Version DL/2

EGT3
ENGINEERING TRIPOS PART IIA

Monday 30 April 2018 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 briefly what Thiessen's polygons are used for in hydrology. [10%]

(b) Explain briefly what the 'field capacity' means when describing the soil water content. [10%]

(c) When rain fell uniformly for a duration of 2 hours over a catchment, the percentages of the rainfall-generated outflow, over successive two-hour intervals starting from the start of the rainfall, were recorded at the catchment outlet to be 3, 18, 35, 27, 12 and 5, respectively.

Prior to a different four-hour rainfall event over this catchment, with an intensity of 30 mm h^{-1}, the Horton f-capacity constants are measured to be f_0 = 20 mm h^{-1}, f_c = 2 mm h^{-1} and K_f = 1 h^{-1}.

(i) Calculate the rainfall excesses (in mm h^{-1}) during the first and second two-hour periods of this rainfall, respectively. [20%]

(ii) The area of this catchment is 6 km^2. Estimate the peak discharge above the base flow (in m^3 s^{-1}) at the outlet of the catchment and the time when this peak discharge occurs as a result of this four-hour rain. [30%]

(d) Sketch the distributions of the shear stress, Reynolds-averaged velocity, eddy viscosity coefficient and suspended sediment concentration over the depth in a uniform open channel flow over a sandy bed. [20%]

(e) Explain briefly what the 'bed layer', 'bed load' and 'suspended load' mean in sediment transport. [10%]

2 (a) Consider uniform flows in a long rectangular water channel with a width of 3.0 m and bed slope of 0.001. When the water depth is 0.8 m, the discharge is measured to be 3.6 $m^3 s^{-1}$. Estimate the discharge of the channel when the water depth is 1.5 m. [25%]

(b) A flat-bottomed river of width 50 m flows past a bridge which is supported on five equispaced piers, as shown in Fig. 1. The width w of each pier is 2.8 m. At cross-section A, upstream of the bridge, the water depth is 2 m. At cross-section B, between the piers, the water depth is 1.5 m. Estimate the discharge in the river in $m^3 s^{-1}$. [15%]

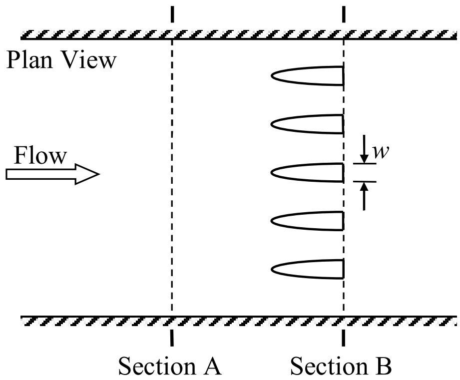

Fig. 1

(c) Using the steady flow theory, prove analytically that the water surface dips over a hump at the river bed when the flow is subcritical. [20%]

(d) A long irrigation channel is controlled by a downstream gate. The gate is initially closed, and the water is at rest with a depth of 2 m. Subsequently, the gate is gradually opened, causing the flow velocity immediately upstream of the gate to increase linearly from 0 to 1 $m s^{-1}$ in 2 min and then to maintain at 1 $m s^{-1}$ thereafter. Neglecting bed friction and slope, sketch the water depth variation along the channel 10 min after the start of the gate opening. On the sketch, label accurately the value of the water depth h_G immediately upstream of the gate and the distance over which the water depth changes from h_G to 2 m. [40%]

3 (a) The bed slope of a fairly straight open channel is 0.004. Its cross-section is of a symmetric trapezoidal shape, with a base width of 3 m and side slopes making a 30º angle with the horizontal. The flow in the channel is uniform, with a flow rate of 48 m^3 s^{-1} and a water depth of 2 m over the flat part of the bed.

(i) Determine whether the flow is supercritical or subcritical. [15%]

(ii) Calculate the Manning roughness coefficient of the channel. [10%]

(b) A river is 5 m wide, with a bed slope of 0.0005 and an overall bed roughness height of 2 cm. The typical water depths in summer and winter are 1 m and 2 m, respectively. The bed is composed of sand of particle diameter 0.2 mm.

(i) Use van Rijn's formula to estimate the reference sediment concentrations 2 cm above the bed, in summer and winter. Assume that the grain-related roughness height is 3 times the grain size. [30%]

(ii) Calculate the suspended loads in kg s^{-1} of sediment transport in summer and winter. Assume the top of the bed layer is 2 cm above the bed. [30%]

(iii) In summer, a shipping accident causes a sudden release of a contaminant, which quickly dissolves in the channel water. One hour after the shipping accident, the peak concentration of the pollutant cloud is measured to be 0.1 kg m^{-3}. Estimate the total mass of contaminant released in the accident. [15%]

4 (a) Explain the meaning of the Peclet number (Pe) in pollutant transport. [15%]

(b) Water needs to be transferred from a sump to a reservoir on a hill. The water surface elevation in the sump is 120 m, while the water elevation in the reservoir varies seasonally. The pipeline that connects the sump and the reservoir is 1 km long, with roughness 0.03 mm and internal diameter 300 mm. A variable speed pump is available with the following characteristics when operated at 1000 rpm.

Q (l 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

The total local head losses of the flow can be estimated to be $20U^2/(2g)$.

(i) In summer, the water level in the reservoir is 140 m and the pump operates at 1000 rpm. Show that the flow rate is around 235 l s^{-1}. [40%]

(ii) In winter, the water level in the reservoir is 150 m. Calculate the rotational speed of the pump in order to maintain the flow rate to be 235 l s^{-1}. [45%]

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