ENGINEERING TRIPOS PART IIA

Friday 25 April 2008 2:30 to 4:00

Module 3D5

WATER ENGINEERING

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

Attachment: 3D5 data sheet (5 pages).

STATIONERY REQUIREMENTS
Single-sided script paper
Graph paper (4 sheets)

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 (a) Explain the meaning of the time of concentration. Describe the rational method for predicting the runoff generated by rainfall. Any terms involved in the description should be defined fully. Why is the application of the rational method limited to small catchments only? [30%]

(b) For a catchment of area 20 km^2, it is known that two hours of uniform excess rainfall generates the distribution percentages for the outflow hydrograph over successive two-hour intervals as follows: 3, 16, 35, 27, 15, 4. The outflow is recorded from the start of the rainfall and the base flow is negligible. The soil is assumed to be dry before the rainfall event and the parameters for the Horton's infiltration model are $f_c = 10$ mm hr^{-1}, $f_0 = 30$ mm hr^{-1} and $K_f = 0.5$ hr^{-1}.

(i) In a four-hour rainfall event, rain falls uniformly at 40 mm hr^{-1} in the first two hours and at 20 mm hr^{-1} in the second two hours. Determine the peak discharge at the catchment outlet in m^3 s^{-1}. [40%]

(ii) In a different rainfall event of one-hour duration over the same catchment, the excess rain is 5 mm hr^{-1}. Estimate the distribution percentages of the outflow hydrograph over intervals of one hour. [30%]

2 (a) During a storm, flood water runs perpendicular to a straight road as shown in cross-section in Fig. 1. The incoming flow is uniform with a depth of 2 m and a velocity of 1 m s^{-1}. The road is 0.7 m above the flat plain.

(i) Ignoring bed friction and flow separation, calculate the water depth over the road. [30%]

(ii) For the same incoming flow, calculate the minimum height of the road necessary for the flow to become critical above the road. [20%]

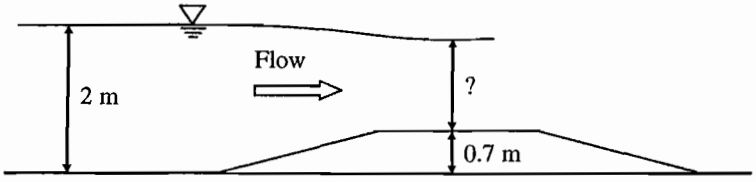

Fig. 1

(b) For gradually varied flows in a wide rectangular channel, show that the following two equations are equivalent to each other.

$$\frac{dh}{dx} = \frac{S_b - S_f}{1 - Fr^2}$$

$$\frac{dH}{dx} = S_b - S_f \quad \text{with} \quad H = h + \frac{U^2}{2g}$$

The symbols are defined in the data sheet. Discuss whether these two equations can be used to analyse hydraulic jumps. [20%]

(c) A wide river is connected to the sea. Initially the water is still, with a depth of 4 m. Then the sea level begins to drop at 1 m hr^{-1}. It can be assumed that the river bed is flat and frictionless. After one hour of the sea level falling, at what distance upriver from the river mouth will the water depth have dropped by 0.5 m? [30%]

3 A wide channel has an average bed slope of 4×10^{-5} and an average depth of 10 m. The bed consists of uniform sand of diameter 0.2 mm. The flow in the channel is uniform with a velocity of 1.0 m s^{-1}. The values of relevant parameters are listed at the end of the data sheet.

(a) What is the bed regime according to Liu's graph? [25%]

(b) Show that the height of Nikuradse's sand roughness, k_s, is about 0.2 m. [20%]

(c) The sediment concentration at 1 m above the bed is measured to be 0.061 kg m^{-3}. Calculate the suspended sediment transport rate per unit width between a height of 0.2 m above the bed and the water surface. [35%]

(d) 10 kg of pollutant is released from a line source close to the channel bank. The line source extends over the whole water depth. The other channel bank is sufficiently distant that its influence can be neglected. Using appropriate formulae in the data sheet, calculate the concentration at the bank 1000 m downstream at a time 1000 s after the release. [20%]

4 (a) Compare centrifugal, mixed and axial pumps in terms of their specific speeds. [10%]

(b) Explain why, when designing a pipeline, the pressure head should not be allowed to fall below a certain value at any point. [10%]

(c) A variable speed pump is used to deliver water from a river with a water level at 52.0 m above datum to a reservoir with a water level at 85.0 m above datum. The pipeline is 2000 m long with diameter D = 350 mm and k_s = 0.15 mm. The sum of the local head losses, including valves and outlet *etc*, can be regarded as $10 \cdot U^2/(2g)$. When running at 1000 rpm the pump has the characteristics tabulated below.

Q_p (litre/s)	0	50	100	150	200
H_p (m)	60	58	52	41	25

Calculate the discharge from the pipeline when the pump runs at 1000 rpm. [50%]

(d) When the pump is running at 1200 rpm, plot the characteristics of the pump and calculate the corresponding discharge in the pipeline. [30%]

END OF PAPER