Version DL/2

EGT2
ENGINEERING TRIPOS PART IIA

Monday 12 May 2025 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.

You may not remove any stationery from the Examination Room.

1 (a) For a catchment of area 20 km^2, it is known that two hours of uniform excess rainfall generates distribution percentages for the outflow hydrograph over successive two-hour intervals as follows: 3, 16, 35, 27, 15, 4. The outflow is recorded from the start of the rainfall and the base flow is negligible.

(i) A four-hour storm produces 40 mm hr^{-1} rain in the first two hours and 20 mm hr^{-1} rain in the second two hours. Before the storm, the soil can be assumed to be dry and the parameters for the Horton's infiltration model are f_c = 10 mm hr^{-1}, f_0 = 30 mm hr^{-1} and K_f = 0.5 hr^{-1}. Determine the peak discharge at the catchment outlet in $m^3\ s^{-1}$. [40%]

(ii) Another rainfall event over the same catchment lasts for 1 hour, with the excess rainfall intensity of 5 mm hr^{-1}. Plot the outflow hydrograph due to this one-hour rain. [40%]

(b) For unsteady open channel flows, under what conditions are one family of characteristic curves straight lines? [20%]

2 (a) The specific discharge in a wide river is 0.4 $m^2\ s^{-1}$. The bed slope is 0.0001, and the Manning's roughness coefficient is 0.03 s $m^{-1/3}$.

(i) Assuming uniform flow, calculate the water depth. [20%]

(ii) Calculate the overall Nikuradse roughness height of the bed. [20%]

(b) The bed slope of a wide rectangular channel is 0.0003, and the Manning's roughness coefficient is 0.02 s $m^{-1/3}$. The flow rate per unit width is 4.65 $m^2\ s^{-1}$. Downstream of a sluice gate, the water depth increases from 0.457 m at cross-section A to 0.5 m at cross-section B. Estimate the distance between these two cross-sections. [30%]

(c) In a channel with rectangular cross section, the flow is initially uniform with a depth of 2.2 m and velocity of 0.6 m s^{-1}. The channel flows into a lake, whose water level begins to rise at a rate of 0.5 m hr^{-1}. Ignoring the bed slope and bottom friction, estimate the time taken for the water level 1.3 km upstream of the lake to rise by 0.3 m. [30%]

3 (a) In a wide river of depth 4 m with bed slope of 0.001, the concentration of sediment 0.04 m above the bed is equal to 10% of the concentration 0.004 m above the bed.

(i) Calculate the fall velocity of the sediment particle. [20%]

(ii) Taking the drag coefficient of a sediment particle to be 1.6, estimate the particle diameter. [15%]

(iii) Assuming the bed roughness height to be 0.004 m, estimate the ratio of the suspended sediment transport rates between the following two regions. The first is from 0.004 m to 0.04 m above the bed, and the second is from 0.04 m above the bed to the water surface. [40%]

(b) A boat is dumping toxic waste at a rate of 10 kg s^{-1} while travelling at a speed of 1 m s^{-1} in the middle of a large and deep lake. The concentration of the waste is measured to be 0.1 kg m^{-3} at the water surface 100 m directly behind the boat. Assuming that the toxic waste has the same density as water, estimate the value of the mixing coefficient. [15%]

(c) In the solutions to the pollutant transport problems, as given in the 3D5 data sheet, what is the physical meaning of the term $\sqrt{2Dt}$, where D is the diffusion coefficient? [10%]

4 (a) Comment on the differences between advective and diffusive pollutant transport and the physical meaning of the Peclet number, which is defined to be the flow velocity times the characteristic length divided by the diffusion coefficient. [15%]

(b) Comment on the similarities and differences between molecular and turbulent diffusion. [15%]

(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 against a static lift of 10 m in a 300 mm diameter pipeline. The pipe is 5000 m long, and has a roughness height 0.15 mm. Neglecting local losses:

(i) show that the flow rate in the pipe is 59 l s^{-1} at 1200 rpm pump speed; [40%]

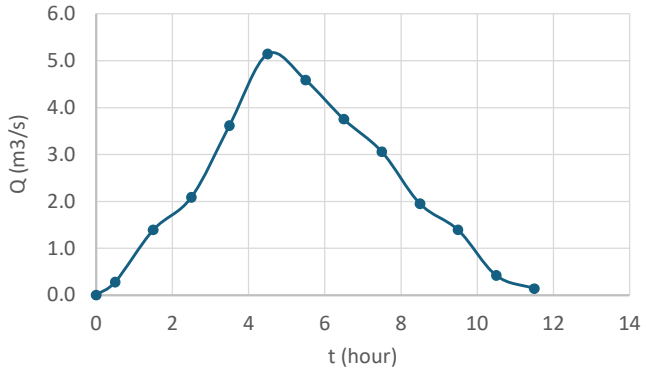
(ii) calculate the pump speed at which the pump will need to operate to achieve a flow rate of 70 l s^{-1}. [30%]

END OF PAPER

Answers

Q1 (a.i) 38.51 m^3/s

(a.ii)



Q2 (a.i) 1.1 m

(a.ii) 0.17 m

(b) 8.2 m

(c) 0.67 hours after the water level in the lake begins to rise

Q3 (a.i) 0.079 m/s

(a.ii) 0.465 mm

(a.iii) 0.36

(b) 0.16 m^2/s

Q4 (c.ii) 1377 rpm