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THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Diploma in Technology - Level 3

CEX 3232 - HYDRAULICS AND HYDROLOGY
CED 1202 – HYDRAULICS AND HYDROLOGY

FINAL EXAMINATION 2006/2007

Time Allowed : **Three Hours** *Index No.*

Date : 06th March, 2007 Time : 0930 - 1230

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.

1) Water is sent through a domestic water meter and a venturimeter to a collecting tank, as shown in Figure 1. The least count of the water meter is 50 ml . The collection tank has a square cross-section of 0.5 m by 0.5 m . The water level in the collecting tank is measured using a scale marked in millimeters. A steady flow of water is sent through this system and measurements are made using the water meter, venturimeter and the collection tank.

The water meter records a volume of 2850 ml in a time of 30 seconds. The time was measured using a stop watch that has a smallest scale interval of 0.1 seconds. The difference in the differential water manometer connected to the venturimeter was found to be 19 mm, using a scale marked in millimeters. The increase in the water level in the tank during a period of 60 seconds was found to be 24 mm . The time was measured using a stop watch that has a smallest scale interval of 0.1 seconds.

a) Explain, using neat figures, how a domestic water meter works.
b) Explain, using neat figures, how a venturimeter works.
c) Estimate the discharge using the measurements made in the collection tank.
d) Calculate the possible range of error in your estimate of the discharge in section c). See below.
e) Estimate the coefficient of discharge of the venturimeter. See the note below.
f) Estimate the discharge using the measurements from the water meter.
g) Calculate the possible range of error in your estimate of the discharge in section f). See below.
h) What can you say about the accuracy of the water meter?

Note : The equation for the venturimeter is $Q = C_d A_2 \left[1 - \left(\frac{A_2}{A_1} \right)^2 \right]^{-1/2} [2g\Delta h]^{1/2}$. The venturimeter has an upstream diameter of 30 mm and a throat diameter of 15 mm .

Note : When a quantity C is calculated from the quantities A and B using the equation $C = \frac{A}{B}$, the error in C - δC - is related to the errors in A and B (δA and δB) by the equation $\frac{\delta C}{C} = \frac{\delta A}{A} + \frac{\delta B}{B}$

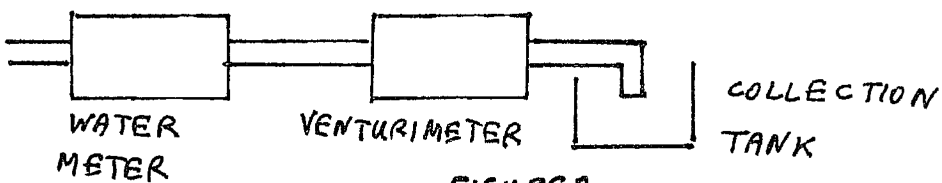

FIGURE 1

2) Water is pumped from Reservoir X to Tank Y through the pipeline ABCD as shown in Figure 2. Water is discharged from Tank Y to the atmosphere through the pipeline EFG, as shown. All the pipes have a diameter of 25 mm and a friction factor of 0.01. The length of the pipes AB, CD, EF and FG are 10 m , 5 m , 15 m and 20 m , respectively. The discharge through both pipelines is 1.2 litres per second.

a) Sketch, on graphs placed one above the other, the variation of the elevation, velocity, pressure and total heads from P, a point on the free surface of Reservoir X, to G. Identify your elevation datum.

b) Calculate the water level in Tank Y. Assume a steady flow and select reasonable values for any parameters that have not been given.

c) Calculate the pump head.

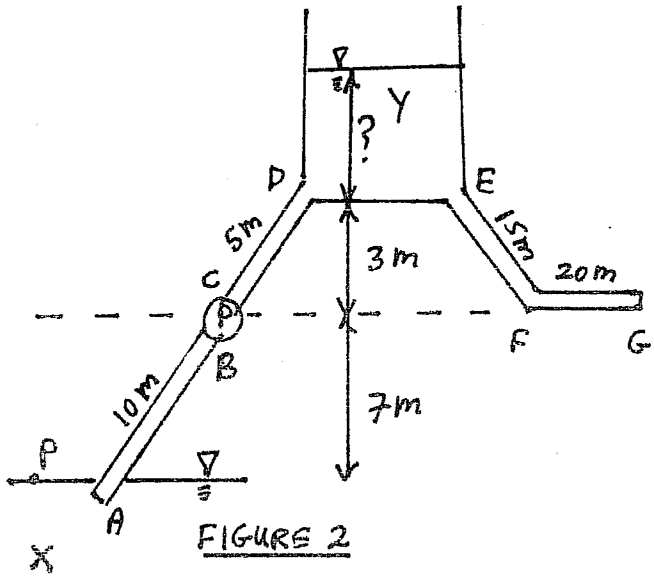

FIGURE 2

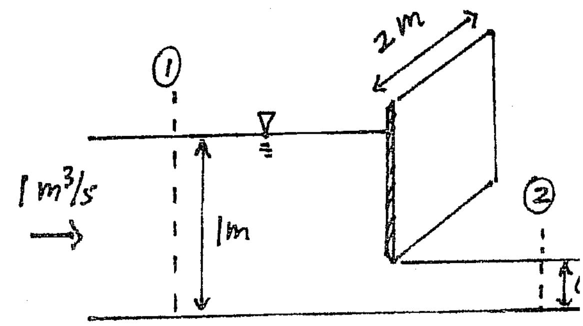

FIGURE 3

3) A tank has a square cross-section, which each side being of length **b** . The tank is filled to a depth of **h** with a liquid of density ρ .

a) What is meant by a "hydrostatic pressure distribution"?

b) Show that the force exerted on one wall of the tank by the liquid is $\frac{\rho g b h^2}{2}$.

The flow of water past a sluice gate in an open channel is shown in Figure 3. The channel has a rectangular cross-section and a width of 2 m . The depth of water at section 1 is 1 m while the depth at section 2 is 0.3 m . The discharge in the channel is 1 m^3/s and the flow is steady. The density of water is 1000 kg/m^3 .

c) State the principle of conservation of momentum as applied to a fluid control volume.

d) Calculate the flux of momentum at sections 1 and 2. Assume that the velocity distribution over the section is uniform.

e) Calculate the pressure forces at sections 1 and 2. Assume that the pressure distribution is hydrostatic.

f) Calculate the magnitude and direction of the force on the sluice gate. Neglect the effects of friction.

PART B

Answer any **two** of the **five** questions.

4) Water (density 1000 kg/m^3) flows in a pipe ABCD – which is angled at 30 degrees to the horizontal as shown in Figure 4. The pipe diameter changes suddenly from 1 cm along AB to 5 cm along CD as shown. A U-tube mercury (density 13,600 kg/m^3) manometer is connected between B and C. The mercury level in the tube connected to C is higher by 1 mm, as shown in the figure. The discharge in the pipe is found to be 1.2 litres/second. The distance between B and C is 0.5 m .

a) In which direction is the water flowing? Explain your answer.
b) Calculate the rate of energy loss between B and C.
c) Estimate, as best as you can, the difference in the manometer levels if the flow direction was reversed. Explain your answer.

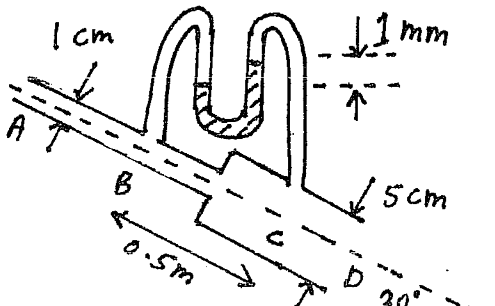

FIGURE 4

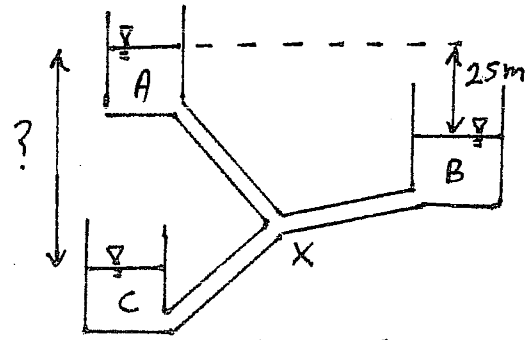

FIGURE 5

5) Three identical tanks, A, B and C, are connected by five pipes, AX, BX and CX, through a pipe junction, X, as shown in Figure 5. The tanks are open to the atmosphere, and have constant cross-section areas of 120 m^2 . The pipes AX, BX, and CX are all identical – with a diameter of 10 cm and a length of 100 m.

At a certain time the free surface of Tank A is 25 m above the free surface of Tank B. The water level of Tank A is **decreasing** at a rate of 0.7 mm/s while the water level of Tank B is **increasing** at a rate of 0.2 mm/s.

a) Calculate the friction factor of the pipes. Assume that pipe friction is the only source of energy losses. State all your assumptions.
b) Calculate the rate of change of the water level in Tank C at this time.
c) Calculate the difference between the water levels of Tank A and Tank C at this time. Explain your answer.

6) a) Explain, using a neat diagram, what the Moody diagram is.

The discharge through a uniform pipe of diameter **d** , is measured together with the head loss, $\mathbf{h_f}$, along a certain length of the pipe, **L** , during an experiment to determine the pipe friction factor. The head loss is measured for several values of the discharge when the flow is steady. It is assumed that the head loss, $\mathbf{h_f}$, is related to the average velocity in the pipe, **v** , by the expression $h_f \,\alpha\, v^n$.

b) Explain how you would estimate the value of the exponent **n** in the expression $h_f \,\alpha\, v^n$ using the results of the experiment.
c) What value of the exponent **n** would you expect when the flow through the pipe is Laminar? Explain your answer.
d) What value of the exponent **n** would you expect when the flow through the pipe is Fully Rough Turbulent? Explain your answer.

7) A large building covers an area of 2500 m^2. The gutters draining the roof of the building all lead to the same location where the water is discharged to a surface drain, as shown in Figure 7a. On a certain day it rains continuously at an intensity of 100 mm/hour beginning at 6.00 am.

a) Sketch the variation of discharge to the surface drain from 6.00 am onwards. Explain your answer.

b) What is the maximum discharge to the surface drain?

A tank is constructed between the gutters and the surface drain as shown in Figure 7b. The tank has a uniform cross-sectional area of 2 m^2 and discharges to the surface drain through a short pipe of diameter 100 mm.

c) Obtain a relationship between the height of water in the tank, **h**, and the discharge from the tank. State all your assumptions.
d) Starting with the principle of conservation of mass applied to a fluid control volume, derive the differential equation that governs the variation of the water level in the tank.
e) Sketch, on the same graph as in section a), the variation of the discharge to the surface drain if the tank is in place.
f) What is the maximum level in the tank for the given rainfall?

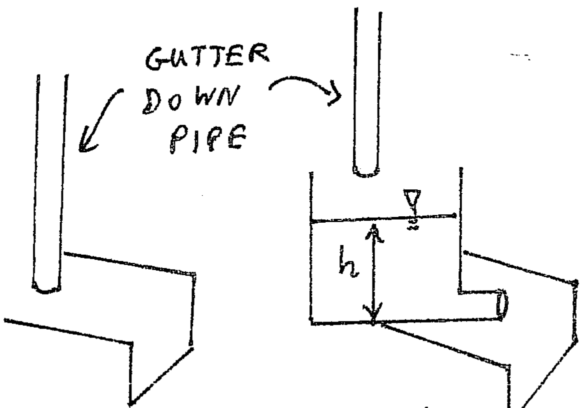

FIGURE 7a

FIGURE 7b

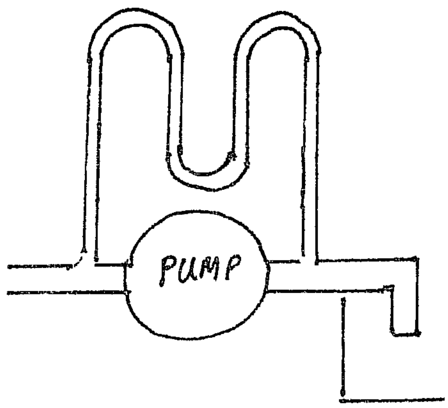

FIGURE 8

8) A Centrifugal Pump is tested at a constant rotational speed of 1,500 r.p.m. using the apparatus shown in Figure 8. The inlet and outlet of the pump is connected to a U-tube mercury (density 13,600 kg/m^3) manometer as shown, while the outlet pipe leads to a collection tank. When the discharge of water (density 1000 kg/m^3) through the pump is 2.3 litres/second the level difference in the mercury manometer is found to be 35 mm. The torque of the drive shaft of the pump under these conditions is found to be 0.2 Nm.

a) Explain, using neat diagrams, how a Centrifugal Pump works.
b) Indicate, on a neat sketch, the levels of mercury in the U-tube manometer.
b) Calculate the Pump Head.
c) Calculate the Pump Output Power.
d) Calculate the Pump Efficiency.
e) Show, on a neat diagram, the expected variation of Pump Head, Pump Output Power and Pump Efficiency with Pump Discharge for a Centrifugal Pump.