Version DL/2

EGT2
ENGINEERING TRIPOS PART IIA

Friday 6 May 2022 9.30 am to 11.10 am

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 extra 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) Explain what is meant by ‘hydrologically effective rainfall’. [10%]

(b) Rain falls for four hours over a small catchment. It can be assumed that the rainfall excess is uniformly distributed in space and time during these four hours. The distribution percentages of the outflow hydrograph over successive intervals of four hours are 4, 14, 30, 25, 16, 8 and 3. Derive the outflow hydrograph that would result from two hours of uniform rainfall excess. [35%]

(c) Rain falls uniformly over a catchment of area 10 km^2 at 10 mm h^{-1} for the first two hours and then at 30 mm h^{-1} for the next two hours. Prior to this rainfall, the Horton *f*-capacity constants are $f_0 = 20$ mm h^{-1}, $f_c = 5$ mm h^{-1} and $K_f = 0.5$ h^{-1}.

(i) Calculate the total volume of runoff as a result of this four-hour rain. [35%]

(ii) Assume that the rainfall-runoff response of this catchment is the same as that of the catchment in part (b). Estimate the peak outflow in m^3 s^{-1} and the time when this peak outflow occurs as a result of this four-hour rain. [20%]

2 (a) Briefly explain what fully developed boundary layer flow is. [10%]

(b) An open channel of symmetric triangular cross section is laid with a bed slope of 0.01, as shown in Fig. 1. The Manning roughness coefficient is 0.013 s $m^{-1/3}$. The side slope angle of the channel is 60^{o} relative to the horizontal. The flow in the channel is uniform with a discharge rate of 6 m^3 s^{-1}.

(i) What is the water depth? [25%]

(ii) Is the flow subcritical or supercritical? [20%]

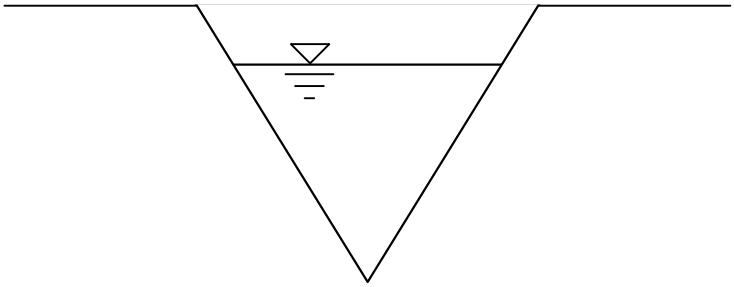

Fig. 1

(c) A rectangular channel of Manning roughness coefficient 0.015 s $m^{-1/3}$, bed slope 0.003 and width 2.5 m carries steady flow of 5.5 m^3 s^{-1}. The water depth at one section is 1.4 m. Estimate the water depth 15 m downstream of this section. [25%]

(d) Water in a long horizontal frictionless flume is initially stationary with a depth of h. The downstream gate is suddenly opened, and the flow there remains critical. The flow inside the flume remains subcritical. Prove that the water depth at the downstream end of the flume is a constant of $4h/9$. [20%]

3 (a) A canal is constructed to convey clear water. The bed slope is 0.001. Its cross-section is of a symmetric trapezoidal shape, with a base width of 1 m and side slopes making a 20^{o} angle with the horizontal. The canal bed and banks are composed of sediment with a grain diameter of 10 mm. Show that the maximum water depth allowed is 1.78 m. [35%]

(b) The flow in a mountain stream occurs with a water depth of 0.2 m and the flow velocity of 0.6 m s^{-1}. The bed slope is 0.001 and the bed consists of sediment of diameter 1 mm.

(i) Predict the bed regime using Liu's diagram. [30%]

(ii) Take the grain-related roughness height to be equal to the sediment diameter. Using the Meyer-Peter and Müller formula, estimate the bedload sediment transport rate per unit width of the stream in kg m^{-1} s^{-1}. [30%]

(iii) Estimate the mixing coefficient in the longitudinal direction of the flow. [5%]

4 (a) Briefly explain the difference between diffusion and advection for the transport of materials in a flowing fluid. [10%]

(b) Water is transferred from a sump to a water tank. The water surface elevations in the sump and water tank are 50 m and 60 m, respectively. The pipeline that connects the sump and water tank is 150 m long, with roughness height 0.02 mm and internal diameter 0.2 m. The entrance and exit loss coefficients are 0.5 and 1.0, respectively.

(i) A pump with an impeller size of 0.3 m and rotational speed of 600 rpm gives the following characteristics. Calculate the flow rate to the water tank. [45%]

Q (litre s^{-1})	0	100	200	300	400	500	600
H (m)	65.0	63.0	59.0	52.0	43.3	31.0	13.0

(ii) The pump in part (i) is replaced by a new pump of the same shape, but with an increased impeller size of 0.4 m and reduced rotational speed of 480 rpm. Estimate the new flow rate to the water tank. [45%]

END OF PAPER

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Answers

1.

(c.i) 3.98×10^5 m^3

(c.ii) 9.12 m^3 s^{-1}, 11 hours after the rain starts.

2.

(b.i) 1.58 m

(b.ii) Supercritical flow

(c) 1.44 m

3.

(b.i) Dunes

(b.ii) 0.0095 kg/(m s)

(b.iii) 0.053 m^2/s

4.

(b.i) 273 litre s^{-1}

(b.ii) 318 litre s^{-1}