Version DL/3

EGT2
ENGINEERING TRIPOS PART IIA

Monday 8 May 2017 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
Graph 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) The distribution percentages for a unit hydrograph, whose unit time is 2 hours, are 5, 20, 30, 40, 5. Determine the maximum flow rate in litre s^{-1} produced at the exit from the drainage area by a one-hour storm with an intensity of 20 mm per hour. The area of the drainage basin is 10,000 m^2 and the infiltration-related coefficients are f_0 = 10 mm h^{-1}, f_c = 2 mm h^{-1} and K_f = 1 h^{-1}. In this calculation, only the loss due to infiltration needs to be considered. [45%]

(b) Only the loss due to infiltration is considered in the above calculations. What other possible losses might exist? [10%]

(c) State the assumptions of the unit hydrograph theory. [10%]

(d) A 3 m wide concrete drain of rectangular section passes beneath a road using a culvert, as sketched in Fig. 1. The bed slope of the drain is 0.01, and its Manning roughness coefficient is 0.013 s $m^{-1/3}$. The width of the open channel flow is reduced to 2.5 m in the culvert. If the channel carries a flow of 19 $m^3 s^{-1}$, show that:

(i) h_1 is approximately 1.11 m; [15%]

(ii) the water depth h_2 in the culvert is approximately 1.56 m. [20%]

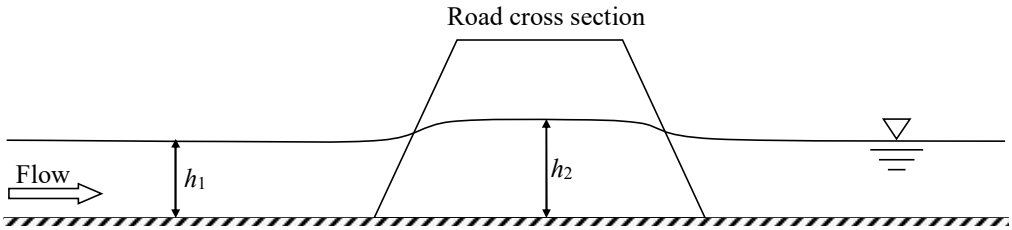

Fig. 1

2 (a) A rectangular channel has width 10 m, bed slope 0.0005 and flow rate 50 $m^3 s^{-1}$.

(i) Calculate the critical water depth. [15%]

(ii) If uniform flow in the channel occurs with a water depth of 3 m, estimate the roughness height of the solid surfaces. [15%]

(b) A fully-developed tidal bore is propagating upstream in a rectangular river at a constant speed. Prior to the arrival of the bore, the flow in the river is uniform with water depth 3 m and velocity 0.5 m s^{-1}. After the arrival of the bore, the water depth rises to 4 m. Treating the bore as a moving hydraulic jump, estimate the propagating speed of the bore. [30%]

(c) A long river of rectangular cross-section flows into a lake. The water depth and flow velocity in the river are 4 m and 1 m s^{-1}, respectively. An underwater landslide in the lake causes the water depth at the river mouth to linearly rise to 4.05 m in 20 s and then linearly drop back to 4 m in the next 20 s. Neglect the river slope and bed friction in the following analysis. Three minutes after the water depth starts to change at the river mouth, calculate:

(i) the streamwise length over which the water depth rises from 4 m to 4.05 m in the direction of the flow; [25%]

(ii) the streamwise length over which the water depth falls from 4.05 m to 4 m in the direction of the flow. [15%]

3 (a) Explain why a smooth transition from supercritical to subcritical flow is not possible in reality. [20%]

(b) Briefly explain the two axes of the Shields diagram and what the Shields curve describes. [10%]

(c) A wide river of depth 3 m has a bed slope of 0.0004 and a depth-averaged flow velocity of 2 m s^{-1}. The suspended sediment concentration is measured to be 200 kg m^{-3} at 1 cm above the bed, and the grain size is measured to be 0.2 mm.

(i) Calculate the sediment concentration at 1 m above the bed. [20%]

(ii) Estimate the sediment transport rate, per metre width of the channel, between 1 cm and 1 m above the bed. [25%]

(iii) Pollutant is discharged through an outfall located 2 m away from the river bank. The concentration of the pollutant at a location 100 m downstream of the outfall and 0.1 m away from the same river bank is measured to be 0.01 kg m^{-3}. Neglecting the influence of the other river bank, estimate the release rate of the pollutant. [25%]

4 (a) A three-metre wide rectangular channel is laid on a slope of 0.002 and has a Manning roughness coefficient of 0.015 s $m^{-1/3}$. At a certain section the water depth is 0.6 m, while 60 m downstream of this section the water depth is 0.67 m. Estimate the flow rate. [25%]

(b) Briefly explain why the longitudinal dispersion coefficient in many rivers is significantly larger than the value given in the Data Book. [10%]

(c) The characteristics of a variable-speed rotodynamic pump when operating at 1200 rpm are as follows:

Q (l s^{-1})	0	10	20	30	40	50	60	70
H (m)	48.0	46.0	43.0	39.5	34.0	27.5	20.0	11.0

The pump is required to deliver water through a static lift of 10 m in a 300 mm diameter pipeline, 5000 m long, and of roughness height 0.15 mm. Neglecting the local losses:

(i) show that the flow rate in the pipe at 1200 rpm pump speed is 59 l s^{-1}; [25%]

(ii) calculate the pump speed at which the pump will need to operate to achieve a flow rate of 70 l s^{-1}. [40%]

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Answers

1.

(a) 7.91 l s^{-1}

2.

(a.i) 1.366 m

(a.ii) 0.021 m

(b) 6.266 m s^{-1}

(c.i) 86.56 m

(c.ii) 124 m

3.

(c.i) 9.62 kg m^{-3}

(c.ii) 28.66 kg m^{-1} s^{-1}

(c.iii) 0.25 kg s^{-1}

4.

(a) 2.53 m^3 s^{-1}

(c.ii) 1377 rpm

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