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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX 4241 Engineering Hydrology**
Academic Year	: 2020/2021
Date	: 5th February 2022
Time	: 0930-1230hrs
Duration	**: 03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **SIX (06)** questions on **Seven (07)** pages.
3. Answer **Any FIVE (05)** questions. All questions carry equal marks.
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 hand writing.
8. Do not use Red colour pen.

Question 3

(a) The natural flow volume at the terminal point of a catchment is expressed by the following water balance equation.

$$R_N = (R_0 - V_r) + V_d + E_x + E + \Delta S$$

where,

R_N = Natural flow volume in time Δt
R_0=Observed flow volume in time Δt at the terminal site;
V_r = Volume of return flow from irrigation, domestic water supply and industrial use;
V_d= Volume diverted out of the stream for irrigation, domestic water supply and industrial use;
E= net evaporation losses from reservoirs on the stream;
E_x= net export of water from the basin;
ΔS= Change in the storage volumes of water storage bodies on the stream.
Based on above equation, logically derive an expression for the yield of the catchment (Y).
(4 marks)

(b) Utilizing the concepts and assumptions of SCS-CN method, derive the following expression for the direct surface runoff (Q)

$$Q = \frac{(P-\lambda S)^2}{P+(1-\lambda)S} \quad \text{for } P>\lambda S$$

where,
Q= Direct surface runoff
P= Total precipitation
S= Maximum potential retention in soil
λ= ratio between the initial abstraction and the maximum potential retention

(6 marks)

(c) A catchment comprises of 60% dense forest and 40% paddy fields, and receives a daily rainfall of 50cm during rainy season. Using the SCS-CN method and the data provided in the data sheet, determine the daily runoff of the catchment. Clearly state all the assumptions you will make during the estimation. (10 marks)

$$S = \frac{25400}{CN} - 254$$

where,
S=Maximum potential retention in soil in mm
CN= Curve number

Question 4

(a) State four desirable features that a flood hydrograph should possess when selected to derive a unit hydrograph. (4 marks)

(b) Derive the S-curve for the 4-h unit hydrograph given in Table Q4. (6 marks)

(c) Using the S-curve derived in part(b), derive ordinates of the 2 hour unit hydrograph for the same catchment. (10 marks)

Table Q4

Time (h)	0	4	8	12	16	20	24	28
Ordinate of the 4-h unit hydrograph ($m^3/s/cm$)	0	10	30	25	18	10	5	0

Question 5

(a) Explain the purpose of reservoir routing in water resources engineering. (3 marks)

(b) A reservoir has the elevation, discharge and storage relationships as given in Table Q5a.

Table Q5a

Elevation (m)	100	100.5	101	101.5	102	102.5	102.75	103
Storage (x 10^6 m^3)	3.35	3.472	3.38	4.383	4.882	5.37	5.527	5.856
Outflow discharge (m^3/s)	0	10	26	46	72	100	116	130

When the reservoir level was at 100.5 m, the flood hydrograph entered the reservoir is given in Table Q5b.

Table Q5b

Time (h)	0	6	12	18	24	30	36
Discharge (m^3/s)	10	20	55	65	58	18	11

Using modified Pul's method, route the flood and obtain the ordinates of the outflow hydrograph for the reservoir.

(17 marks)

Question 6

(a) State two fundamental equations in groundwater flow calculations. (2 marks)

(b) Using clear sketches with standard notations and fundamental equations, derive mathematical expressions for the followings of a confined aquifer. (6 marks)

i. Pore velocity

ii. Discharge in the aquifer

iii. Discharge in terms of fluid potential

(c) Considering the volume element shown in Figure Q6 and using standard notations, derive the following governing equations for groundwater flow.

i. Porous medium is isotropic but heterogeneous (4 marks)

$$\frac{\partial}{\partial x}\left(K\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}$$

ii. Porous medium is homogeneous but anisotropic (4 marks)

$$K_x\frac{\partial^2 h}{\partial x^2}+K_y\frac{\partial^2 h}{\partial y^2}+K_z\frac{\partial^2 h}{\partial z^2}=S_s\frac{\partial h}{\partial t}$$

iii. Porous medium is homogeneous and isotropic (4 marks)

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}=\frac{S_s}{K}\frac{\partial h}{\partial t}$$

Where;

K = Hydraulic Conductivity

h = hydraulic head

S_s =Specific storage

t =time

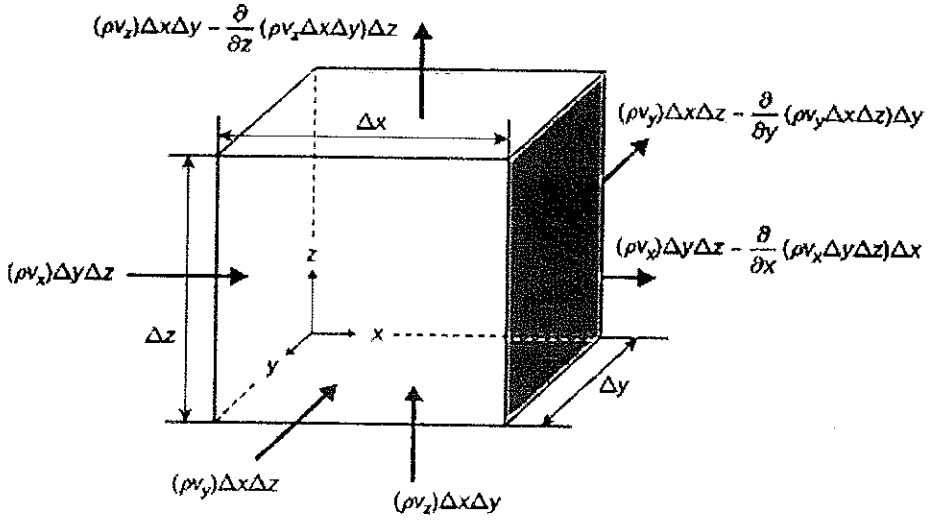

Figure Q6

Data sheet for Question 3

Group-A: (Low Runoff Potential)

Group-B: (Moderately Low runoff Potential)

Group-C: (Moderately High Runoff Potential)

Group-D: (High Runoff Potential)

AMC-I: Soils are dry but not to wilting point. Satisfactory cultivation has taken place.

AMC-II: Average conditions sufficient rainfall has occurred within the immediate past 5 days.

AMC- III: Saturated soil conditions prevail.

Table Q3a ***Antecedent Moisture Conditions (AMC) for Determining the Value of CN***

AMC Type	Total Rain in Previous 5 Days	
	Dormant Season	**Growing Season**
I	Less than 13 mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

Table Q3b ***Runoff Curve Numbers [CNII] for Hydrologic Soil Cover Complexes [Under AMC -II Conditions]***

Land Use	Cover		Hydrologic soil group			
	Treatment or practice	**Hydrologic condition**	***A***	***B***	***C***	***D***
Cultivated	Straight row		76	86	90	93
Cultivated	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
Cultivated	Countered &	Poor	66	74	80	82
	Terraced	Good	62	71	77	81
Cultivated	Bunded	Poor	67	75	81	83
		Good	59	69	76	79
Cultivated	Paddy		95	95	95	95
	With understorey cover		39	53	67	71

	Without understorey cover		41	55	69	73
Forest	Dense		26	40	58	61
	Open		28	44	60	64
	Scrub		33	47	64	67
Pasture	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Wasteland			71	80	85	88
Roads (dirt)			73	83	88	90
Hard surface areas			77	86	91	93

$$CN_I = \frac{CN_{\text{II}}}{2.281 - 0.01284\, CN_{\text{II}}}$$

$$CN_{III} = \frac{CN_{\text{II}}}{0.427 + 0.00573\, CN_{\text{II}}}$$

$$\lambda = 0.2$$

Monogram