EGT2
ENGINEERING TRIPOS PART IIA

Friday 29 April 2016 2 to 3.30

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 Data Book unless otherwise noted in the question.

STATIONERY REQUIREMENTS
Single-sided script paper

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

10 minutes reading time is allowed for this paper.

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

1 (a) For a two-hour rainfall with a total quantity of 40 mm over a catchment with an area of 7 km^2, the excess flow rate over successive two-hour periods at the outlet of the catchment varies according to:

Duration (hours)	0-2	2-4	4-6	6-8	8-10	10-12	12-14
Excess flow rate (m^3 s^{-1})	3	8	5	2	1	0	0

Prior to this rainfall, two of the infiltration-related coefficients are f_0 = 15 mm h^{-1} and K_f = 0.6 h^{-1}. Calculate the value of f_c . [30%]

(b) The distribution percentages for a unit hydrograph with unit time of 2 hours are:

Duration (hours)	0-2	2-4	4-6	6-8	8-10	10-12	12-14
Flow rate (%)	5	20	30	40	5	0	0

The area of an impervious drainage basin is 1 km^2. Determine the maximum flow rate in m^3 s^{-1} produced at the exit of this drainage area by a three-hour storm consisting of 20 mm h^{-1} rain in the first hour and 10 mm h^{-1} rain in the next two hours. [60%]

(c) Briefly explain the difference between rapidly varied flows and gradually varied flows. [10%]

2 (a) Uniform flow occurs in a wide rectangular channel with a water depth of 1.5 m. The shear stress at the bottom of the channel is measured to be 10 N m^{-2}. The Manning roughness coefficient of the channel is estimated to be 0.025 s $m^{-1/3}$.

(i) Calculate the depth-averaged flow velocity. [20%]

(ii) Calculate the Reynolds-averaged flow velocity at the free surface. [20%]

(iii) Fig. 1 shows that a local increase in the bed elevation causes the free surface level to drop by 0.05 m. Estimate the local bed elevation change Δz. [20%]

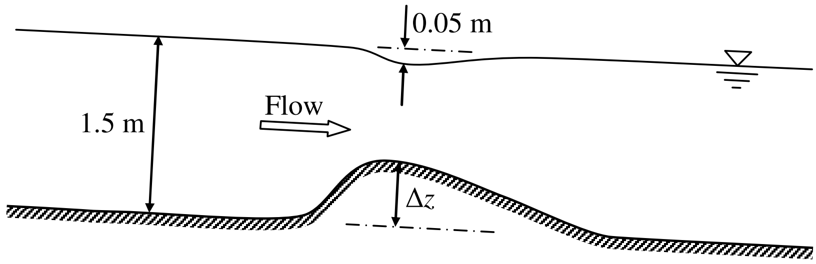

Fig. 1

(b) In a river of rectangular cross section, the flow is uniform with a depth of 2.2 m and velocity of 0.6 m s^{-1}. The river flows into a lake, whose water level begins to rise at a rate of 0.5 m h^{-1}. Ignore the bed slope and the bottom friction of the river.

(i) Prove that one family of characteristic curves is straight. [15%]

(ii) Calculate the time taken for the water level 1.3 km upstream of the river mouth to rise by 0.3 m. [25%]

3 (a) Briefly explain the physical meaning of the Shields parameter. [10%]

(b) A wide river of depth 3 m has a bed slope of 2×10^{-4}. The concentration of sediment at 0.1 m above the bed is found to be ten times larger than that at 1 m above the bed.

(i) Calculate the fall velocity of the suspended sediment. [25%]

(ii) Show that the sediment particle size is roughly 0.2 mm. [10%]

(iii) Using Liu's diagram, determine the type of the bedform. [10%]

(iv) The bed roughness height is measured to be 0.1 m. Use van Rijn's formula to estimate the bedload sediment transport rate per unit width, with the units of kg m^{-1} s^{-1}. Take the grain-related roughness height to be three times the particle diameter. [30%]

(v) Ten kilograms of dye is quickly dumped into the middle of the river and is instantly dissolved. Assuming the dye to be a conservative substance and ignoring the effect of the river banks, estimate the maximum concentration of the dye cloud 10 minutes later. [15

4 (a) For flow in an open channel of circular cross-section, show that the critical flow occurs when:

$$Q^2 = gD^5 \frac{(\beta - \sin\beta\cos\beta)^3}{64\sin\beta}$$

where Q is the flow rate, g is the gravitational acceleration, D is the channel diameter, and β is the angle in radians as defined in Fig. 2. [25%]

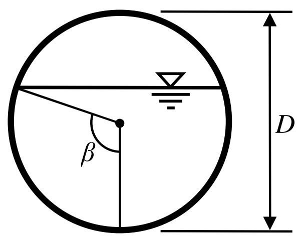

Fig. 2

(b) Water is pumped from one reservoir to another. The water surface elevation in the receiving reservoir is 10 m higher than that in the source reservoir. The pipeline connecting the two reservoirs has length 5 km, diameter 300 mm and roughness height 0.15 mm. When operating at 1200 rpm, the pump characteristic curve can be written as:

$$H_p = 47 - 0.03Q_p - 0.007{Q_p}^2$$

where H_p is the manometric head in metres and Q_p is the flow rate in litres per second. The speed of the pump is varied to deliver a flow rate of 70 litres per second. Ignore the local losses of the pipe flow.

(i) Calculate the head of the duty point. [25%]

(ii) Calculate the rotational speed of the pump. [50%]

END OF PAPER

Answers:

1 (a) $f_c = 3.58$ mm/h

(b) 2.17 m^3/s

2. (a.i) 1.37 m/s, (a.ii) 1.6 m/s, (a.ii) 0.234 m

(b.ii) 2422 s

3. (b.i) 0.0264 m/s, (b.iii) transition bedform, (b.iv) 0.12 kg/m/s, (b.v) 0.0021 kg/m^3

4. (b.i) 70 l/s, 25.4 m, (b.ii) 1380 rpm

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