EGT2
ENGINEERING TRIPOS PART IIA

Friday 7 May 2021 9.00 to 10.40

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 and at the top of each answer sheet.*

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

STATIONERY REQUIREMENTS
Write on single-sided paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed.
Attachment: 3D5 Water Engineering data sheet (5 pages).
You are allowed access to the electronic version of the Engineering Data Books.

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

The time taken for scanning/uploading answers is 15 minutes.

Your script is to be uploaded as a single consolidated pdf containing all answers.

1 (a) For a two-hour rainfall over a catchment, the percentages of the rainfall-generated outflow at the catchment outlet, over successive two-hour intervals, are 5, 20, 30, 40, 5. The area of the catchment is 1 km^2 and the constants in the Horton equation are $f_0 = 10$ mm h^{-1}, $f_c = 2$ mm h^{-1}, $K_f = 1$ h^{-1}. Sketch the hydrograph at the catchment outlet generated by a four-hour rainfall with a constant intensity of 10 mm h^{-1}. [60%]

(b) A two-hour storm over an impervious basin consists of 20 mm h^{-1} rain in the first hour and 40 mm h^{-1} rain in the second hour. Starting from the onset of the rainfall, the excess flow rate over four successive one-hour periods is recorded to be 2.5 m^3 s^{-1}, 8.6 m^3 s^{-1}, 9.3 m^3 s^{-1} and 5.2 m^3 s^{-1}. Assuming the basin response is linear:

(i) show that the 20 mm h^{-1} rain occurring in the first hour generates 3.6 m^3 s^{-1} discharge in the second one-hour period; [20%]

(ii) what is the discharge in the third one-hour period generated by the 20 mm h^{-1} rain occurring in the first hour? [20%]

2 (a) A flood protection scheme involves the replacement of a 1000-metre-long meandering reach of a river by a straight cut-off channel of length 400 m. Both the meandering river and the cut-off channel are 5 m wide and 2.5 m deep. The roughness height of the meandering river is 0.25 m, while it is 0.005 m for the cut-off channel. When both the river and the channel run full, estimate the ratio of the flow rate in the cut-off channel to that in the meandering reach of the river. [25%]

(b) Prove that the water surface drops over a hump in the bed when the flow is subcritical. [25%]

(c) Uniform flow with velocity 0.5 m s^{-1} and depth 2.25 m occurs in a prismatic rectangular channel. At time $t = 0$, a hydroelectric plant begins to release water into the channel, causing the water depth immediately downstream of the hydroelectric plant to increase parabolically for 100 s as follows:

$$h = (1.5 + 0.002t)^2$$

where h is in metres and t in seconds. Ignoring the bed friction and bed slope, estimate the specific discharge 200 m downstream of the hydroelectric plant at $t = 100$ s. [50%]

3 (a) The depth of flow in a wide river is 3 m. The volumetric concentration of sediment is measured to be 10^{-1} at 10 mm above the bed and 10^{-4} at 2 m above the bed. The grainsize of the suspended sediment is 0.2 mm.

(i) Estimate the bed slope of the river. [30%]

(ii) Choose an appropriate graph in the data sheet to decide what bedform is present. [20%]

(iii) A conservative pollutant is discharged into the river from an outfall beside the riverbank at a rate of 5 kg s^{-1}. The peak concentration of the pollutant at the cross-section 150 m downstream of the outfall is 0.5 kg m^{-3}. Estimate the flow speed and the bed roughness height of the river. [30%]

(b) Show how the Colebrook-White formula can be modified to eliminate the friction factor and explain how this modified equation forms the basis of pipe design charts like the example shown in Fig. 1. [20%]

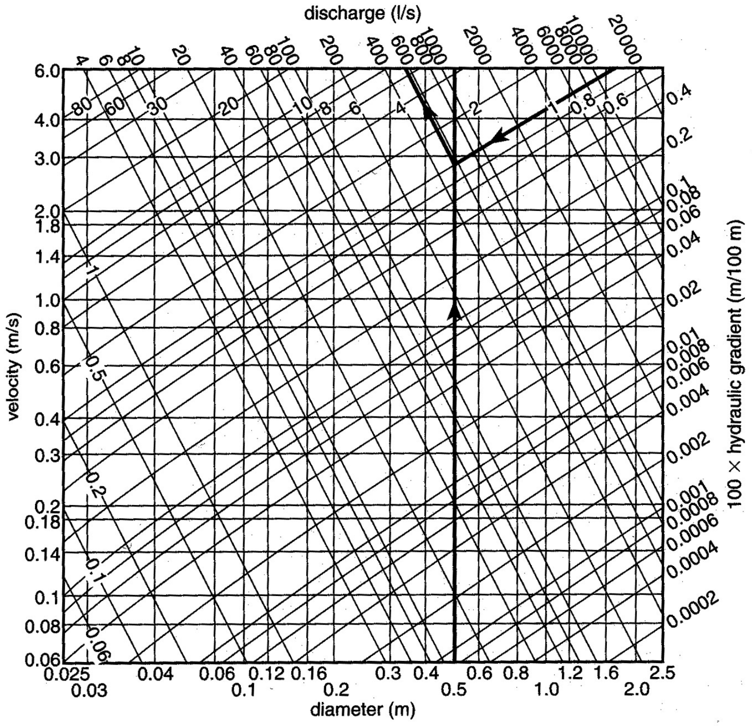

Fig. 1

4 Water is transferred by a one-kilometre-long pipe from a water treatment works, with a water surface elevation of 50 m, to a service reservoir, with a water surface elevation of 20 m. The diameter and roughness height of the cast iron pipe are 225 mm and 0.045 mm, respectively. Ignore all the local losses in the pipe flow.

(a) Calculate the flow rate in the pipe when driven purely by gravity. [50%]

(b) A variable-speed booster pump is available to increase the flow rate to 200 litre s^{-1}. When operated at 1000 rpm, the following characteristics are recorded. Estimate the operating speed of the pump in order to deliver the required flow rate. [50%]

Q (litre s^{-1})	0	50	100	150	200	250	300
H (m)	65	63	59	52	43	31	13

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Answers

1.

(b.ii) 2.1 $m^3 s^{-1}$

2.

(a) 3.1

(c) 3.62 $m^2 s^{-1}$

3.

(a.i) 1.23×10^{-4}

(a.ii) Transition from dunes to antidunes

(a.iii) $U = 0.87$ m s^{-1}, $K_s = 0.11$ m

4.

(a) 116.8 litre s^{-1}

(b) 1090 rpm