ENGINEERING TRIPOS PART IIA

Tuesday 29 April 2003 2.30 to 4.00

Module 3D5

ENVIRONMENTAL ENGINEERING I

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.*

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

(TURN OVER

1 (a) Rain falls uniformly in space and time for a duration of 2 hours over a catchment of area 60 km^2. Over successive two-hour intervals, starting from the first drop of rain, the percentages of the total runoff above base flow recorded at the catchment outfall are 3, 18, 35, 27, 12, 5 respectively.

(i) On graph paper, draw a smooth S-hydrograph for this event, and hence estimate distribution percentages over hourly intervals for the flow above base flow at the outlet produced by uniform rain of 1 hour duration. [20%]

(ii) Estimate the peak outflow above base flow (in m^3s^{-1}) if an isolated storm of 1 hour duration causes 1 cm of excess rain uniformly across the catchment. [30%]

(b) The constants in the f-capacity equation for infiltration are f_0 = 20 mm h^{-1}, f_c = 0.5 mm h^{-1}, and K_f = 1 h^{-1}. Rainfall intensities of 30 mm h^{-1} and 20 mm h^{-1} are recorded over two successive hourly intervals. Estimate the rainfall excess (in mm h^{-1}) within each of the hourly intervals. [25%]

(c) State the assumptions of hydrograph theory, and explain how these assumptions may not hold true in reality. [25%]

2 Water is flowing with a depth of 5 m along a channel which has a constant width of 20 m. The water flows under a sluice gate and when the flow is again uniform the water depth is 1 m. In this region there is an obstruction across the bed of the channel and well downstream of this obstruction the water depth is 3 m.

(a) Sketch the water surface shape from upstream of the sluice gate to downstream of the obstruction marking on the sketch any relevant Froude numbers. [20%]

(b) Calculate the forces on the obstruction and on the sluice gate. [80%]

3 (a) A wide straight stream has a moveable bed.

(i) Describe briefly how the bed regime and water surface profile change as the flow rate varies. [20%]

(ii) State appropriate dimensionless groups which define the water flows and the bed forms. [15%]

(b) What is the bed regime of a mountain stream where the water depth is 1 m, the slope is 0.01 and the bed consists of pebbles of diameter 3 mm and specific gravity 2.65? [20%]

(c) This flow regime is to be modelled in a laboratory flume with an undistorted scale of 1/100. What would be your recommended reduction in the bed particle size? Would you insist on exact geometrical similitude and if not, why not? Explain which features of the flow you would aim to model and give the resulting friction velocity, mean velocity, particle size and particle density that would satisfy your requirements. Take the kinematic viscosity of water to be 10^{-6} m^2 s^{-1}. [45%]

4 (a) Derive the equation for concentration of sediment in suspension

$$\varepsilon \frac{\partial C}{\partial y} + WC = 0,$$

where ε is a mixing coefficient and the other symbols are defined in the Data Sheet. [30%]

(b) State and briefly discuss any assumptions made. [15%]

(c) Hence derive an expression for the way in which concentration would vary with height if ε were constant. [20%]

(d) Is the assumption that ε is constant likely to be correct? What variation of ε with height is usually assumed? [15%]

(e) The concentration of sediment is measured in a river and found to be 2 kg m^{-3} at 1 m below the surface and 10 kg m^{-3} at 3 m below the surface. If ε is assumed constant, what would its value be if the sediment were sand of diameter 0.2 mm and specific gravity 2.65? [20%]

END OF PAPER

Engineering Tripos Part IIa 2003, Module 3D5 Environmental Engineering I

Answers

1.(a) 32 m^3/s;
(b) 17.2 mm, 15 mm

2.(b) 1067.4 kN

3.(b) antidunes

4.(e) 0.046 m^2/s