Version DL/2

EGT2
ENGINEERING TRIPOS PART IIA

Friday 5 May 2023 9.30 to 11.10

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.*

*Write your candidate number **not** your name on the cover sheet.*

The values of relevant parameters are listed at the end of the 3D5 data sheet unless otherwise noted in the question.

STATIONERY REQUIREMENTS
Single-sided script paper
Graph paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 3D5 Water Engineering data sheet (5 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

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

You may not remove any stationery from the Examination Room.

1 (a) Briefly explain ‘rational method’ for estimating the peak runoff rate and why it is only suitable for small drainage areas. [15%]

(b) The unit hydrograph method assumes that the catchment response is linear to the rainfall. Give two examples to show that such an assumption may not hold true in reality. [15%]

(c) The distribution percentages for a unit hydrograph whose unit time is 2 hours are 5, 20, 30, 40, 5. The area of a drainage basin is 100,000 m^2. The constants in the Horton infiltration equation are f_0 = 10 mm h^{-1}, f_c = 2 mm h^{-1} and K_f = 1 h^{-1}. For a storm consisting of 10 mm of rain in the first hour, no rain in the second hour and 10 mm of rain in the third hour, estimate:

(i) the hydrologically effective rainfall in each hour; [30%]

(ii) the maximum discharge rate produced at the exit of this drainage area by this storm. [40%]

2 (a) Explain why a steady open channel flow cannot undergo a smooth transition from upstream supercritical flow to downstream subcritical flow. [15%]

(b) Show that for a stationary hydraulic jump the velocities (U_1, U_2) and water depths (h_1, h_2) on the two sides of the jump are related by: [25%]

$$U_1 U_2 = \frac{1}{2} g(h_1 + h_2) .$$

(c) Using the gradually varied steady flow equation, prove that the water surface observes a dip over a hump when the flow is subcritical. [20%]

(d) An estuary is assumed to be flat and frictionless. Its width b varies with distance x down the estuary as follows, with b and x measured in metres.

$$b = 2 + 0.08x .$$

The initial flow rate and water depth are 10 m^3 s^{-1} and 2 m, respectively, along the whole estuary. Estimate the time taken for a small disturbance at cross section x =100 m to propagate upstream to cross section x = 0. (NB: The small disturbance travels at a speed of $\sqrt{gh}$, which is a constant in this question, relative to mean flow velocity.) [40%]

3 A wide straight stream has a sediment bed. The bed is composed of sand of particle diameter 3 mm, and the bed slope is 0.0005. The water depth is 1 m. Assume that the bed is plane with a roughness height of 6 mm.

(a) Estimate the unit-width flow rate. [10%]

(b) Using Meyer-Peter and Müller formula, estimate the unit-width bedload sediment transport rate in kg m^{-1} s^{-1}. [35%]

(c) Estimate the suspended sediment concentration in kg m^{-3}, 12 mm above the bed based on Zyserman and Fredsøe formula. [40%]

(d) 2 kg of pollutant suddenly falls into the stream from the bank and quickly dissolves. Estimate the maximum concentration of the pollutant at the bank 300 m downstream. It can be assumed that the streamwise pollutant transport is dominated by advection. [15%]

4 (a) Briefly explain the differences between the classical boundary layer flow over an airplane's wing and the boundary layer flow in open channels. [15%]

(b) In unsteady open channel flows, there are two families of characteristic curves. Under what conditions are one family of characteristic curves straight lines? [15%]

(c) A cast iron pipeline of diameter 450 mm, surface roughness height 0.225 mm and length 1500 m links two reservoirs A and B. The water level in Reservoir A is 37 m above that in Reservoir B. There are 6 bends along the pipe, and each has a local loss coefficient of 0.25. The entrance and exit loss coefficients are 0.5 and 1.0, respectively.

(i) Under gravity, flow occurs from Reservoir A to Reservoir B. Estimate the flow rate. [30%]

(ii) A pump with the following characteristics is installed on the pipeline to force water to flow from Reservoir B to Reservoir A. Estimate the flow rate. [40%]

Q (m^3 s^{-1})	0	0.2	0.4	0.6	0.8
H (m)	100	91	75	53	24

END OF PAPER

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Answers

1.

(c.i) 2.94 mm in the 1st hour, 0 in the 2nd hour, 6.14 in the 3rd hour

(c.ii) 45.56 litre/s

2.

(d) 30 s

3.

(a) 1.33 m^2/s

(b) 0.176 kg/(m s)

(c) 0.024 kg/m^3

(d) 0.0214 kg/m^3

4.

(c.i) 0.556 m^3/s

(c.ii) 0.49 m^3/s