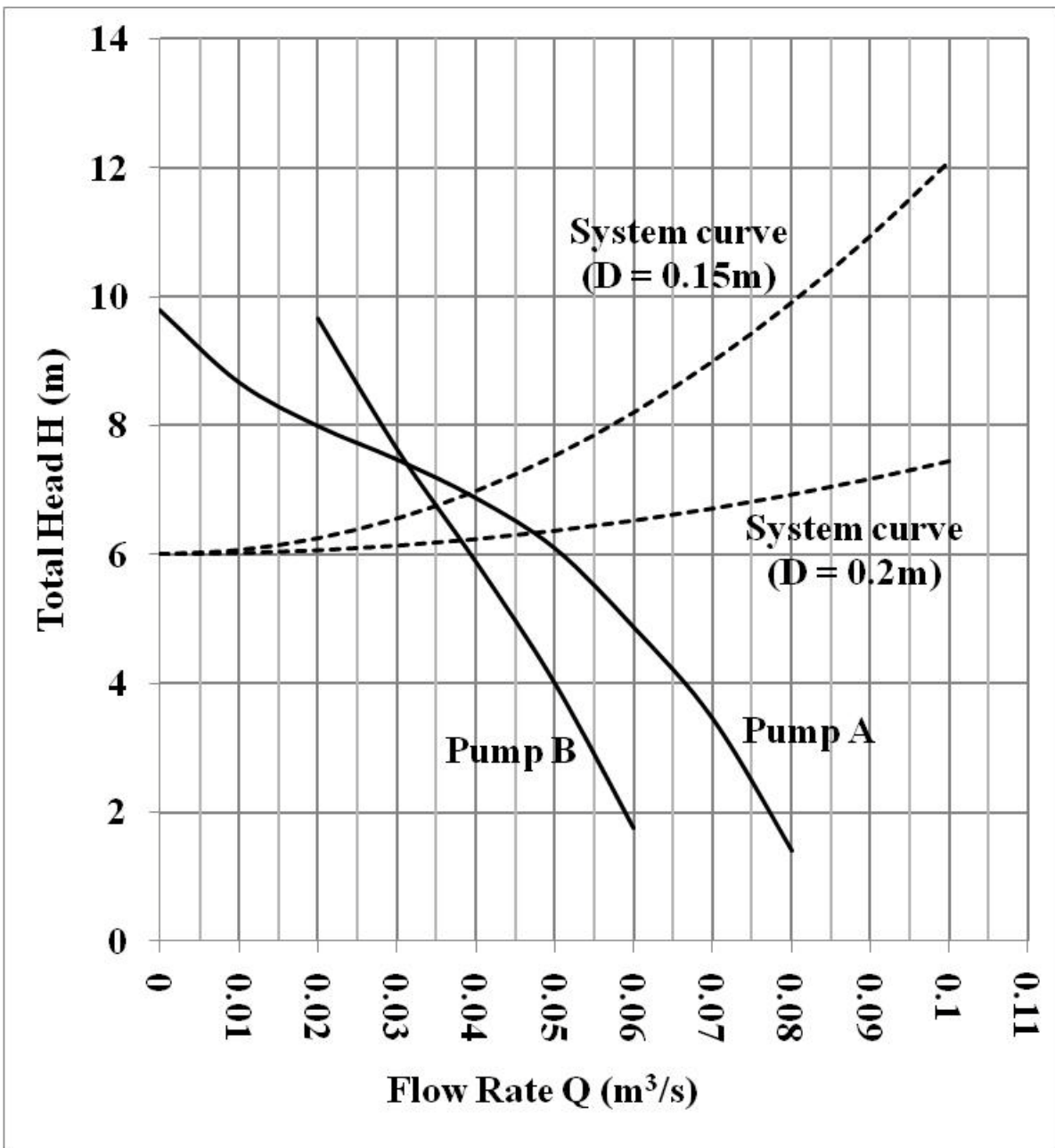
H (m)	9.8	8.68	8	7.48	6.88	6.1	4.87	3.45	1.4
Q (m^3/s)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08

Pump B

H (m)	9.65	7.63	5.88	4	1.75
Q (m^3/s)	0.02	0.03	0.04	0.05	0.06

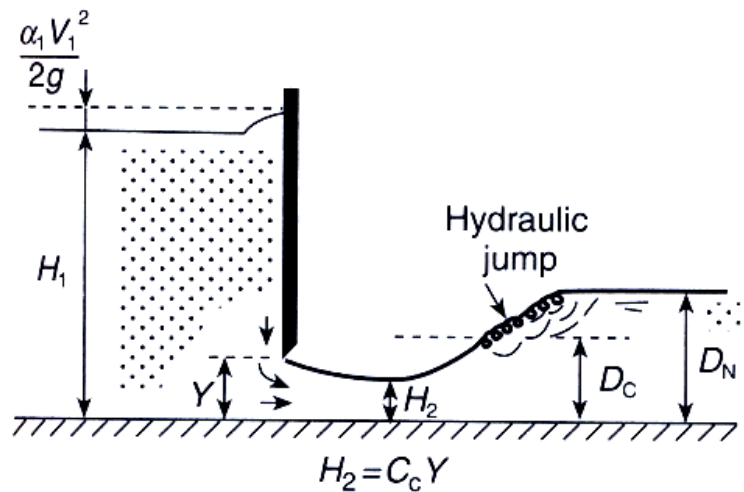
The static lift is 6.0m, and the system curves (taking into account friction and minor losses) have been plotted with the individual pump curves over the page.

- (a) Explain why there is a difference between the system curves for the two rising mains. [1 mark]
- (b) What are the discharge rates obtained from each pump when connected to each of the two possible pipe sizes? [1 mark]
- (c) If a single pump is to be used, which pump and what pipe size do you recommend for maximum flow, and what further information do you think would be needed in order to make a cost-effective decision (considering up-front and ongoing costs)? [2 marks]



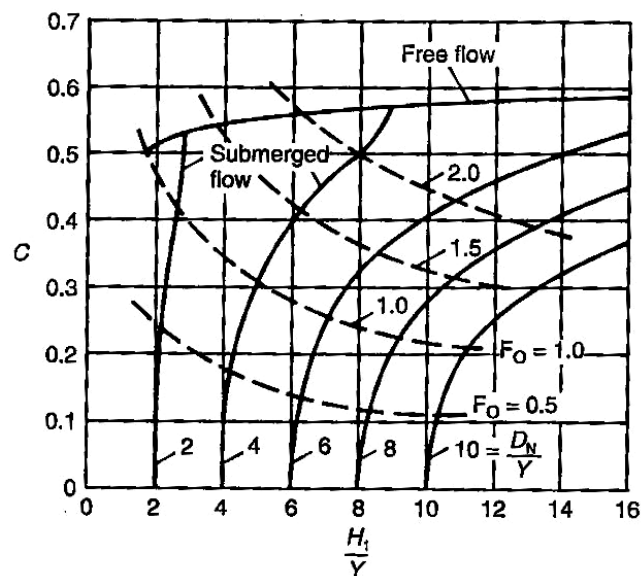
Question 11. [12 marks]

A 4.0m wide vertical sluice gate is positioned in a horizontal, rectangular channel of the same width. The gate must operate freely and allow a discharge of $15.0 \text{ m}^3/\text{s}$ to pass without inducing an upstream water depth greater than 3.5m.



- (a) Using the chart below, determine the height Y at which the gate should be set to give an upstream depth (H_1) of 3.5m. You will need to begin by guessing a value of C , so make sure you double-check this guess, and adjust by trial and error if necessary.

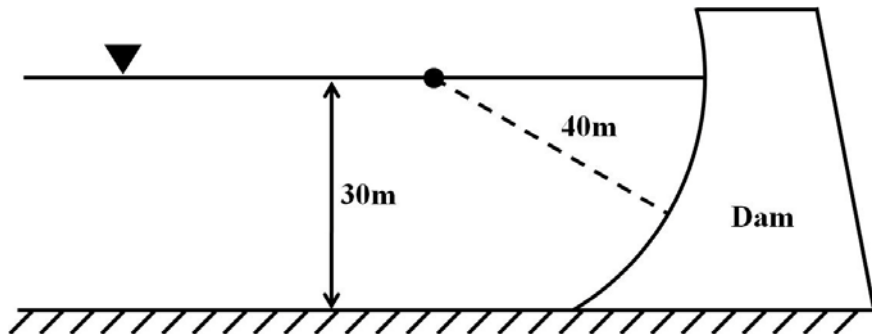
[2 marks]



- (b) Assuming a coefficient of contraction of 0.6, what is the approximate depth of water at the *vena contracta*? [1 mark]
- (c) Assuming an energy head loss through the gate of $0.05V_2^2/2g$ and $\alpha_1 = \alpha_2 = 1.05$, check the answer from (b) using the energy equation. If you find the upstream and downstream values of total energy are not equal, determine the actual depth (H_2) at the *vena contracta* by trial and error, and comment on likely sources of the observed discrepancy between (b) and (c). [5 marks]
- (d) If the normal downstream flow depth (D_N) is 1.95m, determine whether the necessary conditions exist for a hydraulic jump to form, and comment on whether the gate will discharge freely or not. [4 marks]

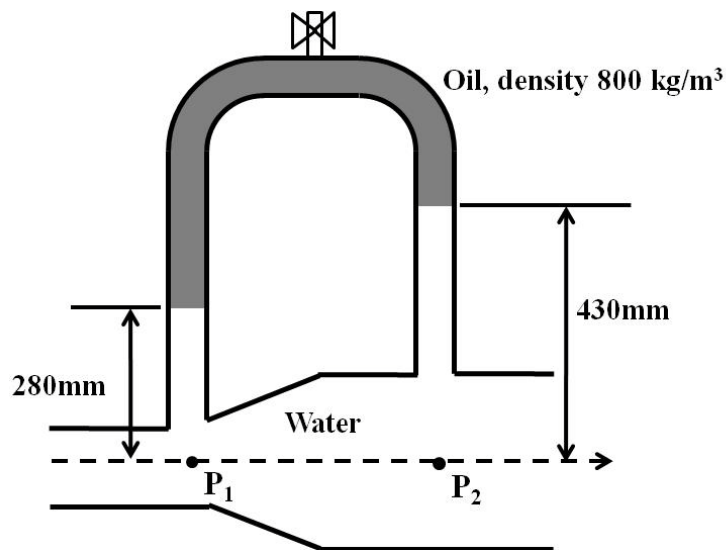
Question 12. [7 marks]

The dam in the figure below has a curved face that is part of a 40m radius circle. The dam holds back water to a depth of 30m. Calculate the magnitude and direction of the resultant hydrostatic force.



Question 13. [8 marks]

The figure below shows an inverted U-Tube manometer with oil of density 800 kg/m^3 above the pipe liquid, which is water. The pipeline is horizontal.



- (a) What is the differential pressure ($P_1 - P_2$)? [5 marks]
- (b) If the velocity at point 1 is 2.5 m/s, use the energy equation to calculate the velocity at point 2. [3 marks]