Version DL/2

EGT3
ENGINEERING TRIPOS PART IIA

Monday 6 May 2019 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.

1 (a) Explain what the excess rainfall is and why infiltration is not accounted for after the rainfall stops in most unit-hydrograph analyses. [30%]

(b) State the assumptions of unit-hydrograph theory and explain how these assumptions may not hold true in reality. [20%]

(c) The distribution percentages for a unit hydrograph whose unit time is 2 hours are 5, 20, 30, 40, 5. The area of an impervious drainage basin is 10 km^2 and the base flow rate is 10 m^3 s^{-1}. Determine the maximum flow rate produced at exit from the drainage area by a storm consisting of 10 mm h^{-1} rain for 2 hours and subsequent 20 mm h^{-1} rain for 1 hour. [50%]

2 (a) For a frictionless rectangular open channel with uniform bed slope S_b and constant unit-width discharge q, prove that the variation of the water depth h with the streamwise coordinate x satisfies the following relationship:

$$x = \frac{1}{S_b}\left(h + \frac{q^2}{2gh^2}\right) + K$$

where K is a constant. [30%]

(b) 100 kg of pollutant falls into a wide river of bed slope 5×10^{-4}, depth 2 m and flow velocity 1 m s^{-1}. The pollutant dissolves quickly in water. The position of the pollutant falling is 5 m away from one bank, while the other bank is sufficiently distant to be neglected. Estimate the pollutant concentration 1000 m downstream, 2 m away from the bank, and 1000 s after the pollutant falls in. [40%]

(c) A rectangular channel carries a steady flow with depth 1.8 m and velocity 0.6 m s^{-1} towards a pumping station at its downstream end. At time zero, the pumping station increases its discharge rate, causing the water depth immediately upstream of the pumping station to drop from 1.8 m to 1.5 m in 1 minute. When does the water depth 500 m upstream of the pumping station decrease to 1.5 m? [30%]

3 (a) Describe briefly how the bedform of a sandy channel evolves as the Froude number increases. [15%]

(b) Explain why dunes migrate downstream while anti-dunes migrate upstream. [10%]

(c) At the equilibrium conditions in steady flows, the equation for the concentration of sediment in suspension is

$$w_s \bar{c} + D_{tz} \frac{d\bar{c}}{dz} = 0$$

(i) State the physical meaning of the two terms in this equation. [15%]

(ii) Assuming D_{tz} is constant, show that the sediment concentration varies exponentially with height. [10%]

(iii) How should D_{tz} vary with depth in order to obtain the Rouse profile? [10%]

(d) The bed of a wide river is composed of sediment of grain size 0.2 mm. The river depth and flow velocity are 1 m and 1.7 m s^{-1} respectively. The thickness of the bed layer and bed roughness are both 0.01 m. The sediment concentration at the top of the bed layer is 9.9 kg m^{-3}. Estimate the sediment transport rate in suspension per metre width of the channel. [40%]

4 (a) Heading downstream, the bed slope of a wide channel suddenly increases from 0.0025 to 0.0050. The channel is very long, so the flow can be regarded as uniform sufficiently upstream or downstream of the break in the slope. The Manning's roughness coefficient is 0.02 s $m^{-1/3}$. The unit-width discharge is 5.75 m^2 s^{-1} along the channel.

(i) Show that the critical water depth h_c is 1.5 m and prove that the critical water depth is observed at the break in the slope. [30%]

(ii) Estimate the distances over which the water depth changes from 1.6 m to 1.5 m and from 1.5 m to 1.4 m. [30%]

(b) When running at 750 rpm, a centrifugal pump gives the following relationship between head and discharge:

Q (litre s^{-1})	0	5	9.5	14	18.5	23
H (m)	32.3	32.0	31.4	29.3	23.8	17.0

(i) The pump is connected to a pipe which discharges to atmosphere at 20 m above sump level, and the total energy loss follows the equation

$$h_f = 0.02Q^2$$

where h_f and Q are in m and litre s^{-1} respectively. Show that the pump discharge is around 17 litre s^{-1}. [20%]

(ii) It is expected that future encrustation in the pipe will reduce the pipe diameter and increase the friction factor so that the total energy losses in the system will become

$$h_f = 0.03Q^2$$

where h_f and Q are in m and litre s^{-1} respectively. Calculate the new pump speed required to maintain the discharge at 17 litre s^{-1}. [20%]

END OF PAPER

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