The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX4241 Engineering Hydrology**
Academic Year	: 2023/2024
Date	: 9th February 2025
Time	: 09:30-12:30 hrs
Duration	**: 03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **SIX (06)** questions on **Six (06)** pages.
3. Answer **Any FIVE (05)** questions.
4. Answer for each question should commence from a new page.
5. Necessary additional information is provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear handwriting.
8. Do not use a Red colour pen.

Q1)

a) The following equation is used in Modified Pul's method in reservoir routing. Briefly explain each term within brackets and how this equation is used in routing reservoirs.

(4 Marks)

$$\left(\frac{I_1 + I_2}{2}\right)\Delta t + \left(S_1 - \frac{Q_1 \Delta t}{2}\right) = \left(S_2 + \frac{Q_2 \Delta t}{2}\right)$$

b) A small reservoir has the following storage elevation relationship as shown in **Table 1.1**.

Table 1.1

Elevation (m)	Storage (10^3 m^3)
55	250
58	650
60	1000
61	1250
62	1500
63	1800

A spillway provided with its crest at 60.0 m elevation has the discharge relationship $Q = 15H^{3/2}$, where H is the head of water over the spillway crest. When the reservoir elevation is at 58.0 m a flood as given below in **Table 1.2** enters the reservoir.

Table 1.2

Time (h)	0	6	12	15	18	24	30	36	42
Discharge (m^3/s)	5	20	40	60	50	32	22	15	10

Route the flood and determine the maximum reservoir elevation. Peak outflow and attenuation of the flood peak.

(16 Marks)

Q2)

a) **Figure 2.1** shows a well completely penetrating a horizontal confined aquifer of thickness B. Consider a well having a steady discharging flowrate of Q. The original piezometric head (static head) is H and the drawdown due to pumping is indicated in **Figure 2.1**. The piezometric head at the pumping well is h_w and the drawdown S_w. Please show that the discharge (Q) can be derived as follows. [You may use Darcy's law for confined aquifers for the derivation.]

(8 Marks)

$$Q = \frac{2\pi KB(h_2 - h_1)}{ln\left(\frac{r_2}{r_1}\right)}$$

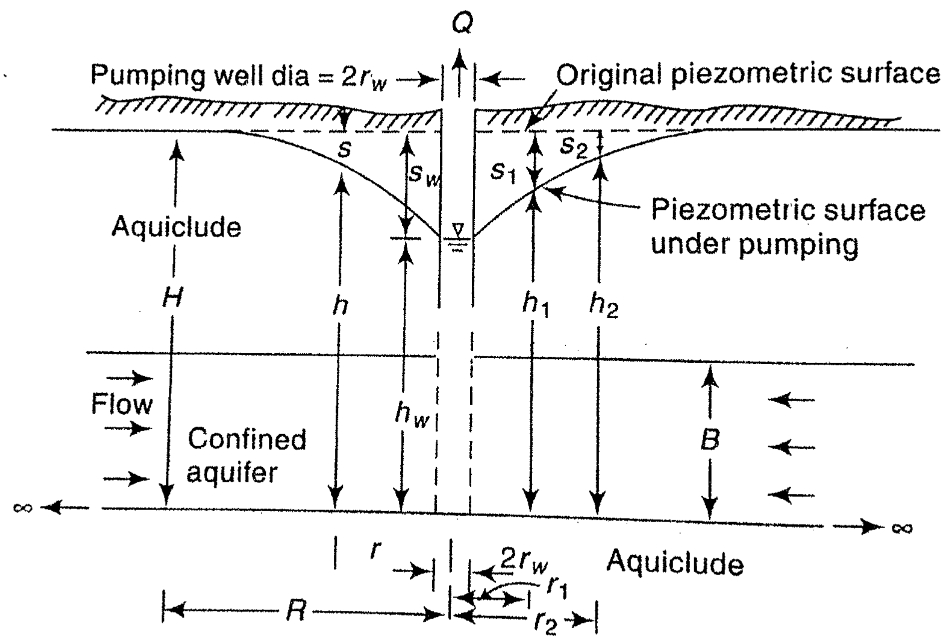

Figure 2.1

b) The discharge from a fully penetrating well operating under a steady state in a confined aquifer of 30 m thickness (B in Figure 2.1) is 2100 liters/minute. The drawdowns observed at two observation wells located at 15 m and 150 m from the well are 3.2 m and 0.28 m, respectively. Calculate the transitivity and the permeability of the aquifer.

(12 Marks)

Q3)

a) Briefly explain the method of superposition used in deriving flood hydrograph by using a unit hydrograph for a catchment. You may use diagrams to explain the method.

(6 Marks)

b) **Table 3.1** shows the ordinates of a 6-h unit hydrograph for a catchment. A storm prevailed over this catchment with accumulated rainfall given in **Table 3.2**. Derive the ordinates of the flood hydrograph by using the method of supper position. (14 Marks)

Assumptions:

ϕ-index: 0.167 cm/h

Base flow of the catchment: 20 m^3/s

Table 3.1

Time (h)	0	6	12	18	24	30	36	42	48	54	60	66
Ordinates (m^3/s)	0	20	60	150	120	90	66	50	32	20	10	0

Table 3.2

Time from the beginning of the storm/(h)	0	6	12	18
Accumulated Rainfall (cm)	0	4	5	10

Q4)

a) Briefly describe the following aspects of surface hydrology (8 Marks)

- Surface runoff
- Evaporation
- Infiltration
- Initial losses

b) Results of an infiltrometer test on a soil are as follows (see **Table 4** ~~Table 1~~):

Table 4

Time from start/ (minutes)	5	10	15	20	30	40	60	120	150
Cumulative infiltration/ (mm)	1	1.8	2.5	3.1	4.2	5.1	6.6	11.00	12.9

Determine the parameters of Kostiakov's equation, which is used to model the infiltration. Use the provided semi-log sheet for finding the parameters.

$$F_p = at^b$$

Where;

F_p : Cumulative infiltration capacity

t : time

a and b are local parameters with $a > 0$ and $0 < b < 1$

(12 Marks)

Q5)

a) The following equation shows a Muskingum equation used in canal routing.

$$S = K[xI + (1 - x)Q]$$

For a given channel reach by selecting a routing interval Δt and using the Muskingum equation, write an equation for change in storage. You may use the suffix 1 and 2 refer to the conditions before and after the time interval Δt. (2 Marks)

b) Write the continuity equation for the same canal segment in above question 5(a) and derive the Muskingum Routing Equation given below.

$$Q_2 = C_0I_2 + C_1I_1 + C_2Q_1$$

$$C_0 = \frac{-Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

$$C_1 = \frac{Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

$$C_2 = \frac{K - Kx - 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

(6 Marks)

c)

Route the following flood hydrograph through a river reach for which K=12.0h and x=0.2. At the start of the inflow flood, the outflow discharge is 10m^3/s.

Table 5

Time (h)	0	6	12	18	24	30	36	42	48	54
Inflow (m^3/s)	10	20	50	60	55	45	35	27	20	15

Q6)

a) Briefly explain the difference between Actual Evapotranspiration (AET) and Potential Evapotranspiration (PET). (2 Marks)

b) Briefly explain 'Reference Crop Evapotranspiration' (ETo) and how it is used to estimate Potential evapotranspiration of crops (PET). You may use mathematical expressions to describe this correlation. (4 Marks)

c) Using the Blaney-Criddle formula, estimate the PET of an area for the season November to February in which wheat is grown. The area is in North India at a latitude of 30° N with mean monthly temperatures as below. (14 Marks)

Table 6.1

Month	November	December	January	February
Temperature (°C)	16.5	13.0	11.0	14.5

Table 6.2: Values of K for Selected Crops

Crop	Average value of K	Range of monthly values
Rice	1.10	0.85-1.30
Wheat	0.65	0.50-0.75
Maize	0.65	0.50-0.80
Sugarcane	0.90	0.75-1.00
Cotton	0.65	0.50-0.90

Table 6.3: Monthly Daytime Hours Percentages, P_h, for use in Blaney-Criddle Formula

North Latitude (deg)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8.50	7.66	8.49	8.21	8.50	8.22	8.50	8.49	8.21	8.50	8.22	8.50
10	8.13	7.47	8.45	8.37	8.81	8.60	8.86	8.71	8.25	8.34	7.91	8.10
15	7.94	7.36	8.43	8.44	8.98	8.80	9.05	8.83	8.28	8.26	7.75	7.88
20	7.74	7.25	8.41	8.52	9.15	9.00	9.25	8.96	8.30	8.18	7.58	7.66
25	7.53	7.14	8.39	8.61	9.33	9.23	9.45	9.09	8.32	8.09	7.40	7.42
30	7.30	7.03	8.38	8.72	9.53	9.49	9.67	9.22	8.33	7.99	7.19	7.15
35	7.05	6.88	8.35	8.83	9.76	9.77	9.93	9.37	8.36	7.87	6.97	6.86
40	6.76	6.72	8.33	8.95	10.02	10.08	10.22	9.54	8.39	7.75	6.72	6.52

Blaney-Criddle Formula

$E_T = 2.54KF$

Where; $F = \sum \frac{P_h \bar{T}_f}{100}$

ET= PET in a crop season in cm

K= an empirical coefficient, depends on the type of the crop and stage of growth

F= sum of monthly consumptive use factors for the period

$\bar{T}_f$= mean monthly temperature in (°F =°C X 9/5+32)