31

Important Information to Students on UPSC Competitions and Conventional Questions of the Past Years

The Union Public Service Commission, Dholpur House, Shahjahan Road, New Delhi-110011, conducts every year two competitions, in which, you as civil engineering graduates (even with exam. results awaited) can participate for securing a direct class I Govt. appointment.

The first competition is named as **Combined Engineering Services (CES) exam,** and the other competition is known as **Civil Services Exam.**, popularly called *IAS competition.*

Press notifications for obtaining and submitting application forms are released by Secretary UPSC, through news papers including "Employment News" sometimes in Feb. every year. The exams are usually held in August.

On the basis of the first competition, you are likely to be appointed as Asstt. Executive Engineer or Asstt. Director or on an equivalent post in civil engineering side of the various Government Departments like Railways, CPWD, P&T, Central Water Commission, etc. whereas, on the basis of the second competition, you are liable to become an IFS, IAS, IPS, or an officer on allied services, such as Asstt. Custom Collector or Asstt. Excise Collector, etc.

Most of the engineering degree students aspire to clear any one of these two competitions, for an excellent career full of promotional avenues, just after doing BE degree. The syllabus for both these competitions, now a days, provide full opportunities to Civil Engineering degree holders, to make through these competitions.

We will here discuss the syllabus and examination schemes as may be of use to you as civil engineering graduates, for both of these competitions.

COMBINED ENGINEERING SERVICES EXAM.
(Civil Engg.)

In this competition, there will be 5 papers in all, 3 being of objective type, and 2 of conventional type. Each paper carries 200 marks, with a total of 1000 marks. 200 marks are reserved for Personal Interview, making a grand total of 1200 marks, as below:

Section I — Objective Type Papers		
1. *General Ability Test*	2 hr.	200 marks
2. *Civil Engineering Paper I*	2 hr.	200 marks
3. *Civil Engineering Paper II*	2 hr.	200 marks
Section II — Conventional Papers*		
4. *Civil Engineering Paper I*	3 hr.	200 marks
5. *Civil Engineering Paper II*	3 hr.	200 marks
	Total	1000 marks
*Personality Test cum Interview** (only for those candidates who qualify on the basis of the written examination)		200 marks
Grand Total Marks		1200

The syllabus for these papers (revised wef year 2000) is given below :

Syllabus for General Ability Test (Objective Type)

Part A — *General English.* The question paper in General English will be designed to test the Candidate's understanding of English and workman like use of words.

Part B — *General Studies.* The paper in General studies will include knowledge of current events and of such matters as of every day observation and experience in their scientific aspects as may be expected of an educated person. The paper will include questions on History of India and Geography of a nature which candidates should be able to answer without special study.

Syllabus for Civil Engineering Paper I (Revised wef the year 2000)

(Same as for Objective as well as Conventional Papers)

1. Building Materials

Timber. Different types and species of structural timber, density-moisture relationship, strength in different directions, defects, influence of defects on permissible stress, preservation, dry and wet rots, codal provisions for design, Plywood.

Bricks. Types, Indian Standard classification, absorption, saturation factor, strength in masonry, influence of mortar strength on masonry strength.

Cement. Compounds of, different types, setting times, strength.

Cement Mortar. Ingredients, proportions, water demand, mortars for plastering and masonry.

Concrete. Importance of W/C Ratio, Strength, ingredients including admixtures, workability, testing for strength, elasticity, non-destructive testing, mix design methods.

2. **Solid Mechanics.** Elastic constants, stress, plane stress, Mohr's circle of stress, strains, plane strain, Mohr's circle of strain, combined stress; Elastic theories of failure; Simple bending, Shear; Torsion of circular and rectangular sections and simple members.

3. **Structural Analysis.** Analysis of determinate structures - different methods including graphical methods.

Analysis of indeterminate skeletal frames - moment distribution, slope-deflection, stiffness and force methods, energy methods, Muller-Breslau principle and application.

Plastic analysis of indeterminate beams and simple frames-shape factors.

* In the personality test special attention will be paid to assessing the candidates capacity for leadership, initiative and intellectual qualities, mental & physical energy, powers of practical application and integrity of character.

4. **Design of Steel Structures.** Principles of working stress method. Design of connections, simple members; Built-up sections and frames, Design of Industrial roofs. Principles of ultimate load design. Design of simple members and frames.

5. **Design of Concrete and Masonry Structures.** Limit state design for bending, shear, axial compression and combined forces. Codal provisions for slabs, beams, walls and footings. Working stress method of design of R.C. members.

Principles of prestressed concrete design, materials, methods of prestressing, losses. Design of simple members and determinate structures. Introductions to prestressing of indeterminate structures.

Design of brick masonry as per I.S. Codes.

6. **Construction Practice, Planning and Management.**

Concreting Equipment : Weight Batcher, Mixer, vibrator, batching plant, concrete pump. Cranes, hoists, lifting equipment.

Earthwork Equipment : Power shovel, hoe, dozer, dumper, trailers and tractor, rollers, sheep foot rollers, pumps.

Construction, Planning and Management : Bar chart, linked bar chart, work-break down structures, Activity - on - arrow diagrams. Critical path, probabilistic activity durations ; Event-based net-works.

PERT network : Time-cost study, crashing; Resource allocation.

Syllabus for Civil Engg. Paper II (Revised wef year 2000)

1. (*a*) **Fluid Mechanics, Open Channel Flow, Pipe Flow.** Fluid Properties, pressure, Thrust, Buoyancy; Flow Kinematics; Integration of flow equations; Flow measurement; Relative motion; Moment of momentum; Viscosity, Boundary layer and Control, Drag, Lift; Dimensional Analysis, Modelling; Cavitation; Flow oscillations; Momentum and Energy principles in Open channel flow, Flow controls, Hydraulic jump, Flow sections and properties; Normal flow, Gradually varied flow; Surges; Flow development and losses in pipe flows, Measurements; Siphons; Surges and Water hammer; Delivery of Power Pipe networks.

(*b*) **Hydraulic Machines and Hydropower.** Centrifugal pumps, types, performance parameters, scaling, pumps in parallel; Reciprocating pumps, air vessels, performance parameters; Hydraulic ram; Hydraulic turbines, types, performance parameters, Controls, choice; Power house, classification and layout, storage, pondage, control of supply.

(2) (*a*) **Hydrology.** Hydrological cycle, precipitation and related data analyses, PMP, Unit and synthetic hydrographs; Evaporation and transpiration; Floods and their management, PMF; Streams and their gauging; River morphology; Routing of floods; Capacity of Reservoirs.

(*b*) **Water Resources Engineering.** Water resources of the globe : Multipurpose uses of Water : Soil-Plant-Water relationships, Irrigation systems, Water demand assessment; Storages and their yields, Ground water yield and well hydraulics; Water logging, drainage design; Irrigation revenue; Design of rigid boundary canals, Lacey's and Tractive force concepts in canal design, Lining of canals; Sediment transport in canals; Non-Overflow and overflow sections of gravity dams and their design, Energy dissipators and tail water rating; Design of headworks, distribution works, falls, cross-drainage works, outlets; River training.

(3) (*a*) **Water Supply Engineering.** Sources of supply, yields, Design of intakes and conductors; Estimation of demand; Water quality standards; Control of Water-borne diseases; Primary and secondary treatment, detailing and maintenance of treatment units; Conveyance and distribution systems of treated water, leakages and control; Rural water supply; Institutional and industrial water supply.

(*b*) **Waste Water Engineering.** Urban rain water disposal; Systems of sewage collection and disposal; Design of sewers and sewerage systems; Pumping; Characteristics of sewage and its treatment, Disposal of products of sewage treatment, Stream flow rejuvenation, Institutional and industrial sewage management; Plumbing Systems; Rural and semi-urban sanitation.

(*c*) **Solid Waste Management.** Sources, classification, collection and disposal; Design and Management of landfills.

(*d*) **Air and Noise Pollution and Ecology.** Sources and effects of air pollution, monitoring of air pollution; Noise pollution and standards; Ecological chain and balance, Environmental assessment.

(4) (*a*) **Soil Mechanics.** Properties of soil, classification and interrelationship; Compaction behaviour, methods of compaction and their choice; Permeability and seepage, flow nets, Inverted filters; Compressibility and consolidation; Shearing resistance, stresses and failure; soil testing in laboratory and in-situ; stress path and applications. Earth pressure theories, stress distribution in soil; soil exploration, samplers, load tests, penetration tests.

(*b*) **Foundation Engineering.** Types of foundations, Selection criteria, bearing capacity, settlement, laboratory and field tests; Types of piles and their design and layout, Foundations on expansive soils, swelling and its prevention, foundation on swelling soils.

5. (*a*) **Surveying.** Classification of surveys, scales, accuracy; Measurement of distances - direct and indirect methods; optical and electronic devices; Measurement of directions, prismatic compass, local attraction; Theodolites - types; Measurement of elevations - Spirit and trigonometric levelling; Relief representation; Contours; Digital elevation modelling concept; Establishment of control by triangulations and traversing - measurements and adjustment of observations, computation of coordinates; Field astronomy, Concept of global positioning system; Map preparation by plane tabling and by photogrammetry; Remote sensing concepts, map substitutes.

(*b*) **Transportation Engineering.** Planning of highway systems, alignment and geometric design, horizontal and vertical curves, grade separation; Materials and construction methods for different surfaces and maintenance. Principles of pavement design; Drainage.

Traffic surveys, Intersections, signalling : Mass transit systems, accessibility, networking.

Tunnelling, alignment, methods of construction, disposal of muck, drainage, lighting and ventilation, traffic control, emergency management.

Planning of railway systems, terminology and designs, relating to gauge, track, controls, transits, rolling stock, tractive power and track modernisation; Maintenance; Appurtenant works; Containerisation.

Harbours - layouts, shipping lanes, anchoring, location identification; Littoral transport with erosion and deposition; sounding methods; Dry and Wet docks, components and operational Tidal data and analyses.

Airports - layout and orientation; Runway and taxiway design and drainage management; Zoning laws; Visual aids and air traffic control; Helipads, hangers, service equipment.

Note 1. Calculators are not allowed in objective Type papers but are allowed in conventional type papers.

Note 2. In Question papers, wherever required, SI units will be used.

A perusal of this syllabus shows that **Paper I** covers the entire Structural Engineering field, including *Building construction, Applied mechanics, Strength of materials, Theory and design of Structures* including *R.C.C., Steel, Masonry* and *Timber structures.*

Similarly, **Paper II** covers *Fluid mechanics, Irrigation and Hydrology, Water Supply and Sewage, Soil mechanics, Surveying, and Transportation.*

Both the objective papers; *i.e. Paper I (objective)* as well as *Paper II (objective)* usually contain 120 questions each, to be solved in 120 minutes. All the subjects covered in these papers usually get almost equal weightage. The objective questions from Irrigation side (*i.e.* water resources side for the years 1993 to 2002 have been given in the next chapter.

Similarly, both the conventional papers; *i.e. Paper I (conventional)* as well as *paper II (consventional)* usually respectively contain 8 questions, out of which 5 questions are to be solved. This paper-II usually carries 2 questions from Irrigation and Hydrology side, which are fully covered through this book. The other 2 to 3 questions are covered from author's other books on "Water Supply Engineering", "Sewage Disposal and Air Pollution Engineering" and "Soil-Mechanics and Foundation Engineering", thus enabling you to fetch near about cent per cent marks in this paper, thus, opening your way for selection in this competition for an excellent professional career.

You, *my dear students*, would further feel enlightened, when we inform you that in the past years, many numerical questions on water resources engineering side, have been directly set from the solved examples of this book, besides setting almost all the theoretical questions from this book.

Say for example, *in the year 1980, only two numerical questions of 80 marks were set, and both from this book in toto, without any change even in the numerical data values. In the year 1978, only one question appeared from irrigation, and that too from this book. In the year 1983, $2\frac{1}{2}$ questions were set from Irrigation, and all these were from this book* (with very slight modifications in the numerical data values), *similarly, one numerical question on 'Economics of Lining' appeared in 1986, with exactly the same data as solved in this book. In 1989, one full question on determining gross irrigation requirement for wheat crop was set from this book (with slight modifications in rainfall values), besides a question on S-hydrograph, which was also fully covered by this book. In 1993 as well as in the year 2000, all the three numerical questions on irrigation side were set from the solved examples of this book.*

In other years also, questions which appeared in this UPSC paper, were fully covered by this book.

In order to enable you to check these facts, and for your facility and guidance, given below are the questions that appeared during the last 23 years since the year 1978, from Irrigation and Hydrology side in this UPSC competition.

Questions of the Past Years Relating to Water Resources Engg. from the Engg. Services Competitions (Civil Engineering Paper II)

Year 1978 *(Engineering Services)*

Q. 5. Wheat is to be grown in a field having field capacity equal to 27% and the permanent wilting point is 13%. Find the storage capacity at 80 cm depth of the soil, if the dry unit weight of the soil is 1.5 gm/cc, if irrigation water is to be supplied when the average soil moisture falls to 18% , find the water depth required to be supplied to the field if the field application efficiency is 80%. What is the amount of water needed at the canal outlet if the water lost in the water courses and the field channel is 15% of the outlet discharge ? (40*)

[**Note.** Pl. refer solved Example 2.14. **This question was set from this book**].

Year 1979 *(Engineering Services)*

Q. 2. (*a*) Define critical tractive stress and state the main factors on which it depends. A wide unlined channel carrying silt free water has a depth of 2.0 m. The maximum tractive stress permissible on the bed to prevent scour is 0.20 kg/m^2. What is the maximum slope that can be given to the channel. (16)

[**Hint.** $\tau_0 = \gamma RS,$

$$\therefore \quad \tau_{0\,(max)} = \gamma R . S_{max}$$

$$= 1000 \times 2.0 \times S_{max} = 0.20 \text{ kg/cm}^2$$

$$\therefore \quad S_{max} = 1 \text{ in } 10{,}000.$$ **Ans.**]

(b) Water discharging from an overfall spillway flows to a jump type basin. The discharge intensity is 30 m^3/s/m and the water depth is 1.5 m. Find the conjugate depth for the jump to form. Give the sketch of the basin showing approximate dimensions and basin appurtenances considered desirable. (17)

[**Hint.** Conjugate depth

$$= y_2 = -\frac{y_1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2q^2}{gy_1}}$$

$$= -\frac{1.5}{2} + \sqrt{\frac{1.5^2}{4} + \frac{2 \times 30^2}{9.81 \times 1.5}}$$

$$= -0.75 + \sqrt{0.5625 + 122.324}$$

$$= -0.75 + 11.08$$

$$= 10.33 \text{ m}$$

Length of jump basin

$$= 5\,(y_2 - y_1) = 5\,[10.33 - 1.5] = 44.15 \text{ m.}$$ **Ans.**]

Or

The ordinates of a 3 hour unit hydrograph are as given :

Time, hours	*0*	*3*	*6*	*9*	*12*	*15*	*18*	*21*	*24*	*27*	*30*
Ordinates, m^3/s	*0*	*10*	*25*	*20*	*16*	*12*	*9*	*7*	*5*	*3*	*0*

Find the ordinates of 6 hour hydrograph for the same basin :

[**Note.** Please refer Example 7.33]

Year 1980 *(Engineering Services)*

In 1980, five questions, each of 40 marks, were to be attempted. There were two full questions on "Irrigation and Hydrology", which were set from this very book, as given below :

* Marks allotted for the question, out of maximum 200 marks of Civil Engg. Paper II.

Q. 3. *The rainfall runoff relation for the 655.2 sq. km. of drainage basin under dry soil conditions is given below :*

Rainfall (cm)	*Runoff (cm)*
1.5	*0.0*
5.0	*2.0*
7.5	*4.0*
10.0	*6.5*
12.5	*8.75*

A storm of 2 hr effective duration occurred over this basin at a time when the soil was dry. The resulting hydrograph was as follows :

Time (hr)	*Flow (cumecs)*
0	*0*
3	*300*
6	*500*
9	*400*
12	*250*
15	*75*
18	*0*

Determine the number of mm of runoff from this basin from this storm, assume zero base flow. Approximately how much rain was there in this storm ? What was the average coefficient of runoff during this storm ? (40)

[**Note.** Pl. refer solved Example 7.40. **This question was set from this book**. The value of C.A. has since been revised.]

Q. 6. (*a*) A 1.5 m Sarda type fall is provided at a canal with a discharge of 12 cumecs, with the following data :

Bed level upstream	= *103.0 m*
Side slope of channel	= *1 : 1*
Bed level downstream	= *101.5 m*
Full supply level upstream	= *104.5 m*
Bed width U/S & D/S	= *1.0 m*
Soil	= *good loam*
Bligh's coefficient	= *6*

Calculate the following elements of the fall :

(*i*) *Crest R.L.*

(ii) Length of the crest and the thickness at the base.

(iii) Depth of the cistern. (40)

Or

(*b*) Calculate the elements of the fall required on Q. 6 (*a*) using as much of the data as you require. Assume data not given.

[**Note.** Pl. refer solved Example 12.3. **This question was set from this book**].

Year 1981 *(Engineering Services)*

Q. 6. (*a*) Define specific energy and critical depth. (8)

(*b*) Draw the specific energy diagram and label its various parts with brief explanation. The critical depth may also be shown. Discharge remains constant. (12)

(*c*) A trapezoidal channel has a bottom width of 6.0 m and side slopes of 1 : 1. The depth of flow is 1.5 m at a discharge of 15 m^3/sec. Determine the specific energy. (12)

(*d*) If the critical depth is 0.9 m, discuss the type of flow very briefly, corresponding to the critical depth. (8)

Q. 8. Using Rational method, rainfall-intensity duration curves (Diagram I) and the data given on diagram II, compute the diameter of the outfall sewer. The length of lines, drainage areas, and inlet times are marked on diagram II itself.

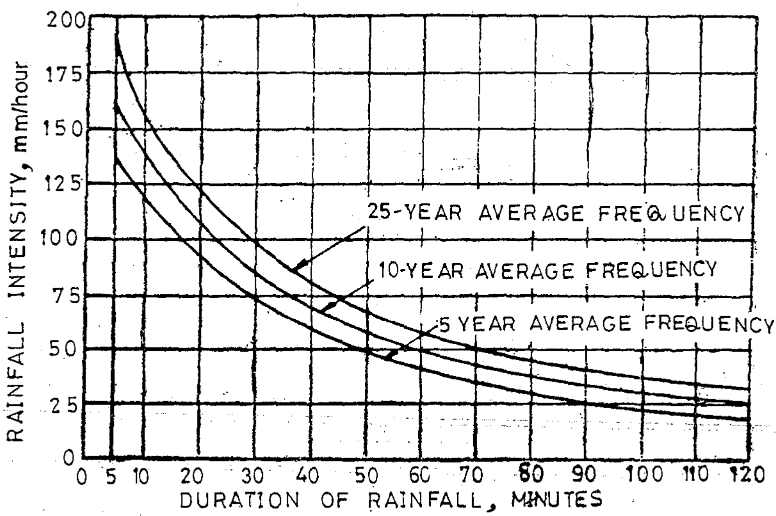

Diagram I (Fig. 31.1)

Assume :

(i) Runoff coefficient for the entire area = 0.30.

(ii) Velocity of flow in sewers flowing full = 0.75 m/sec.

(iii) 5 year average frequency curve may be used (Diagram II).

(iv) Table 1 gives the hydraulic elements for circular pipes flowing full.

Table 1. Hydraulic Elements for a Circular Pipe Flowing Full

Quantity of flow, l/s	*Dia. of pipe, mm*	*Slope of pipe, m/m*	*Velocity m/sec*
400	450	0.025	2.7
600	525	0.020	2.8
690	1050	0.00055	0.75
1500	1350	0.001	1.55
2000	1450	0.001	1.20

(40)

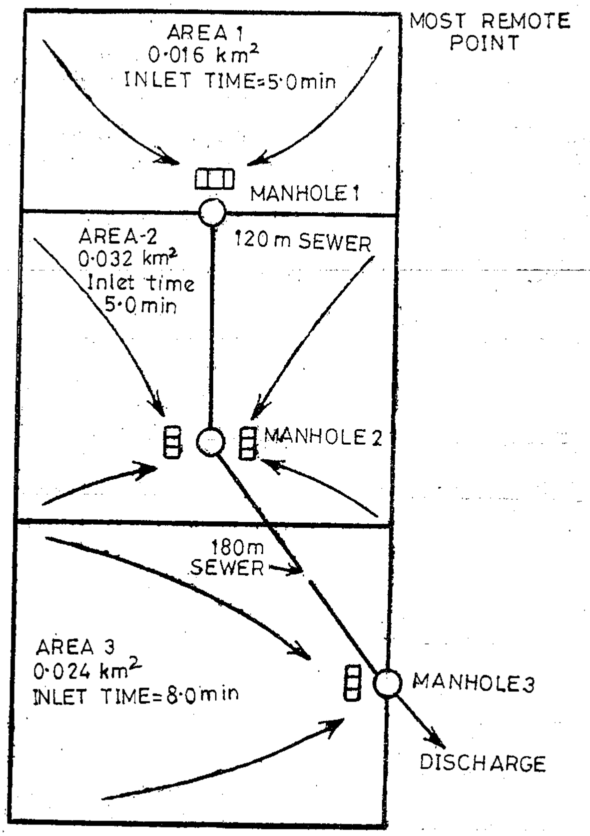

Diagram II (Fig. 31.2)

Hint. This question has been solved on Pages 790 to 791 in author's another book titled "Sewage Disposal and Air Pollution Engg." (11th Edition – 1998)

Year 1982 *(Engineering Services)*

Q. 2. *(a) Explain briefly the concept of a unit hydrograph.* (5)

(b) What is a S-curve ? What is its use ? (5)

(c) On a catchment area of 20 hectares, rainfalls of 7.5 cm, 2.0 cm and 5.0 cm occurred on three consecutive days. The average ϕ_{index} was 2.5 cm/day. The distribution graph percentages of surface runoff which extended over six days for every rainfall of such magnitudes are 5, 15, 40, 25, 10 and 5. Determine the ordinates of the discharge hydrograph and determine the peak discharge. Neglect base flow. (30)

[**Note.** Please refer Example 7.47]

Q. 3. *(a) List the various forces to be considered in the stability analysis of a gravity dam. Indicate the expressions to determine their value.* (15)

(b) Investigate the stability against overturning of a solid gravity dam at the base section. The dam is in the shape of a rightangled triangle with the upstream face vertical.

Ht. of dam	=	*120 m*
Slope of d/s face	=	*0.75 H : 1 V*
Ht. of water	=	*120 m*
Free-board	=	*0*
Ht. of tail water	=	*0*
Unit wt. of concrete	=	*2400 kg/m³*
Uplift intensity factor	=	*0.5*
Allowable coeff. of friction	=	*0.75*

Neglect silt pressure, earthquake forces, waves forces and its pressure. Assume any suitable data as required. (25)

Year 1983 *(Engineering Services)*

Q. 1. *(b) Design a concrete lined channel to carry a discharge of 500 cumecs at a slope of 1 in 4000. The side slopes of the channel may be taken as 1 : 1. The Manning's roughness coefficient for the lining is 0.014. Assume permissible velocity in the section as 2.5 m/sec.* (20)

[**Hint.** Follow Solved Example 5.4]

Q. 2. *(a) Describe briefly how the profile of ogee-shaped spillway section is designed.* (12)

(b) The tail water rating curve for the channel below an overflow spillway is below the "jump height curve" for all expected discharges. For this case, explain with the help of neat sketches the energy dissipation arrangements which can be provided below the spillway. (16)

(c) What are the functions and design considerations of canal head regulators? (12)

Q. 4. *(a) A flood of a certain magnitude has a return period of 25 years. What is its probability of exceedence ? What is the probability that this flood may occur in the next 12 years ?* (10)

[**Note.** Please refer Example 7.52.]

(b) In a typical 4 hour storm producing 100 mm of runoff from a basin, the stream flows observed are as follows :

Time in hr.	0	2	4	6	8	12	16	20
Flow in cumecs	0	2.44	8.10	13.50	11.34	6.75	2.70	0.0

Estimate the peak flow in the stream and the time of its occurrence in a flood created by an 8 hr storm which produces 50 mm of runoff during the first four hours and 75 mm of runoff during the second four hours. Assume base flow to be negligible. (20)

[**Note.** Please refer solved Example 7.32. **This question was set from this book by just doubling the data values**].

(c) Explain how the average depth of precipitation over an area, due to a storm is computed from isohyetal map of the storm. (10)

Year 1984 *(Engineering Services)*

Q. 2. *(a) Mention the various types of canal falls commonly used indicating distinctive features, and describe briefly design principles of any one popular type.* (20)

(b) A weir has a solid horizontal floor length of 50 m with two lines of cutoff 8 m depth, below the river bed, at its two ends. The floor thickness is 1 m at the upstream end and 2 m at the downstream end, with its upper level being in flush with the river bed. For an effective head of 5 m over the weir, calculate the uplift pressure at the two inside corner points junction of bottom of floor with the cutoff), and also exit gradient. (20)

Q. 3. *(a) Describe briefly Kennedy's theory for the design of regime channels.* (10)

(b) Design a regime channel to carry a discharge of 100 cumecs in a soil having silt factor of 1.1, using Lacey's theory. Assume side slopes of 0.5 horizontal to 1.0 vertical. (18)

[**Note.** Please follow solved Example 4.9].

Q. 4. *(a) What are the basic propositions of unit hydrograph theory as propounded by L.K. Sherman ?* (10)

(b) The mass curve of precipitation resulted from the storm of 14th August 1983 gave the following values :

Hour	*Accumulated depth at the end of periods in mm*
22.00	0.0 (Beginning of storm)
22.05	10.2
22.10	20.8
22.15	33.0
22.20	47.2
22.25	55.8
22.30	64.0
22.35	71.6
22.40	78.8
22.45	85.4
22.50	91.4 (End of storm)

For the above storm, construct hydrograph, and draw maximum intensity duration curve. (20)

[**Note.** Please refer Example 7.11]

(c) Describe the function and design consideration of undersluices provided in diversion head works. (10)

Year 1985 *(Engineering Services)*

Q. 2 *(a) Describe briefly the main functions of a distributary 'Head Regulator' and 'Cross Regulator'. Mention the salient steps for their design.* (20)

(b) Design an irrigation channel by Kennedy's method to carry 50 cubic metres per second of discharge with base width to depth ratio as 2.5. The critical velocity ratio is

1.1. Assume Kutter's rugosity coefficient as 0.025 and side slopes of the channel as 0.5 horizontal to 1.0 vertical. (20)

[**Note.** Please follow solved Example 4.7].

Q. 3. *(a) How do you determine the storage capacity of a reservoir with the help of mass curve of runoff, if a constant or a variable demand is known ?* (12)

(b) Explain briefly the 'Infiltration Indices'. (8)

(c) In estimating the peak discharge of a river at X, the catchment area was divided into four parts A, B, C and D. The time of concentration and the area for different parts are as follows :

Part	*Time of concentration*	*Area in square metres*
A	*One hour*	600×10^4
B	*Two hours*	750×10^4
C	*Three hours*	1000×10^4
D	*Four hours*	1200×10^4

Records for a rain storm lasting for four hours as observed, and the runoff factor during different hours are as follows :

Time in hr.		*Rainfall (in mm)*	*Run-off factor*
From	*To*		
0	*1*	*25.0*	*0.50*
1	*2*	*50.0*	*0.70*
2	*3*	*50.0*	*0.80*
3	*4*	*23.5*	*0.85*

Calculate the maximum flow to be expected at X in cumecs, assuming a constant base flow of 42.5 cumecs. (20)

[**Note.** Please refer Example 7.31].

Q. 4. *(a) Explain briefly the functions and requirements of a good module. How are modules classified ? Mention common examples of each type.* (18)

(b) What are the various assumptions made in two dimensional design of gravity dams ? (12)

(c) Describe briefly uplift Pressure on Syphon Flooring in cross-drainage works. (10)

Year 1986 *(Engineering Services)*

Q. 3. *(a) Explain 'Retrogression of Downstream Levels' consequent to weir construction.* (8)

(b) Describe briefly causes of failure of earthen dams. (12)

(c) An unlined canal giving a seepage loss of 4.0 cumecs per million sq metres of wetted area is proposed to be lined with 12 cm thick cement concrete lining, which costs Rs. 20.0 per sq. m. Workout the economics of lining and show if the scheme is justified on the basis of the following data:

Annual revenue from crops = Rs. 4,00,000 per cumec of water.
Discharge of the channel = 50 square metre
Wetted perimeter of the channel = 22.4 m
Wetted perimeter of the lining = 22.0 m
Annual maintenance cost of unlined channel = 12 paise per sq. metre
Seepage loss in lined channel = 0.01 cumec per million sq. metre of wetted perimeter.
Saving in annual maintenance as a consequence to lining = 40%
Life of lining = 40 years
Rate of interest = 6 per cent
Assume additional suitable data, if required. (20)

[**Note.** Please refer solved Example 5.1. **This question was set from this book with slight modifications in numerical data values.**]

Q. 4. *(a) Explain how maximum intensity-duration frequency curve is obtained.* (12)

(b) Define :

(i) Maximum Probable Flood

(ii) Standard Project Flood (10)

(c) Estimate the average depth of precipitation from depth area curve, that may be expected over an area of 2400 sq km, due to the storm of 27th Sept. 1978, lasting for 24 hours, assuming the storm centre to be located at the centre of the area. The isohyetal map for the storm gave the areas enclosed between different isohyets as follows :

Isohyetal in mm	*21*	*20*	*19*	*18*	*17*	*16*	*15*	*14*	*13*	*12*
Enclosed area in sq km	*543*	*1345*	*2030*	*2545*	*2955*	*3280*	*3535*	*3710*	*3880*	*3915*

Hence, determine the depth of rainfall, due to the storm that may be expected to be recorded by a raingauge placed at the storm centre. (18)

[**Note.** Please refer Example 7.7].

Year 1987 *(Engineering Services)*

Q. 5. (*a*) A round crested spillway passes a design discharge of 1 m^3/sec per metre length. The coefficient of discharge may be taken as $C_d = 0.7$. If the height of the crest above the downstream stilling basin floor level is 10 m, design the

(*i*) depth, and

(*ii*) length of the stilling basin. Depth of flow in the stream on the downstream of the spillway is 1 m at the design discharge of 1 m^3/sec. Enquire if the bed of the stilling basin has to be depressed. (20)

Q. 6. (*b*) A railway embankment is 16 m wide with side slopes 2 : 1. Assume the ground to be level in the direction transverse to the centre line. Calculate the volume contained in a length of 100 m, the centre heights at 20 m intervals being in m : 2.0, 4.5, 4.0, 3.5, 2.5, 1.5. Use Trapezoidal formula. (20)

Year 1988 *(Engineering Services)*

Q. 1. *(a) A certain stretch of lined trapezoidal channel has one vertical side wall and the other 45° sloping wall. If it is to deliver water at 30 m^3/sec with a velocity of 1 m/sec, compute bed width and flow depth for minimum lining area.* (10)

Q. 6. *(a) Define unit hydrograph.*

Ordinates of 8 hour unit hydrograph for a drainage basin are given below. Obtain a 24 hour unit hydrograph by tabulation method. Neatly sketch it.

Time hours (1)	*Ordinates of 8 hr unit hydrograph* (2)	*Time hours (contd.)* (1)	*Ordinates of 8 hr unit hydrograph (contd.)* (2)
0	0.00	48	57.00
4	5.50	52	42.00
8	13.50	56	41.00
12	26.50	60	22.00
16	45.00	64	14.00
20	82.00	68	9.50
24	162.00	72	6.60
28	240.00	76	4.00
32	231.00	80	2.00
36	165.00	84	1.00
40	112.00	88	0.00
44	79.00		

(40)

[**Note.** Please refer Example 7.34].

Year 1989 *(Engineering Services)*

Q. 2. *For use in Hargreaves method, in respect of Group D wheat crop, the following K values are suggested :*

% age of crop growing season	0	5	10	15	20	25	30	35	40	45	50
K	0.08	0.08	0.15	0.19	0.27	0.33	0.40	0.46	0.52	0.58	0.65

% age of crop growing season	55	60	65	70	75	80	85	90	95	100
K	0.71	0.77	0.82	0.88	0.90	0.90	0.80	0.70	0.60	0.60

Wheat is grown between 1 November to 15 March. The effective rainfall in the individual months is taken as follows :

Nov.–0.5 cm ; Dec.–1.6 cm; Jan–3.2 cm; Feb.–2.7 cm ; March–Nil. Percolation losses are nil throughout, Field Irrigation Efficiency is 70% and Gross Irrigation Efficiency is 75%. The mean class A pan evaporation through the respective months are:

Nov.–13 cm; Dec.–11 cm; Jan.–7 cm; Feb.–15 cm; March–10cm. Compute the gross irrigation requirement for the whole crop period including 7 cm of net pre-sowing requirement. (40)

[**Hint.** Follow the sample calculations given for wheat crop in table 2.14, and compute G.I.R. as equal to 55.02 cm, as per table given on next page].

Solution Table for Q. 2 of 1989 (Engg. Services) : *Growth period* = 1 Nov. to 15 March (135 days)

Dates	*No. of days upto mid point of interval from start*	*%age of growing season col. (2)* $\times \frac{100}{135}$	*Pan evaporation* (E_p) *in cm*	*Coefficient (K) interpolated values for %age values of col. (3) from given values*	$E_t = KE_p = C_u$ *i.e. col. (4) × col. (5); consumptive use in cm*	R_e = *Effective rainfall in cm (given)*	*Net irr. requirement NIR* $= C_u - R_e$ *= col. (6) – col. (7)*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Nov. 1—30	15	11	13	0.16	2.08	0.50	1.58
Dec. 1—31	46	34	11	0.46	5.06	1.60	3.46
Jan. 1—31	77	57	9	0.73	6.57	3.20	3.37
Feb. 1—28	106	78	15	0.90	13.50	2.70	10.80
March 1—15	128	95	10	0.60	6.00	Nil	6.0
					Z = 33.21 cm	8.00 cm	25.21 cm

$$\text{N.I.R.} = 25.21 \text{ cm}$$

$$\text{F.I.R.} = \frac{N.I.R.}{\eta_f} = \frac{25.21}{0.70} = 36.01 \text{ cm}$$

$$\text{G.I.R.} = \frac{F.I.R.}{\eta_c} = \frac{36.01}{0.75} = 48.02 \text{ cm}$$

Net presowing requirement before 1 Nov. = 7 cm.

∴ Total gross irrigation requirement = 48.02 + 7 = 55.02 cm. **Ans.**

Q. 8. *(b) A 2 hour unit hydrograph in a rather steep catchment is given below :*

Time, hour	0	2	4	6	8	10	12
Discharge, 100 m^3/s	0	0.54	1.75	1.27	0.58	0.25	0

Compute the 1 hour unit hydrograph for the catchment. (25)

[**Hint**. Please refer Solved Example 7.51].

Year 1990 *(Engineering Services)*

Q. 1. *(c) Given that the unit discharge in a rectangular channel is 18 m^3/sec and that the head loss across a hydraulic jump that forms in this channel is 1.1 m, estimate the prejump and post jump depths.* (15)

Solution. Using eqn. (10.5), and (10.12), we have

$$y_1 y_2 (y_1 + y_2) = \frac{2q^2}{g} = \frac{2 \times 18^2}{9.81} = 66.06 \quad ...(i)$$

[q = unit discharge *i.e.*, discharge per unit width]

and $$H_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$

where $H_L = 1.1$ m (given)

$$\therefore \quad (y_2 - y_1)^3 = 4.4\, y_1 y_2 \quad ...(ii)$$

Putting $y_2 = m y_1$ in (*ii*), we get

$$(m-1)^3 \cdot y_1{}^3 = 4.4 \cdot m y_1{}^2$$

$$\therefore \quad y_1 = \frac{4.4m}{(m-1)^3} \quad ...(iii)$$

Putting $y_2 = m y_1$ and this value of y_1 in (*i*), we get

$$y_1 \cdot m \cdot y_1 (y_1 + m \cdot y_1) = 66.06$$

or $$m(m+1) \cdot y_1{}^3 = 66.06$$

or $$m(m+1)\left[\frac{4.4m}{(m-1)^3}\right]^3 = 66.06$$

or $$\frac{m(m+1)(m)^3}{(m-1)^9} = \frac{66.06}{4.4^3}$$

or $$\frac{m^4(m+1)}{(m-1)^9} = 0.775$$

Solving by hit and trial, we get

$$m = 2.93$$

Substituting it in (*iii*), we get

$$y_1 = \frac{4.4 \times 2.93}{(1.93)^3} = \mathbf{1.79\ m}$$

$$\therefore \quad y_2 = 2.93 \times 1.79 = \mathbf{5.25\ m}$$

Ans.

Q. 2. *Work out the irrigation schedule based on the soil moisture concept, given the following information. Also extract the data on the total depth of irrigation water required and the respective dates of irrigation water supply :*

(a) The crop is grown in an appropriate soil with no restrictive layers within the top 1.5 m depth of soil.

(b) Normal root zone depth of the crop is 1.2 m.

(c) Bulk density of soil is 1.35.

(d) Field capacity is 18% and permanent wilting point is 7%.

(e) Moisture level in the soil is to be maintained at not less than one-third of available retention. Irrigation will then be done over a duration of 2 days at a uniform rate of supply and at a uniform rate of advance to fully and just compensate for the depletion.

(f) No extra water is ever required for leaching.

(g) Sowing is done on 1 November when the soil moisture is left just at field capacity in the entire root zone.

(h) For the crop, at the location, the average evapotranspiration rates are :

1 Nov. — 30 Nov.	:	*1.1 mm/day*
1 Dec. — 31 Dec.	:	*1.7 mm/day*
1 Jan. — 31 Jan.	:	*2.4 mm/day*
1 Feb. — 28 Feb.	:	*1.5 mm/day*
1 March—25 March	:	*3.5 mm/day*

(i) Harvesting is done on or after 26 March.

(j) There is expected an effective rainfall of 24 mm during 4 January to 19 January, both days inclusive with uniform intensity.

(k) By the end of the crop growth season, only the minimum water needed to be left unused in the root zone.

[**Hint.** Pl see Solved Example 2.16]

Q. 3. *(c) An equipment used in construction activity costs Rs. 40,000 at first purchase. The average annual expenditure thereon for OMR is estimated to be Rs. 9,000 for the next three years for which funds be procured at the beginning of each year. At the end of the third year, it can be scrapped at a then value of Rs. 10,000. If the acceptable rate of return is 15% per annum, what should be the annual income by this machine as reckoned at the end of each year ?*

[**Note.** Please refer Solved Example 20.2 in "*Hydrology and Water Resources Engineering*" (11th-2000 Edition) by the same author].

Q. 8. *(a) The average rainfall values over a catchment in three successive 2-hour intervals are 3, 5 and 2 cm, respectively. The ϕ index for the catchment is taken as 0.2 cm/hr. The 2 hr unit hydrograph ordinates are given in table. Base flow can be taken as 7 m^3/sec at the beginning of the storm linearly increasing to 9 m^3/sec at 2 hours after the direct runoff peak discharge, and later linearly decreasing to 8 m^3/sec at 4 hours after the end of the direct runoff. Compute the resulting flood hydrograph.*

Time, hours	*0*	*2*	*4*	*6*	*8*	*10*	*12*	*14*	*16*
Discharge, m^3/sec	*0*	*10*	*40*	*70*	*50*	*20*	*10*	*6*	*0*
			(Peak)						

(15)

[**Solution.** Unit hydrograph (U.H.) ordinates are tabulated in col. (2) of the solution table given below. The discharge hydrographs are now produced in three successions, by 3 successive storms, each containing effective rainfalls equal to $R-\phi$; *i.e.* $3-2\times0.2 = 2.6$ cm ; $5-2\times0.2=4.4$ cm ; and $2-2\times0.2 = 1.6$ cm, respectively. Hydrograph ordinates due to these three rains are computed by multiplying U.H. ordinates by each, because U.H. is produced by 1 cm rain. These values are worked out in col. (3), (4) and (5) respectively. All of them are then added in col. (6) to obtain direct runoff hydrograph (D.R.H.). Base flow is then computed, and added to obtain hydrograph of resulting discharge as given in table below..

Solution Table for Q. 8 (*a*) of Year 1990 (Engg. Services)

Time from start, hr (1)	*U.H. ordinates* (2)	*Discharge ordinates caused by 1st rain = col. (2) × 2.6* (3)	*Discharge ordinates caused by 2nd rain (at 2 hr lag) = col. (2) × 4.4* (4)	*Discharge ordinates caused by 3rd rain = col. (2) × 1.6 at 4 hr lag* (5)	*Total D.R.H. = col. (3) + (4) + (5)* (6)	*Base flow* (7)	*Total flow ordinates in m^3/sec = col. (6) + (7)* (8)
0	0	0	—	—	0	7	7.0
2	10	26	0	—	26	7.4	33.4
4	40	104	44	0	148	7.8	155.8
6	70	182	176	16	374	8.2	382.2
8	50	130	308	64	502	8.6	510.6*
10	20	52	220	112	384	9	393.0
12	10	26	88	80	194	8.85	202.85
14	6	6	44	32	82	8.71	90.71
16	0	0	26.4	16	42.4	8.57	50.97
18	—	—	0	9.6	9.6	8.43	18.03
20	—	—	—	0	0	8.29	8.29
22	—	—	—	—	—	8.15	8.15
24	—	—	—	—	—	8	8.0

* Peak = 510.6 m^3/sec.

Year 1991 (*Engineering Services*)

Q. 5. *(a) Enumerate the assumptions on which Dupuit-Theim theory of ground water flow is based and state the range of validity of the law governing the flow. Define the following terms :*

(i) Storage coefficient, (ii) Specific yield, (iii) Specific retention, (iv) Porosity, stating clearly the relationship which exists among some of these terms. (20)

Year 1992 (*Engineering Services*)

Q. 4. *(b) The following data pertains to healthy growth of a crop :-*

(i) Field capacity of soil	*= 30%*
(ii) Permanent wilting percentage	*= 11%*
(iii) Density of soil	*= 1300 kg/m*^{3}
(iv) Effective depth of root zone	*= 700 mm*
(v) Daily consumptive use of water for the given crop	*= 12 mm*

For healthy growth, moisture content must not fall below 25% of the water holding capacity between the field capacity and the permanent wilting point. Determine the watering interval in days. (20)

[**Solution.** Max. water holding capacity of soil

= Field capacity m.c. – Permanent wilting pt. m.c.
= 30% – 11% = 19%

25% of Max. holding capacity = 0.25 × 19% = 4.75%

The left out available m.c. must at no stage be allowed to fall below this value and watering should be applied as soon as the left out m.c. falls to such a low level. Hence lower limit to which m.c. can be allowed to fall = 4.75% above wilting point m.c. (at which plants fade away) = 4.75% + 11% = 15.75%.

In other words, the m.c. will be allowed to vary between 30% and 15.75%. Water depth stored between these two limits

$$= \frac{\gamma d}{w} [30\% - 15.75\%]$$

$$= \frac{1300}{1000} \times 0.7 \, [0.30 - 0.1575]$$

$$= 0.1297 = 12.97 \text{ cm.}$$

Since consumptive use is 12 mm/day ;

12 mm of water is consumed in = 1 day

∴ 12.97 cm of water will be consumed in

$$= \frac{1}{12} \times (12.97 \times 10) = 10.8 \text{ days.}$$

The watering should, therefore, be applied after every 10 days.

Note. 10.8 days cannot be rounded to 11 days, as otherwise the left out m.c. will fall down below the minimum required. **Ans.**]

Q. 7. *(b) A sluice across a channel 6 metre wide discharges a stream 1 meter deep. What is the flow rate when the depth upstream of the sluice is 7 metre ? On the downstream side, concrete blocks have been placed to create conditions for hydraulic jump to occur. Determine the force on the blocks if the downstream depth is 3 metre.* (15)

[**Solution.** Discharge through the sluice gate

$$Q = C_d (6 \times 1) \sqrt{2gH}$$

as width of channel $= 6$ m
area of flow $= 6 \text{ m} \times 1 \text{ m}$

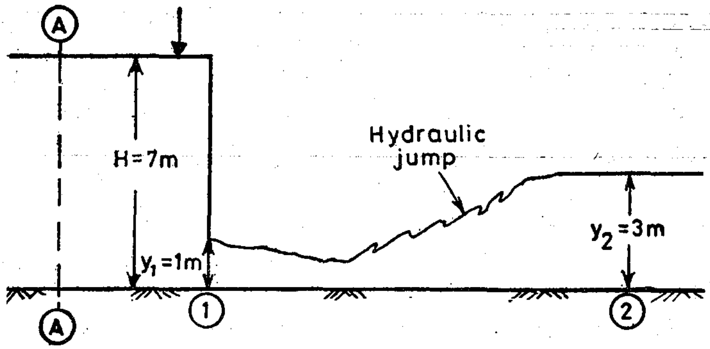

Fig. 31.3

where $C_d = C_c \cdot C_v$

Assuming $C_v = 0.95$

$C_c = 0.62$

$C_d = C_v \cdot C_c = 0.59$

$$Q = 0.59 \times 6 \times 1 \times \sqrt{2 \times 9.81 \times 7}$$

$$= 41.49 \text{ m}^3/\text{s} \quad \textbf{Ans.}$$

(*b*) Force acting on concrete blocks is given by the rate of change of momentum per unit channel width.

$$= \left(\frac{w}{g}\right) q (V_1 - V_2) \text{ kg}$$

where $q = \frac{Q}{6} = \frac{41.49}{6} = 6.91 \text{ m}^2/\text{s}$

$$V_1 = \frac{q}{C_c \cdot y_1} = \frac{6.91}{0.95 \times 1} \text{ m/s}$$

$$= 7.28 \text{ m/s}$$

$$V_2 = \frac{q}{y_2} = \frac{6.91}{3} = 2.3 \text{ m/s}$$

$$= \frac{1000 \times 6.91}{9.81} (7.28 - 2.3)$$

$$= 3504 \text{ kg} = 3504 \times 9.81 \text{ Newton} = 34.37 \text{ kN.} \quad \textbf{Ans.}]$$

Year 1993 *(Engineering Services)*

Q. 1. *(a) A water course commands an irrigated area 1000 hectares. The intensity of irrigation of rice in this area is 70%. The transplantation of rice crop takes 15 days and during the transplantation period, the total depth of water required by the crop on the field is 500 mm. During the transplantation period, the useful rain falling on the field is 120 mm. Find the duty of irrigation water for the crop on the field during transplantation at the head of the field, and also at the head of the water course* *assuming losses of water to be 20% in the water course. Also calculate the discharge required in the water course.* (20)

[**Note :** Please follow exactly similar solved Example 3.5, and Compute : (*i*) 341 ha/cumec; (*ii*) 273 ha/cumec ; and (*iii*) 2.57 cumecs. **Ans.**]

Q. 2. *(c) A precipitation station X was inoperative for some time during which a storm occurred. At three stations A, B and C surrounding X, the total precipitation recorded during this storm are 75, 58 and 47 mm respectively. The normal annual precipitation amounts at stations X, A, B and C are respectively 757, 826, 618 and 482 mm. Estimate the storm precipitation for station X.* (10)

[**Note.** Please follow Exactly Similar Solved Example 7.1, and compute ppt. to be **71.2 mm. Ans.**]

Q. 3. *(c) During a recuperation test, the water in an open well was depressed by pumping by 2.5 m and it recuperated 1.8 m in 80 minutes. Calculate the yield from a well 4 m diameter under a depression head of 3 m.* (10)

[**Note.** Please follow exactly similar solved example 16.9, and compute yield as **10 l/sec. Ans.**]

Year 1994 *(Engineering Services)*

Q. 2. *(b) The information available from an isohyetal map of 1100 sq km basin is as follows :*

Zone	*Area km^2*	*Rain gauge station*	*Normal annual rainfall, cm*
I.	*85*	*A*	*120*
II.	*290*	*B* *C*	*95* *96*
III.	*395*	*D* *E* *F*	*60* *65* *70*
IV.	*230*	*G*	*45*
V.	*65*	*H*	*21*
VI.	*35*	—	—

How many additional rain gauge stations will be required if the desired limit of error in the mean value of rainfall is not to exceed 10 cm? Suggest how you propose to distribute these stations.

What factors will you consider in locating the additional rain gauge stations between different isohyetals ? (20)

[**Solution.** Follow Solved Example 7.3, and compute

$$\text{Mean rainfall } = \overline{P} = \frac{120+95+96+60+65+70+45+21}{8} = \frac{572}{8} = 71.5 \text{ cm}$$

$$\overline{P^2} = \frac{\Sigma p^2}{n}$$

$$= \frac{(120)^2+(95)^2+(96)^2+(60)^2+(65)^2+(70)^2+(45)^2+(21)^2}{8} = 5979$$

$$\sigma = \sqrt{\frac{n}{n-1}[\overline{P^2} - (\overline{P})^2]}$$

$$= \sqrt{\frac{8}{7}(5979 - (71.5)^2} = 31.47$$

$$C_v = \frac{100\sigma}{\overline{P}} = \frac{100 \times 31.47}{71.5} = 44.019$$

Optimum No. of Rain gauges

$$= N = \left(\frac{C_v}{E}\right)^2$$

where E = % error allowed in mean rainfall

$$= \frac{10 \text{ cm}}{\overline{P}} = \frac{10}{71.5} \times 100 = 13.986$$

$$\therefore \quad N = \left(\frac{44.019}{13.986}\right)^2 = 9.91 : \textbf{say 10}$$

Additional gauges required

= 10 – 8 = **2 No.** **Ans.]**

One of these two additional gauges can be installed in Zone IV, which is having only one gauge, although covering an area of 230 km^2, *i.e.* about 20% of total catchment, and thus may need about 20% × 10 gauges = 2 gauges. The other additional gauge can be installed in Zone VI, which at present, is not having any gauge at all. **Ans.]**

Q. 5. *(c) The base period, intensity of irrigation, and duty of water for various crops under the canal system are given. Determine the reservoir capacity if the culturable commanded area is 40,000 hectares, canal losses are 25%, and reservoir losses are 15%.*

Crop	*Base period days*	*Duty of the water at the field hec/cumec*	*Intensity of irrigation %*
Wheat	*120*	*1800*	*20*
Sugarcane	*360*	*1700*	*20*
Cotton	*180*	*1400*	*10*
Rice	*120*	*800*	*15*
Vegetables	*120*	*700*	*15*

(15)

[Solution. Follow Example 3.6, and compute Areas of different crops under irrigation by multiplying *CCA* (40,000 hectares) with intensity of irrigation, as given in column (5) of solution table. Water required by each crop in cumecs is then determined in column (6) by dividing crop area in hec by duty in hec/cumec. The volume of water required by each crop in *B* days is finally computed in column (7) by multiplying base period in secs with water required in m^3/sec *i.e.* column (2) × 24 × 60 × 60 × column (6).

Solution Table for Q. 5 (c) of Year 1994 *(Engg. Services)*

Crop	*Base period (B) in days*	*Duty at the field in hec/cumec*	*I.I. %*	*Area of each crop under irrigation CCA × I.I. = 40,000 × Col. (4)*	*Water required by each crop in m^3/sec = Col. (5) / Col. (3)*	*Volume of water required in m^3 in (B) days = Col. (2) × 24 × 60 × 60 × Col. (6)*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Wheat	120	1800	20	8,000	4.444	46.08 M-m^3
Sugarcane	360	1700	20	8,000	4.706	146.37 M-m^3
Cotton	180	1400	10	4,000	2.857	44.43 M-m^3
Rice	120	800	15	6,000	7.50	77.76 M-m^3
Vegetables	120	700	15	6,000	8.571	88.87 M-m^3
Σ			80%	32,000		403.51 M-m^3

Hence, total water required at the field

$$= 403.51 \text{ Mm}^3.$$

Canal losses $= 25\%$

∴ Water required at Canal Head

$$= \frac{403.51}{0.75} \text{ Mm}^3 = 538.013 \text{ Mm}^3$$

Reservoir losses $= 15\%$

∴ Gross Reservoir Capacity $= \dfrac{538.013}{0.85} \text{ Mm}^3 = 632.96 \text{ Mm}^3$

say **633 Mm³** **Ans.]**

Year 1995 *(Engineering Services)*

Q. 1. *(b) Calculate the bed width for an irrigation channel to carry a discharge of 5 cumec. Side slopes of the channel are 1/2 horizontal to 1 vertical. Assume critical velocity ratio as 0.8. Take first trial depth of flow as 1 m. The channel has a bed slope of 0.2 m per kilometre. Using Kutter's equation $V = C \cdot \sqrt{R \cdot S}$, check the depth. The value of C for the given conditions is computed as 30. V is the mean velocity of flow in m/sec, and R is the hydraulic mean radius in metre.*

State the factors on which the value of C will depend. (15)

[**Hint.** Using $y = 1.0$ m (*assumed in 1st trial as given*), compute $V_0 = \mathbf{0.44\ m/s}$;

and $A = \dfrac{Q}{V_0} = \dfrac{5}{0.44} = 11.36 = \left(B + \dfrac{1.0}{2}\right) 1.0$ or $B = 10.86$ m;

$P = 10.86 + \sqrt{5} \times 1.0 = 13.10$, $R = \dfrac{11.36}{13.10} = 0.867$.

Then $V = 30 \cdot \sqrt{0.867 \times \dfrac{0.2}{1000}} = \mathbf{0.395\ m/s}$. To reduce V_0 reduce y in second trial to about 0.7 m, when we get $V \approx V_0 \approx 0.35$ and $B = 20$ m. **Ans.]**

Q. 2. *(a) A stream has a width of 30 m, depth of 3 m and a mean velocity of 1.25 m/sec. Find the height of a weir to be built on the stream floor to raise the water level by 1 m. Assume value of discharge coefficient as 0.95.* (15)

[Hint. If x is the height of the weir, then head over the weir causing flow $= (4 - x)$, because D/s water depth is 3 m, and U/s water depth is 4m.

$$Q = \frac{2}{3} \cdot C_d \cdot \sqrt{2g} \cdot B \cdot h^{3/2} = 30 \times 3 \times 1.25$$

or $$\frac{2}{3} \times 0.95 \sqrt{2 \times 9.81} \times 30 \times (4 - x)^{3/2} = 30 \times 3 \times 1.25$$

or $$x = \mathbf{2.79\ m} \quad \textbf{Ans.]}$$

Q. 3. *(b) An aquifer of 20 m average thickness is overlain by an impermeable layer of 30 m thickness. A test well of 0.5 m diameter and two observation wells at a distance of 10 m and 60 m from the test well are drilled through the aquifer. After pumping at a rate of 0.1 m³/sec for a long time, the following drawdowns are stabilised in these wells : first observation well, 4 m, second observation well 3 m. Show the arrangement in a diagram. Determine the coefficient of permeability and drawdown in the test well. State the validity of Darcy's Law.* (15)

[Hint. Solve the question using Thiem's formula for confined aquifers, and determine $K = \mathbf{1.425 \times 10^{-3}}$ **m/sec Ans.**

Then use r_w in place of r_1 and s_w in place of s_1 in this formula and compute $s_w = \mathbf{6.059}$ **m. Ans.]**

Q. 5. *(c) A farmer wishes to have his own pump set for the following cropping pattern to be followed in five hectares of his land. Calculate the right size of the centrifugal pump he should have, litres/sec.*

Season	*Crop*	*Area to be irrigated, ha*	*Intensity of irrigation, cm*	*Rotation period, days*
Rabi	*Wheat*	2.0	7.5	12
	Cotton	0.4	7.5	20
	Vegetables	0.4	7.5	10
	Mustard	2.2	5.0	40

For each crop, duration of pumping hours per day is 10. (10)

[Hint. It can be seen from the given data that the water is required for different crops as below :

(*i*) *for wheat* $= (2 \times 10^4\ \text{m}^2) \times \frac{7.5}{100}\ \text{m} = 300\ \text{m}^3$ @ every 12th day in 10 hrs.

(*ii*) *for cotton* $= (0.4 \times 10^4\ \text{m}^2 \times \frac{7.5}{100}\ \text{m} = 300\ \text{m}^3$ @ every 20th day in 10 hrs.

(*iii*) *for vegetables* $= (0.4 \times 10^4\ \text{m}^2) \left(\frac{7.5}{100}\ \text{m}\right) = 300\ \text{m}^3$ @ every 10th day in 10 hrs.

(*iv*) *for mustard* $(2.2 \times 10^4 \text{ m}^2)\left(\frac{5}{100}\text{ m}\right) = 1100 \text{ m}^3$ @ every 40th day in 10 hrs.

This shows that maximum water is required for wheat, *i.e.* 1500 m^3 in 10 hrs.

$\therefore$ Water required in l/s to be pumped

$$= \frac{(1500 \times 1000)\ l}{(10 \times 3600)\ \text{sec}} = \mathbf{41.67\ l/s} \quad \textbf{Ans.}$$

Q. 7. *(b) A masonry dam 10 m high is trapezoidal in section with a top width of 1 m and bottom width of 8.25 m. The face exposed to water has a batter of 1 : 10. Calculate (i) the factor of safety against overturning; (ii) Factor of safety against sliding; (iii) Shear friction factor. Assume coefficient of friction as 0.75. Unit weight of masonry as 2240 kg/cu.m. Permissible shear stress of joint = 14 kg/cm². Based on the results give your remarks.* (15)

[**Hint.** Draw the section of the dam, and compute

$\Sigma V = 103.6 \text{ t}$; $\Sigma H = 50 \text{ t}$

$\Sigma M_V = 528 \text{ tm}$; $\Sigma M_H = 166.5 \text{ t.m.}$

$$\therefore \text{ F.S. against overturning} = \frac{\Sigma M_V}{\Sigma M_H} = \frac{528}{166.5} = \mathbf{3.17} \quad \textbf{Ans.}$$

$$\text{F.S. against sliding} = \frac{\mu \cdot \Sigma V}{\Sigma H} = \frac{0.75 \times 103.6}{50} = \mathbf{1.55} \quad \textbf{Ans.} \quad (> 1\ ;\ \text{OK})$$

$$\text{S.F.F.} = \frac{\mu \Sigma V \cdot B \cdot q}{\Sigma H} = \frac{0.75 \times 103.6 + 8.25 \times 14}{50}$$

$$= \mathbf{3.86} \quad \textbf{Ans.} \quad (> 3\text{–}5\ ;\ \text{OK})$$

The structure is safe. **Ans.**]

Year 1996 (*Engineering Services*)

Q.1. *(a) For a date of maximum recorded flood of a river, the mean and standard deviation are 4200 m³/s and 1705 m³/s, respectively. Using Gumbel's extreme value distribution, estimate the return period of a design flood of 9500 m³/s. Assume an infinite sample size.* (20)

[**Hint.** Use eqn = (7.142) as :

$$X = \bar{X} + k \cdot \sigma$$

where $\bar{X} = 4200 \text{ m}^3/\text{s}$

$\sigma = 1705 \text{ m}^3/\text{s}$

$X = 9500 \text{ m}^3/\text{s}$

$\therefore \quad K = 3.1085$

Now, use eqn. (7.148) as :

$$K = \frac{y_{(T)} - 0.577}{1.2825} \quad \text{for infinite sample size as given } i.e.\ N \to \alpha$$

$\therefore \quad y_{(T)} = 4.5637$

Now, use eqn. (7.146) as :

$$y_{(T)} = -\left[\ln \ln \frac{T}{T-1}\right]$$

$$\therefore \quad (-)\, 4.5637 = \left[\ln \ln \frac{T}{T-1}\right]$$

or $$\frac{T}{T-1} = 1.0104$$

or $$\frac{T-1}{T} = 1 - \frac{1}{T} = 0.9896$$

or $$T = 96.43$$

Hence, the return period of design flood of 9500 m^3/s = **96.43 Yrs. Ans.**]

Q.2. *(b) The following is the set of observed data for successive 15 minute period of 105 minutes storm in a catchment.*

Duration (Min)	*Rainfall cm/hr.*
15	*2.0*
30	*2.0*
45	*8.0*
60	*7.0*
75	*1.25*
90	*1.25*
105	*4.5*

If the value of ϕ_{index} is 3.0 cm/hr, estimate the net runoff, the total rainfall and the value of W_{index} (20)

[Hint. Follow exactly 'similar solved example 7.24 and compute :

$$\text{Total runoff } (Q) = (8-3)\frac{15}{60} + (7-3)\frac{15}{60} + (4.5-3)\frac{15}{60}$$

or $$Q = \frac{5}{4} + \frac{4}{4} + \frac{1.5}{4} = \frac{10.5}{4} = \mathbf{2.625\ cm} \quad \textbf{Ans.}$$

Total rainfall = P

$$= 2 \times \frac{15}{60} + 2 \times \frac{15}{60} + 8 \times \frac{15}{60} + 7 \times \frac{5}{60} + 1.25 \times \frac{15}{60} + 1.25 \times \frac{15}{60} + 4.5 \times \frac{15}{60}$$

$$= 26 \times \frac{1}{4} = \mathbf{6.5\ cm} \quad \textbf{Ans.}$$

$$W_{index} = \frac{P-Q}{Tr} = \frac{6.5 - 2.625}{\left(\frac{105}{60}\right)} = \mathbf{2.214\ cm/hr} \ \textbf{Ans.}$$]

Q.3. *(a) During a recuperation test, the water in an open well was depressed by pumping by 2.1 m and it recuperated by 1.6 m in 90 minutes. Find the diameter of a well to yield 10 litre/sec under a depression head of 2m.* (20)

[**Hint.** Follow exactly similar solved example 16.10, and compute :

$$\frac{C'}{A} = \frac{2.3}{T} \log \frac{s_1}{s_2} \qquad \text{(Eqn 16.39)}$$

$$= \frac{2.3}{90 \times 60} \log \frac{2.1}{2.1 - 1.6}$$

$$= 2.64 \times 10^{-4} \text{ m}^3/\text{sec/m}^2/\text{m}$$

Now use eqn. (16.40) as :

$$Q = \left(\frac{C'}{A}\right) \cdot A \cdot s$$

$$\therefore \quad \frac{10}{1000} \text{ m}^3/\text{s} = (2.654 \times 10^{-4}) \times A \times 2$$

or $$A = 18.83$$

$\therefore$ diameter of well giving 10 $l/s = d =$ **4.9 m Ans.**]

Q 5. *(b) Enumerate the various types of energy dissipation devices which may be recommended below spillway in relation to the relative position of tail water rating curve and jump height rating curve.* (30)

[**Hint.** See article 21.6]

Q. 6. *(a) Design a lined canal to carry 100 m³/s on a slope of 1 in 2500. The maximum permissible velocity is 2 m/s, n = 0.013 in Manning's formula, and the side slope = 1.25 H : 1.0 V.* (20)

[**Hint.** Follow exactly similar solved example 5.4 and compute.

$$2 = \frac{1}{0.013} \times R^{2/3} \cdot \frac{1}{\sqrt{2500}}$$

or $$R = 1.482 \text{ m} \qquad \text{...}(i)$$

$$\cot \theta = 1.25$$

$$\theta = 0.675 \text{ radians}$$

From eqn = (5.8) ; $A = y\,(B + 1.925y) = \frac{Q}{V} = \frac{100}{2} = 50$

or $$(B + 1925y) = \frac{50}{y}$$

or $$B = \left(\frac{50}{y} - 1.925y\right) \qquad \text{...}(ii)$$

From eq. 5.9 ; $P = B + 3.85\,y$

$$R = \frac{A}{P} = \frac{50}{(B + 3.85\,y)} = 1.482 \qquad \text{...}(iii)$$

$\therefore$ $$B + 3.85y = 33.74$$

or $$B = 33.74 - 3.85y \qquad \text{...}(iv)$$

Equating (*ii*) and (*iii*)

$$\frac{50}{y} - 1.925y = 33.74 - 3.85\,y$$

or $$50 - 1.925y^2 = 33.74\,y - 3.85\,y^2$$

$$1.925y^2 - 33.74y + 50 = 0$$

or $$y = \frac{33.74 \pm \sqrt{33.74^2 - 4 \times 50 \times 1.925}}{2 \times 1.925} = \frac{33.74 \pm 27.45}{3.85}$$

$$\left.\begin{array}{l} y = 1.634 \text{ m} \\ B = 27.45 \text{ m} \end{array}\right] \textbf{Ans.}$$

Q.8. *(a) Calculate the seepage through an earthen dam resting on an impervious foundation. The relevant data are given below :*

Height of the dam	= 60.0 m
Upstream slope	= 2.75 : 1 (H : V)
Downstream slope	= 2.50 : 1 (H : V)
Freboard	= 2.5 m
Crest width	= 8.0 m
Length of drainage blanket	= 120.0 m

Coefficient of permeability of the embankment material in

X-direction $= 8 \times 10^{-7}$ m/s

Y-direction $= 2 \times 10^{-7}$ m/s

(20)

[Hint. As a matter of fact such problems have generally been solved in "Soil Mechanics", and hence the students will have to refer and study article 7.7.1.1 in authors another book titled "Geotech Engineering – Soil Mechanics and Foundation Engineering – 3rd 1999 edition)", before attempting to solve this question.

According to the theory explained in that article, we have by eqn. (7.30)

q = discharge through dam = K.S.

where $K = \sqrt{K_H \cdot K_V}$

$S =$ Focal distance of base parabola forming the top seepage line in the dam body.

S is further given by eq. (7.28) as

S = Focal distance w.r. Fig. 7.22 in "Soil Mechanics"

$= \sqrt{b^2 + H^2} - b$

where H = Max. water depth $= 60 - 2.5 = 57.5$ m

$= 47 + 8 + 30$ (Please see Fig. 31.4)

$= 85$ m

$\therefore\ S = \sqrt{85^2 + 57.5^2} - 85 = 17.62$ m

$q = \sqrt{K_H \cdot K_v} \cdot S$

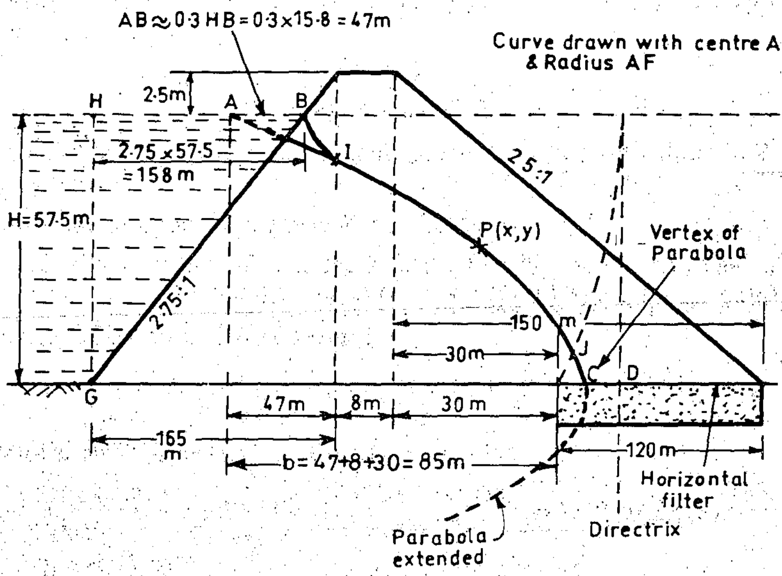

Fig. 31.4.

$= \sqrt{8 \times 10^{-7} \times 2 \times 10^{-7}} \times 17.62 \text{ m}^3/\text{sec}$ per m width of dam

$= 4 \times 10^{-7} \times 17.62 \text{ m}^3/\text{s.m}$

$= 70.48 \times 10^{-7} \text{ m}^3/\text{sec.m} = 0.610 \text{ m}^3/\text{day. m}$

$=$ 610 litres per day per m width of dam. **Ans.**

Year 1997 (*Engineering Services*)

Q. 1. *(a) A large sample of peak floods data was available for a river. Flood frequency computations using Gumbel's method, yield the following results.*

Return Period T (Years)	*Peak Flood m^3/sec*
50	*30,800*
100	*36,300*

Estimate the magnitude of a flood for this river with a return period of 200 years. (15)

[Hint. Follow exactly similar solved Example 7.57 and determine $X_{(200)} = 41780 \text{ m}^3/\text{sec}$ **Ans.]**

Q. 1. *(c) A most efficient trapezoidal section is required to give a maximum discharge of 21.5 m^3/s of water. The slope of the channel bottom is 1 in 2500. Taking C = 70 $m^{1/2}/s$ in Chezy's equation, determine the dimensions of the channel. Also determine the value of Manning's 'n' taking the value of velocity of flow as obtained for the channel by Chezy's equation.* (15)

[Hint. Pl refer Solved Example 4.5]

Q. 2. *(c) Show that the drawdown in the case of a partially penetrating well in a confined aquifer (well just penetrating to the top of an infinite porous medium) is given by the equation.*

$$S_w = \frac{Q_s}{2\pi \cdot r_w \cdot K}$$

where Q_w = discharge from well under steady conditions

r_w = radius of the well

K = Coefficient of permeability

S_w = drawdown at the well

Also find an expression for $\frac{Q_s}{Q_r}$

where Q_r = discharge from a fully penetrating well in confined aquifer under steady state (derivation for Q_r not required)

(10)

[**Hint.** Please refer article 16.13]

Q. 3. (*a*) Sugarcane (root zone depth 1.8 m) is grown in a particular area where the ground watertable is 2.0 m below ground. If the size of the soil pores is 0.08 mm in diameter and surface tension $\sigma = 0.054$ N/m, is the field water-logged ? If so, determine the vertical location of closed dreius below ground, spaced at 15 m. Take drainage coefficient as 0.116 *cumecs/km*^{2}, Coefficient of permeability as 10^{-6} m/s, and the impervious stratum to occur at 7.0 m below ground. Assume the capillary rise from ground watertable not to interfere with the root zone of plant. (15)

[**Hint.** Please refer Solved Example 6.5]

Q. 6. (*c*) The following figure gives profile of a gravity dam with reservoir level as shown. If the coefficient of friction is 0.75, is the dam safe against sliding ? Take weight density of concrete = 2.4 Tonnes/m^3.

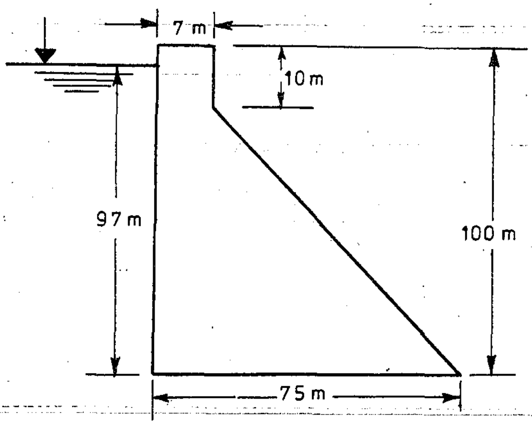

Fig. 31.5

(15)

Year 1998 (*Engineering Services*)

Q. 3. (*c*) What are the factor affecting evaporation from water surfaces ? Describe briefly a method of estimating the evaporation from weather data. (10)

Q. 6. *(c) Compute and draw the storm hyetograph and the intensity duration curve for the following storm (of a given-frequency) on a drainage basin.*

Duration (Minutes)	*Accumulated Precipitation (cm)*
0	–
30	5.0
60	7.5
90	8.5
120	9.0

(15)

[**Hint.** Follow exactly similar solved numerical Example 7.11]

Q. 7. (*a*) A soil 50 cm deep over rock has two horizons, the first being a fine sandy loam 20 cm thick and the second a clay loam 30 cm thick. The field capacity, wilting point and volume weight for the first horizon are 20 percent, 10% percent and 1.5 gm/cm^3, respectively. The corresponding values for the second horizon are 25 percent, 13 percent and 1.2 gm/cm^3. Determine the available moisture storage capacity of the soil profile. If consumptive use requirements of a crop in a particular season is 0.5 mm/day and the soil is initially at field capacity, how long will the crop survive without irrigation. (15)

[**Solution.**

(*i*) Moisture holding capacity of first horizon (fine sandy loam of 20 cm thick)

$$= \frac{\gamma_d \cdot d}{\gamma_w} [F.C. - W.P]$$

$$= \frac{1.5}{1} \times 20 \text{ cm } [20\% - 10\%] = 3 \text{ cm} \quad ...(i)$$

(*ii*) Moisture holding capacity of 2nd horizon (clay loam of 30 cm depth)

$$= \frac{1.2}{1} \times 30 \text{ cm } [25\% - 13\%] = 4.32 \text{ cm} \quad ...(ii)$$

Total max available moisture *i.e.* storage capacity of the soil

$$= (i) + (ii)$$

$$= 3 \text{ cm} + 4.32 \text{ cm} = \mathbf{7.32 \text{ cm}} \quad \textbf{Ans.}$$

Consumptive use requirement per day

$$= 0.5 \text{ mm/day} = 0.05 \text{ cm/day}$$

Max. No. of days in which the entire moisture storage capacity will be utilised *i.e.* the absolute No. of days for which crop will survive

$$= \frac{\text{Moisture Storage capacity in cm}}{\text{Consumptive use in cm/d}}$$

$$= \frac{7.32 \text{ cm}}{0.05 \text{ cm/day}} = \mathbf{146.4 \text{ days.}} \quad \textbf{Ans.}$$

Q. 7. *(c) A vertical lift gate 5m × 2.5 m size weighing 0.5 Tonnes slides along guides (coefficient of friction 0.25) fitted on the side walls of an overflow spillway and its crest. What force will have to be exerted at the hoisting mechanism to lift the gate when the head of water over the crest is 2 m ?* (10)

[**Solution.** In article 24.14.3, while describing the vertical lift gate, we have clearly stated that when such a gate is sliding between groove guides not provided with rollers, force will be required to lift the gate at the hoisting mechanism for not only lifting the self wt. of the gate but also to overcome the friction that will be developed between the gate and the d/s groove guides due to the hydrostatic force caused by the water standing against the gate

(*i*) self weight of gate = 0.5 tonne wt.

$$= 0.5 \times 9.81 \text{ kN}$$
$$= 4.91 \text{ kN} \quad ...(i)$$

(*ii*) Hydrostatic force acting on the gate of ht 2.5 m & 5 m span with 2 m water height

$$P_H = \frac{1}{2} \times (9.81 \times 2) \times 2 \text{ m} \times 5 \text{ m} = 98.1 \text{ kN}$$

$$\mu = 0.25$$

∴ Friction force (downward)

$$= \mu \cdot P_H = 0.25 \times 98.1 \text{ kN}$$
$$= 24.53 \text{ kN} \quad ...(ii)$$

Total Upward force required to lift the gate

$$= (i) + (ii) = 4.91 + 24.53 = 29.44 \text{ kN.}$$

Hence, the force required at hoisting to lift the gate

$$= 29.44 \text{ kN} = \frac{29.44}{9.81} \text{ t force} \quad \textbf{Ans.}$$

$$= 3 \text{ t} \cdot \textbf{force} \quad \textbf{Ans.}$$

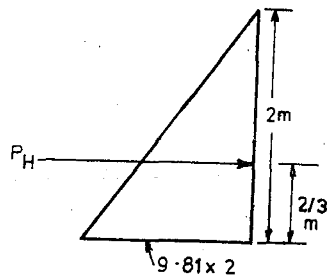

Fig. 31.6

Q. 8. *(a) An irrigation canal takes off from a perennial river. Sketch a typical layout of a diversion headworks. Indicate therein the various components of the headworks.* (15)

Year 1999 (Engineering Services)

Q. 4. (*a*) *The amounts of water flowing from a certain catchment area at the proposed dam site are as tabulated below :*

Month	*Inflow*
January	*2.83*
February	*4.25*
March	*5.66*
April	*18.40*
May	*22.64*
June	*22.64*
July	*19.81*
August	*8.49*
September	*7.10*
October	*7.10*
November	*5.66*
December	*5.66*

Determine :

(*i*) *the minimum capacity of reservoir if water is to be used to feed the turbines of hydropower plant at a uniform rate and no water is to be spilled over.*

(*ii*) *the initial storage required to maintain the uniform demand as above (15)*

[**Hint.** Follow exactly similar solved example 18.8, and compute

(*i*) Min capacity of reservoir = 40.08×10^5 cum
(*ii*) Initial storage reqd. = 19.82×10^5 cum.] **Ans.**

Q. 5. (*a*) *A river discharges 1000 cum/sec of water at high flood level of RL. 103 m. A weir is constructed for flow diversion with a crest length of 255m and total length of concrete floor as 40m. The weir has to sustain the under-seepage at a maximum static head of 2.4m. The silt factor and the safe exit gradient for the river bed material are 1.1 and 1/6, respectively. Determine the depth of cut off required at the downstream end of the concrete floor. Take the level of downstream concrete floor as RL 100.0m. Check for exit gradient.* (15)

[**Solution.** High flood discharge = Q = 1000 m^3/s.

Length of weir = L = 255 m

$$q = \frac{Q}{L} = \frac{1000}{255} = 3.92\ m^2/s$$

f = 1.1 (given)

$$R = 1.35\left(\frac{q^2}{f}\right)^{1/3} = 1.35\left(\frac{3.92^2}{1.1}\right)^{1/3} = 3.25\ m$$

Provide D/s cutoff up to 1.5 R below d/s water level.

$$1.5\ R = 1.5 \times 3.25 = 4.88\ m$$

D/s W.L. = ?

U/s WL = U/s HFL = 103.00 m (given)

H = Max. Static head causing seepage = 2.4 m (given)

∴ D/s W.L. = U/s HFL − H = 103.0 − 2.4 = 100.6 m

Hence, R.L. of bottom of d/s cutoff = 100.6 − 4.88 = 95.72 m.

R.L. of D/s floor = 100.0 m (given)

∴ depth of d/s cutoff = 100.0 − 95.72 = 4.28 m.

Hence d = **4.28 m** **Ans.**

Exit gradient $G_E = \frac{H}{d} \cdot \frac{1}{\pi\sqrt{\lambda}}$

where $\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$

where $\alpha = \frac{b}{d} = \frac{\text{Length of weir floor}}{\text{depth of d/s cutoff}}$

where, b = 40 m (given)

d = 4.28 m (calculated above)

$$\therefore \quad \alpha = \frac{40}{4.28} = 9.346$$

$$\therefore \quad \lambda = \frac{1+\sqrt{1+9.346^2}}{2} = 5.2$$

$$\therefore \quad G_E = \frac{2.4\ m}{4.28\ m} \cdot \frac{1}{\pi.\sqrt{5.2}} = \mathbf{0.078}\ \textbf{Ans.}$$

$$= \frac{1}{12.77} < \frac{1}{6}\ \text{(Safe exit gradient)}$$

Hence, the weir is safe from exit gradient considerations with bottom of d/s cut off at RL 95.72 m. **Ans.**

Q. 6. (*c*) *What are the assumptions and limitations of Sherman's Unit Hydrograph Theory ?* (10)

[**Hing.** Pl See article 7.45. 1].

Q. 8. (*b*). *A sandy loam soil holds water at 140 mm/m depth between field capacity and permanent wilting point. The root depth of the crop is 30 cm and the allowable depletion of water is 35%. The daily water use by the crop is 5 mm/day. The area to be irrigated is 60 ha and water can be diverted at 28 lps. The surface irrigation application efficiency is 40%. There are no rainfall and ground water contribution.*

Determine

(*i*) *allowable depletion depth between irrigations.*

(*ii*) *frequency of irrigation*

(*iii*) *net application depth of water*

(*iv*) *Volume of water required*

(*v*) *time to irrigate 4 ha plot* (15)

[**Hint:** Pl see Solved Example 2.16]

Year 2000 (*Engineering Services*)

Q.5(*a*). *The regression analysis of a 30-year flood data at a point on a river yielded sample mean* $\bar{x} = 1200\ m^3/sec$ *and standard deviation* $s_x = 650\ m^3/sec$. *For what discharge would you design the structure at this point to provide 95% assurance that the structure would not fail in the next 50 years ? Use Gumbel's method. The value of mean and standard deviation of the reduced variate for* $n = 30$ *are 0.53622 and 1.11238, respectively.* (15)

[**Solution.** Follow article 7.50 3.2 and solved examples 7.58 & 7.55 and compute as under:

$\bar{y}_n$ = reduced mean for $n = 30$

= **0.53622**

s_n = reduced standard deviation for $n = 30$

= **1.11238**

X *i.e.* $\bar{x} = 1200\ \text{m}^3/\text{sec.}$ (given)

σ = standard deviation of variate x

$= 650\ \text{m}^3/\text{sec}$ (given under symbol s_x)

$X_{(T)}$ = Discharge for return period T years = ?

$T = ?$

Return period T has to be such that the structure does not fail in the next 50 years with 95% assurance. To find this value of T, please refer solved example 7.55, and compute as under :

The structure has not to fail in the next 50 years with 95% assurance means that it can tolerete a risk of 5% ; *i.e.* $R = 5\% = 0.05$ in 50 years (*i.e.* $n = 50$ years]

Using $R = [1 - (1 - p)^n]$, we get

where $n = 50$ years

$$0.05 = [1 - (1 - p)^{50}]$$

or $$(1 - p)^{50} = 1 - 0.05 = 0.95$$

or $$1 - p = (0.95)^{1/50} = (0.95)^{0.02} = 0.9989746$$

or $$p = 1 - 0.9989746 = 0.001025$$

$\therefore$ $$T = \frac{1}{p} = \frac{1}{0.001025} = \mathbf{975.29\ yrs.}$$

For this value of T, we have to determine $X_{(T)}$ as below

$$X_T = \bar{X} + K_{(T)}\,\sigma$$

where $K_{(T)} = \dfrac{y_{(T)} - \bar{y}_n}{s_n}$ (*i.e.* Eq. 7.148*a*)

For $T = 975.29$ year, $y_{(T)}$ is given by eqn. (7.146) as :

$$y_{(T)} = -\left[I_n \,.\, I_n \,.\, \frac{T}{T-1}\right]$$

$$y_{(975.29)} = -I_n \,.\, I_n \,.\left(\frac{975.29}{974.29}\right) = 6.882222$$

$\therefore$ $$K_{(975.29)} = \frac{6.882222 - 0.53622}{1.11238} = 5.70488$$

The expected peak discharge having frequency of 975.29 years is now given as

$$X = \bar{X} + K.\sigma$$

or $$X_{(979.29)} = 1200 + 5.70488 \times 650$$

$$= 1200 + 3708 = \mathbf{4908\ m^3/sec}\quad \textbf{Ans.}$$

Q. 6(*a*). *In order to compute the flood discharge in a stream by the slope-area method, the following data have been obtained :*

	u/s Section	*Middle Section*	*d/s Section*
Area	108.6 m^2	103.1 m^2	99.8 m^2
Wetted Perimeter	65.3 m	60.7 m	59.4 m
Gauge Reading	316.8 m	—	316.55 m

Determine the flood discharge assuming Manning's n = 0.029 and length between d/s and u/s sections as 250 m (15)

[**Hint.** *Follow exactly similar solved numerical example 7.23.* The only point here is that the values of Area (A) and wetted perimeter (P) given here at mid section are not to be used any where, except to infer that the stream is a *gradually contracting* one, since the area of cross-section as well as wetted perimeter values are gradually decreasing. Additionally, in solved example 7.23, the values of hydraulic mean depths(R) were given ; here they can be worked out as $R = \dfrac{A}{P}$; otherwise this numerical example can be solved similarly, by assuming $h_e = K_e\left(\dfrac{V_2^2}{2g} - \dfrac{V_1^2}{2g}\right)$; where $K_e = 0.1$. The computed value of flood discharge initially works out to 159.89 m^3/sec. which on correction for velocity head & eddy loss h_e, works out to **154** m^3/sec **Ans.**]

Q. 7(*b*). *For border strip method of irrigation, determine the time required to irrigate a strip of land of 0.04 hectares in area from a tube-well with a discharge of 0.02 cumec. The infiltration capacity of the soil may be taken as 5 cm/hr. and the average depth of flow on the field as 10 cm. Also determine the maximum area that can be irrigated from this tubewell.* (15)

[**Hint.** Refer solved example 1.1. **This numerical question was set from this book**]

Q. 8(*a*). *Fig given below shows the section of a gravity dam (non-overflow portion) built of concrete. Calculate the maximum vertical stresses at the heel and toe of the dam. Assume weight of concrete at 23.5 kN/m^3. Neglect earthquake effects.*

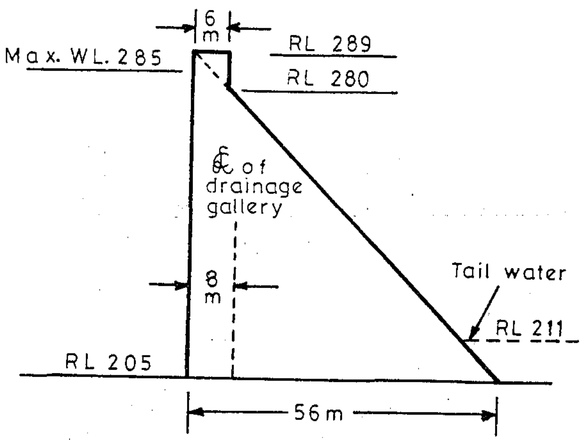

Fig. 31.7

[**Note.** Pl refer solved example 19.1 (*i*) **This numerical question was set from this book**]

Year 2001 (*Engineering Services*)

Q. 2. (*b*) *An unlined irrigation canal has its bed and sides composed of cohesionless material having mean diameter 6 mm. Angle of repose of the material is 40°. The bed width of the canal is 5 m and the side slope 1.5 (H) : 1 V. Determine the maximum discharge that can be admitted into the canal without any sediment movement. Longitudinal slope of the canal is 1 in 5000, and Manning's n = 0.025.* (15)

[**Solution.** Follow & refer solved Example 4.3, and compute as under :

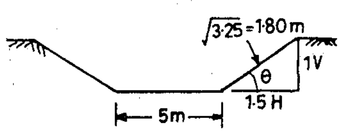

Fig. 31.8

$\phi = 40°$ (given) $\qquad \tan\theta = \dfrac{1}{1.5}$

$\sin\phi = \sin 40° = 0.6428 \qquad \sin\theta = \dfrac{1}{\sqrt{3.25}} = \mathbf{0.5547}$

$$\frac{\tau_c'}{\tau_c} = \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}} = \left[1 - \frac{(0.5547)^2}{(0.6428)^2}\right]^{1/2} = \sqrt{0.255} = 0.505.$$

∴ Min. shear stress required to dislodge the soil grain on side slope of canal is given by

$$\tau_c' = 0.505\, T_c$$

Hence, for stability, the shear stress actually going to be generated on slopes of the channel of given R & S must be less than or equal to 0.507 τ_c ; *i.e.*

$$\tau_0' \le 0.507\, \tau_c$$

The actual shear stress actually going to be generated on the side slopes of a channel of given R & S is given by Eqn. (4.17) as :

$$\tau_0 = 0.75\, \gamma_w \cdot R.S.$$

$$\therefore \quad 0.75 \cdot \gamma_w \cdot R.S. \le 0.507 \cdot \tau_c$$

But $$\tau_c = \gamma_w \cdot R.S. = \gamma_w \cdot \frac{d}{11}$$

$$\therefore \quad 0.75 \cdot \gamma_w \cdot R.S. \le 0.507\, \gamma_w \cdot \frac{d}{11}$$

or $$RS \le \frac{0.507}{0.75 \times 11}\, d \quad \text{or} \quad RS \le 0.0615\, d$$

where d = mean particle dia = 6 mm = 0.006 m

S = 1 in 5000

or $$RS \le 0.0615 \times 0.006 = 3.69 \times 10^{-4}$$

or $$R \times \frac{1}{5000} \le 3.69 \times 10^{-4} \quad \text{or} \quad R \le 1.845 \text{ m.}$$

using 20% factor of safety, we have

max. R = 1.47 m.

For 5 m wide trapezoidal channel with 1.5 (H) : 1 (V) side slopes, we have

$$R = \frac{A}{P} = \frac{(5 + 1.5y)\, y}{(5 + 2 \times 1.8y)} = \frac{(5 + 1.5y)\, y}{(5 + 3.6y)}$$

$$\therefore \quad 1.47 = \frac{(5 + 1.5y)\, y}{5 + 3.6\, y}$$

Solve by Hit & Trial, and find

$$y \approx 2.3 \text{ m.}$$

$$\therefore \quad A = (5 + 1.5 \times 2.3)\, 2.3 = 19.44$$

$$P = (5 + 2 \times 1.8 \times 2.3) = 13.28$$

$$R = 1.46 \approx 1.47 \text{ (ok)}$$

$$Q_{\text{max.}} = \frac{1}{n} \cdot A \cdot R^{2/3} \cdot \sqrt{S}$$

$$= \frac{1}{0.025} \times 19.44 \times (1.46)^{2/3} \frac{1}{\sqrt{5000}} = \mathbf{14.15\ m^3/sec.} \quad \textbf{Ans.}$$

Q. 3. (*b*) ***The following are the ordinates for a flood hydrograph resulting from an isolated storm of 6 hours duration.***

Time (hr.)	0	12	24	36	48	60	72	84	96
Ordinates of Flood hydrograph (cumecs)	5	15	40	80	60	50	25	15	5

Determine the ordinates of 1 cm-6 hr. unit hydrograph, if the catchment area is 450 sq. km. (15)

[**Hint :** Follow similar Solved Example 7.39, Assuming base flow = 5 m^3/s, list the ordinates of flood hydrograph as 0, 10, 35, 75, 55, 45, 20, 10 & 0. Compute vol. of water contained in this hydrograph as :

$$= \frac{12 \times 60 \times 60}{3}\left[\frac{0+0}{2} + 4\,(10+75+45+10) + 2\,(35+55+20)\right]$$

$$= 11.232 \times 10^6 \text{ m}^3.$$

Catchment area $= 450 \times 10^6 \text{ m}^2$

$\therefore$ Depth of water in the hydrograph $= \frac{11.232 \times 10^6}{450 \times 10^6}$ m = 2.5 cm.

Ordinates of U.H. (of 1 cm depth) can be obtained by dividing the above ordinates of flood hydrograph by 2.5. Hence, the ordinates of U.H. are : 0, 4, 14, 30, 22, 18, 8, 4, 0 **Ans.**]

Q. 4. (*c*). *A lined irrigation canal with trapezoidal cross-section has 5 m bed width, 2.5 m depth and 1.5 (H) : 1(V) side slope, longitudinal bed slope of the canal is 1 in 1000 and Manning's n = 0.016. What is the maximum carrying capacity of the canal ? What area of land in hectares the canal can irrigate if the crop has 150 mm field irrigation requirement in a core period of 10 days.* (10)

[Solution.

For a lined trapezoidal channel, corners are rounded, due to which A & P are computed by Eqn. 5.8 & 5.9 as :

$$A = y\,(B + y\,\theta + y \cot \theta)$$

$$P = B + 2y\,\theta + 2y \cot \theta$$

Here for 1.5 (H) : 1(V) side slopes, we have

$$\tan \theta = \frac{1}{1.5} = 0.8,$$

$$\cot \theta = 1.5, \quad \theta = 0.588 \text{ radians}$$

$$y = 2.5 \text{ m}, \quad B = 5 \text{ m}$$

$$\therefore \quad A = 2.5\,(5 + 2.5 \times 0.588 + 2.5 \times 1.5) = 25.55$$

$$P = (5 + 2 \times 2.5 \times 0.588 + 2 \times 2.5 \times 1.5) = 15.44$$

$$R = \frac{A}{P} = \frac{25.55}{15.44} = 1.655$$

$$Q = \frac{1}{n} \cdot A \cdot R^{2/3} \cdot \sqrt{S}$$

$$= \frac{1}{0.016} \times 25.55\,(1.65)^{2/3} \frac{1}{\sqrt{1000}} = 70.65 \text{ m}^3/\text{s}$$

Hence, max. carrying capacity of channel = **70.65 m^3/sec.** **Ans.**

During core period of 10 days, vol. of water which can be supplied by the channel

$$= 70.65 \times (10 \times 24 \times 60 \times 60) \text{ m}^3 = 61.04 \times 10^6 \text{ m}^3.$$

Area which can be irrigated (A) × Depth of water required

= Vol. of water available

$\therefore \quad A \times 0.15 \text{ m} = 61.04 \times 10^6 \text{ m}^3$

or $\quad A = \frac{61.04 \times 10^6}{0.15} \text{ m}^2 = 407 \times 10^6 \text{ m}^2 =$ **407 sq. km Ans.]**

Q. 7 (*b*). *Following particulars were recorded from a barrage :*

(*i*) Maximum reservoir level	= 212 m
(*ii*) Pond level	= 211 m
(*iii*) Downstream high flood level in the river	= 210 m
(*iv*) Maximum design flood discharge	= 3500 m^3/s
(*v*) Crest level of the barrage	= 207 m
(*vi*) Crest level of the head regulator	= 208 m
(*vii*) Coefficient of discharge	= 2.10 $m^{1/2}$/sec for barrage
	= 1.50 $m^{1/2}$/sec for head regulator
(*viii*) River bed level	= 205 m
(*ix*) Design discharge of main canal	= 500 m^3/sec

Determine the number of gates required for the barrage and the head regulator if each gate has 10 m clear span. Neglect :

(1) end contractions due to piers and abutments ;

(2) velocity of approach.

If a stilling basin is provided downstream of the barrage for the energy dissipation, find the length and RL of the basin floor. Assume that the length of basin is 5 times the conjugate depth required for hydraulic jump. Neglect losses due to friction. (20)

Solution. (1) **Waterway for Barrage :**

High flood discharge of 3500 m^3/s has to pass through the gated openings provided at the barrage site, with the following data.

Max. water level at high flood U/S of barrage = 212.00 m

Crest level of barrage = 207.00 m

Opening available or Head causing flow above the crest of barrage

= 212.00 − 207.00 = 5.00 m.

(ignoring Vel. head)

Now, $\quad Q = C \cdot L H^{3/2}$

where C = coeff. of discharge through the barrage

= 2.10 (given)

L = Effective waterway of barrage (openings)

H = 5.00 m

$\therefore \quad 3500 = 2.10 \times L \times (5)^{3/2}$

or $\quad L = \frac{3500}{2.1 \times (5)^{3/2}} = 149.1 \text{ m}$; say 150 m

Effective water way = Total water way (ignoring end contractions)

Hence, provide 15 bays, each of 10 m clear span.

$\therefore$ **No. of gates required for barrage = 15 Ans.**

(2) **Water way for Canal Head Regulator.**

The discharge through canal regulator = 500 m^3/s

Coefficient of discharge for regulator opening = 1.5

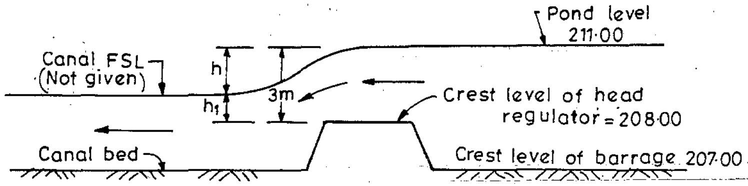

Fig. 31.9.

Head over the crest of regulator at pond Level = 211.00 − 208.00 = 3.00 m.

$$Q = C_1 \cdot L_1 \cdot H_1^{3/2}$$

$\therefore$ $$500 = 1.5 \times L_1 \times (3)^{3/2}$$

or $$L_1 = \frac{500}{1.5 \times (3)^{3/2}} = 64 \text{ m.}$$

Provide 7 bays each of 10 m clear span, thereby providing 70 m water way.

No. of gates required for canal head regulator each of 10 m span = **7 Ans.**

(3) **Design of Stilling Basin.**

$U/S\ HFL = 212.00$

$D/S\ HFL = 210.00$

$U/S\ TEL = 212.00$ (ignoring vel. of approach)

$D/S\ TEL = 210.00$ (– do –)

$\boldsymbol{H_L} = 212.00 - 210.00 = \mathbf{2\ m}$

$\boldsymbol{q}$ = Discharge intensity through barrage bays

$= 3500/150 = \mathbf{23.34}\ \text{m}^3/\text{s/m}$.

E_{f_2} for $H_L = 2$ m & $q = 23.34$, from Blench curves – (Plate 10.1) is found to be = **7.2** m

$\therefore$ Level at which jump will form

$= D/S\ TEL - E_{f_2} = 210.00 - 7.2 = \mathbf{202.8\ m}$

y_2 corresponding to E_{f_2} of 7.2 m from plate 10.2 = 6.6 m.

Length of cistern $= 5y_2 = 5 \times 6.6 = 33$ m.

Hence, provide 33 m long stilling basin at level say *202.6 m* (slightly lower than the calculated value of 202.8 m) as shown in Fig. 31.10 below.

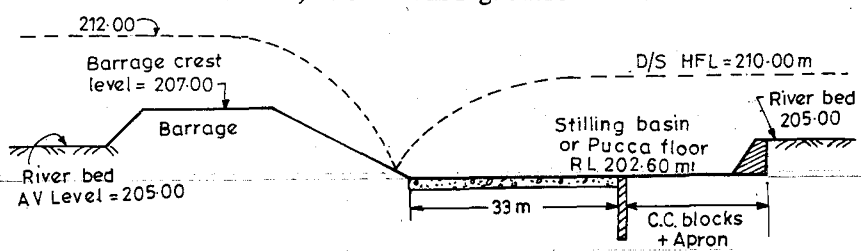

Fig. 31.10.

Alternatively, if Blench curves are not supplied in the Examination Hall, then we can compute the value of y_2 as follows :

$$y_c = \sqrt[3]{\frac{q^2}{g}} \qquad \text{(from Eqn. 10.3)}$$

$$= \sqrt[3]{\frac{23.3^2}{9.81}} = \mathbf{3.81\ m.}$$

Now let $Y = y_2/y_c$ (Eqn. 10.5)

and $Z = H_L/y_c$ (Eqn. 10.6)

Compute Value of $Z = \dfrac{2\text{ m}}{3.81\text{ m}} = \mathbf{0.5248}$

Use Eqns. 10.9 & 10.10 to compute the value of Y for known value of Z.

Here $Z < 1$, hence Eqn. (10.9) is applicable

$\therefore$ $Y = 1 + 0.93556\, Z^{0.368}$ (for $Z < 1$)

or $Y = 1 + 0.93556\,(0.5248)^{0.368} = \mathbf{1.738}$

$\therefore$ $Y = y_2/y_c = 1.738$

or $y_2 = 1.738\, y_c = 1.738 \times 3.81\text{ m} = \mathbf{6.6\ m.}$

$5y_2$ = Length of cistern = $5 \times 6.6 = \mathbf{33\ m.}$ **Ans.**

Also, E_{f_2} can be calculated by Eq. (10.13) as :

$$\frac{E_{f_2}}{y_c} = Y + \frac{1}{2Y^2} = 1.738 + \frac{1}{2 \cdot (1.738)^2}$$

or $E_{f_2} = 1.904 \times 3.81 = \mathbf{7.25\ m}$

Level at which jump will form

$= D/S\ TEL - E_{f_2}$ $D/S\ TEL = D/S\ HFL$

$= D/S\ HFL - E_{f_2}$ (on neglecting vel. of approach)

$= 210.00 - 7.25 = 202.75$ m

Provide cistern at RL **202.6 m** **Ans.**

Q. 7. (*c*) *During re-cuperation test, the water level in an open well was depressed by pumping up to 2.5 m. The water level was raised by 1 m within 60 minutes, just after stopping the pumping. Determine the yield from the well of 2m diameter when the depression head in 3 m.* (10)

[**Hint.** Follow exactly similar Solved Example 16.11 and compute :

$$\frac{C'}{A} = \frac{2.3}{3600} \log_{10} \frac{2.5}{1.5} = 1.417 \times 10^{-4}$$

Q = yield from a well of 2m dia with 3m depression head

$$= \left(\frac{C'}{A}\right) \cdot A \cdot s = (1.417 \times 10^{-4}) \times \left(\frac{\pi}{4} \times 2^2\right) \times 3\ \text{m}^3/\text{s}$$

$= \mathbf{1.335}\ \boldsymbol{l/s}$ **Ans.]**

Q. 8. (*b*) *Explain the purpose of providing groins. State the factors which affect the selection of type and performance of groin. Mention about the orientation, desirable length and spacing of groins in a groin system.* (10)

[Please refer article 8.5.3 (3)]

Year 2002 (*Engineering Services*)

Q. 2. (*b*) *For a drainage basin of 640 km², isohyetals based on a storm event yield the following data :*

Isohyetal interval (cm)	*14-12*	*12-10*	*10-8*	*8-6*	*6-4*	*4-2*	*2-0*
Inter isohyetal area (km²)	*90*	*140*	*125*	*140*	*85*	*40*	*20*

Estimate the average depth of precipitation over the basin.

[**Hint :** Please follow exactly similar solved example 7.5, and compute]

$$P = \frac{90 \times 13 + 140 \times 11 + 125 \times 9 + 140 \times 7 + 85 \times 5 + 40 \times 3 + 20 \times 1}{90 + 140 + 125 + 140 + 85 + 40 + 20 = 640}$$

$= \mathbf{8.41\ cm}$ **Ans.**]

Q5. (*b*) *Design a regime channel for a discharge of 35 m³/s with silt factor of 0.9 by Lacey's theory, taking side slopes as 1 H : 2 V.*

[**Hint :** Please follow exactly similar solved Question 4.9 ; and compute

$B = 24$ m, $y = 1.83$ m, $S_o = 1$ in 7200 **Ans.**]

Q7. (*a*) *At an energy dissipater structure below a low spillway, the discharge is 19 m²/s, and the energy loss is 1 m at the hydraulic jump forming therein. Determine the depth of flow at both ends of the jump.*

Solution. $q = 19\ m^2/s$; $H_L = 1$ m ; $y_1 = ?$; $y_2 = ?$

Use equations as :

$$y_1 y_2 (y_2 + y_1) = \frac{2q^2}{g} \quad \text{...(Eqn. 10.5)}$$

and

$$H_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2} \quad \text{...(Eqn. 10.12)}$$

Solve the above equations for two unknowns, y_1 and y_2, as follows :

From Eqn. (10.5), we get

$$y_1 y_2 (y_2 + y_1) = \frac{2 \times 19^2}{9.81} = 73.6 \quad \text{...}(i)$$

From Eqn. (10.12), we get

$$1 = \frac{(y_2 - y_1)^3}{4 \cdot y_1 y_2} \quad \text{...}(ii)$$

Let $\frac{y_2}{y_1} = x$

$\therefore$ $y_2 = y_1 \cdot x$

Substituting in (*i*), we get

$$y_1 \cdot y_1 x (y_1 x + y_1) = 73.6$$

or $y_1^2 \cdot x \cdot y_1 (x + 1) = 73.6$

or $x \cdot y_1^3 (x + 1) = 73.6$ ...(*iii*)

Also from (*ii*),

$$1 = \frac{(y_1 x - y_1)^3}{4 \cdot y_1 \cdot x \cdot y_1} = \frac{y_1^3 (x-1)^3}{4 \cdot x \cdot y_1^2} = \frac{y_1}{4x}(x-1)^3$$

or $4x = y_1 (x - 1)^3$

or
$$y_1 = \frac{4x}{(x-1)^3} \qquad ...(iv)$$

Substituting in (*iii*), we get

$$x \cdot \left[\frac{4x}{(x-1)^3}\right]^3 [\,x+1\,] = 73.6$$

Solve by hit and trial, for x, as :

$$x = \mathbf{2.548}$$

$$\therefore \qquad y_1 = \frac{4 \times 2.548}{(2.548-1)^3} = \mathbf{2.748\ m}$$

$$y_2 = y_1\, x = 2.748 \times 2.548 = \mathbf{7.0\ m}$$

Hence, the depth at both ends, of jump, y_1 and y_2 will be 2.748 m and 7.0 m, respectively. Ans.

Q8. (*a*) *The daily flows in a river for three consecutive years are given in the table by class interval along with the number of days the flow belonged to this class. What are the 50% & 75% dependable flows for the river ?*

Daily mean discharge m^3/s		*100-90.1*	*90-80.1*	*80-70.1*	*70-60.1*	*60.50.1*
No. of days in each class interval	1981	0	16	27	21	43
	1982	6	19	25	60	51
	1983	10	16	38	67	58

Daily mean discharge m^3/s		*50-40.1*	*40-30.1*	*30-20.1*	*20-10.1*	*10-Negligible*
No. of days in each class interval	1981	59	64	22	59	54
	1982	38	29	48	63	26
	1983	38	70	29	26	13

[**Hint :** Please refer Solved Example 18.3]

Year 2003 (Engineering Services)

Q2. (*b*) *During the passage of a flood the following data was estimated at two sections 500 m apart :*

Sections	*Water surface elevation, m*	*Area of flow section,* m^2,	*Hydraulic mean depth, m*
Upstream, *P*	85.233	91.746	2.835
Downstream, *R*	85.176	84.354	2.917

The eddy loss coefficient for gradual contraction is to be taken as 0.1 and for gradual expansion as 0.35. Estimate the flood discharge passing through the reach. n = 0.022. (15)

[**Hint.** Follow exactly similar solved example 7.23]

Q5. (*b*) *Water discharges at the rate of 298 m³/sec over a spillway 14 m wide into a stiling basin of the same width. The water level behind the spillway is 61 m over datum. The river water level in the downstream is 29.2 m over datum. The river bed is paved flush with the bed level to just adequate length to form the jump basin. Assuming that no energy is dissipated in the flow down the spillway, find the basin invert level required for a hydraulic jump to be formed within the basin* (15)

[**Solution.** Here $H_L = (61.0 - 29.2)$ m = 31.8 m

$$q = \frac{Q}{B} = \frac{298}{14} = 21.29 \text{ m}^3/\text{s/m}$$

This is a case where H_L and q are known, and we have to find the value of y_2, since the invert level of jump basin will be equal to (RL 29.2 – y_2). To determine y_2, proceed as given in article 10.3.1—when Blench curves are not a·ailable.

From

$$\text{Determine } y_c = \sqrt[3]{\frac{q^2}{g}} \text{ (i.e. Eq. 10.3)} = \sqrt[3]{\frac{(21.29)^2}{9.81}} = 3.59 \text{ m}$$

Now use Eq. (10.6) as :

$$Z = \frac{H_L}{y_c} = \frac{31.8}{3.59} = 8.86$$

Now use Eq. (10.10) as :

$$Y = 1 + 0.93556 \,.\, Z^{0.24} \text{ for } Z > 1$$

For $Z = 8.86$ (> 1) $\quad Y = 1 + 0.93556 \times (8.86)^{0.24} = 2.58$

Now, use Eq. (10.5) as :

$$\frac{y_2}{y_c} = Y$$

or $$\frac{y_2}{3.59} = 2.58 \qquad \text{or} \quad y_2 = 9.26 \text{ m}$$

The basin invert level = 29.2 – 9.26 = **19.94 m** above datum. **Ans.**]

Q6. (*b*) *A channel is 40 m wide, 2.6 m deep with slope of 1 in 5000. The representative bed material size D_{65} is 0.64 mm, and mean diameter of the bed material is 0.38 mm. Mannings n = 0.021. Neglecting the side friction, find the bed load transported by the channel in tonnes per day by Meyer-Peter equation, considering B/D as large and τ_c = 0.075 d.*

Solution. Meyer-Peter's equation, giving bed load transport in N/m.s is given by Eq. (4.51) as :

$$g_b = 0.417\left[\tau_0\left(\frac{n'}{n}\right)^{3/2} - \tau_c\right]^{3/2}$$

where $\tau_0 = 0.97\ \gamma_w$ R.S. for the channel

where γ_w = unit wt. of water

$= 9.81\ \text{kN/m}^3 = 9.81 \times 10^3\ \text{N/m}^3$

$R = \frac{A}{P} = \frac{B\,.\,y}{B} = y$ for wider channels having B/y large

$= 2.6$ m

$$S = \frac{1}{5000}$$

$$\therefore \quad \tau_0 = 0.97 \times (9.81 \times 1000) \times 2.6 \times \frac{1}{5000} = \mathbf{4.948\ N/m^2}$$

$n' = 1/24\,.\,d^{1/6}$ where d is the representative size of the bed material in m, usually taken as median size (d_{50}) or d_{65}, which is given as equal to 0.64 mm.

$$\therefore \quad d = 0.64 \times 10^{-3}$$

$$\therefore \quad n' = \frac{1}{24}(0.64 \times 10^{-3})^{1/6} = \mathbf{0.01223}$$

n = **0.021 (given)**

τ_c is usually given as $\tau_c = 0.687\,.\,d_a$ when τ_c is in N/m^2, and d_a is in mm.

Here it is given that $\tau_c = 0.075d$. Eventually, the given eqn. is meant for τ_c, when τ_c is expressed in kg/m^2. For S.I. units, the given eqn. will hence become.

$$\tau_c = 0.075\, d_a \times 9.81\ \text{N/m}^2$$

$$= 0.736\, d_a\ (\text{N/m}^2)$$

d_a is mean size of the bed particles, which is given as equal to 0.38 mm.

$$\therefore \quad \tau_c = 0.736 \times 0.38\ \text{N/m}^2 = \mathbf{0.279\ N/m^2}$$

Now, $$g_b = 0.417\left[4.948\left(\frac{0.01223}{0.021}\right)^{3/2} - 0.279\right]^{3/2}$$

$$= 0.417\,[2.199 - 0.279]^{3/2} = 0.417\,(1.92)^{1.5}$$

or $$g_b = 1.109 \text{ N/m.s} = \frac{1.109}{9.81} \text{ kg/s/m}$$

∴ Bed load transported by 40 m wide channel

$$= \frac{1.109}{9.81} \times 40 \text{ kg/sec} = 4.522 \text{ kg/sec}$$

$$= \frac{4.522 \times 24 \times 3600}{1000} \text{ t/day} = \mathbf{390.69\ tonnes/day.\ Ans}]$$

Q7. (*a*) *Flood frequency computations for a flashy river at a point 50 km upstream of a bund site indicated the following :*

Return period, T_{year}	*50*	*100*
Peak flood, m^3/sec	*20,600*	*22,150*

Estimate the flood magnitude in the river with a return period of 500 year through use of Gumbel's method (15)

[**Hint.** Follow exactly similar Solved Example 7.58.]

Q8. (*a*) *Given below are the monthly rainfall, P, and the corresponding run off values, R, for a period of 10 months for a catchment. Develops a correlation between R and P :*

Month No.	*P, cm*	*R, cm*
1	*4*	*0.2*
2	*22*	*7.1*
3	*28*	*10.9*
4	*15*	*4.0*
5	*12*	*3.0*
6	*8*	*1.3*
7	*4*	*0.4*
8	*15*	*4.1*
9	*10*	*2.0*
10	*5*	*0.3*

[**Hint.** To obtain a linear relation between rainfall *P* and runoff *Q* (here represented by *R*), we have to plot a curve taking *R* on *X*-axis and *P* on *Y*-axis, as to plot a curve like the one obtained in Fig. 7.105. The slope of straight line portion is then determined to compute the desired relation between *P* and *R*. This relation is worked out as

$R = 0.47P$ in Fig. 3.11. **Ans.**

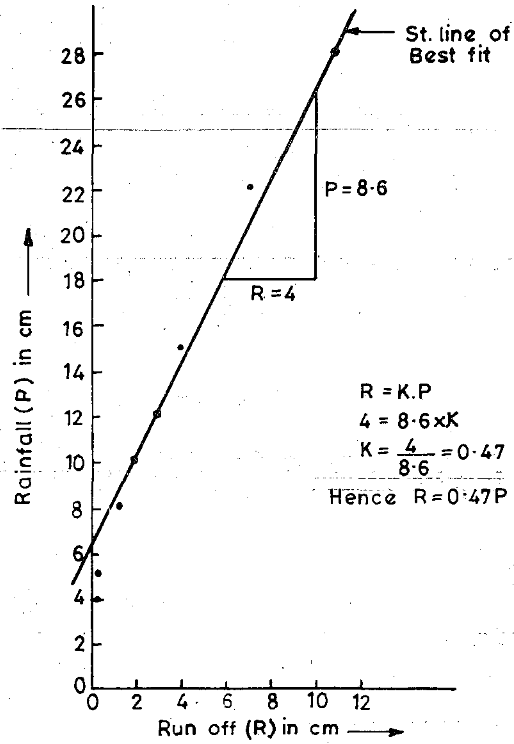

Fig. 31.11

Year 2004 (*Engineering Services*)

Q3. (*a*) *A watershed has five non-recording rain gauges, installed in its area. The amount of rainfall recorded for one of the years is given below :*

Rain gauge station	I	II	III	IV	V
Annual rainfall in cm	100	120	190	95	125

Find the required optimum number of non-recording and recording rain gauges for this watershed. Assume an error of 10% in the estimation of mean rainfall. (15)

[**Hint.** Pl. follow exactly similar solved example 7.3]

Q6. (*a*) *Explain briefly the functions of the following for a typical canal headworks :*

(*i*) *divide wall,*

~~(*ii*) *guide bank,*~~

(*iii*) *sediment ejector.*

Explain briefly how does seepage endanger the safety of a hydraulic structure on permeable foundation. (15)

Q7. (*a*) *In a catchment, the average rainfall for a storm at two successive 6 hr intervals was 3.0 cm and 6.0 cm respectively. The abstraction losses* ϕ*-index, were estimated to be 0.20 cm/hour. For the same catchment, the calculated data for a 6 hour unit hydrograph is available and is given below. Find the direct run-off hydrograph due to the storm.*

Time (hours)	0	6	12	18	24	30	36	42	48	54	60
Unit hydrograph ordinate (m^3/s)	0	10	25	40	100	150	100	75	25	15	0

(20)

[**Hint.** Pl. follow similar solved question 7.35. The excess rainfall here, in two successive 6 hr rainfall periods, will be [3.0 – 6 × 0.2 = 1.8 cm] and [6 – 6 × 0.2 = 4.8 cm], respectively. The ordinates of D.R.H. for first rain will be calculated by multiplying the given ordinates of U.H. by 1.8. While the ordinates of DRH caused by 2nd rain will be obtained by multiplying the given ordinates of U.H. by 4.8. The ordinates due to 2nd rain will start after 6 hr from those of the first, as usual. The summation of the two set of ordinates will give ordinates of total S.R. hydrograph.]

Q8. (*a*) *Define, duty, delta and base period of a crop and express the relationship connecting them. Explain briefly with the help of a diagram the concept of 'frequency of irrigation'.* (10)

(*b*) *A loam soil has a field capacity of 25 per cent and wilting coefficient of 10 per cent. The dry unit weight of soil is 1.5 g/cc. If the root zone depth is 60 cm, determine the storage capacity of the soil. Irrigation water is applied when moisture content falls to 15 per cent. If the water application efficiency is 75 per cent, determine the water depth required to be applied in the field.* (10)

[**Solution.** Pl. follow exactly similar solved question 2.15 and compute as :

Max. storage capacity in root zone of depth, d

$$= \frac{\gamma_d \cdot d}{\gamma_w}\left[\frac{\text{Field capacity mc}}{100} - \frac{\text{Wilting pt. mc}}{100}\right]$$

$$= \frac{\rho_d \cdot d}{\rho_w}\left[\frac{\text{F.C.}}{100} - \frac{\text{W.P.}}{100}\right]$$

$$= \frac{1.5\,\frac{\text{gm}}{\text{cc}} \times 60\text{ cm}}{1\,\frac{\text{gm}}{\text{cc}}}\left[\frac{25}{100} - \frac{10}{100}\right]$$

$$= 90\left[0.25 - 0.10\right]\text{cm} = \mathbf{13.5\ cm.}\quad \textbf{Ans.}$$

Irrigation water is to be supplied when *mc* falls to 15%. It means that m.c. is allowed to vary between 25% (F.C. mc) and 15%. The deficiency of water depth created during this fall of m.c.

$$= \frac{\rho_d \cdot d}{\rho_w}[0.25 - 0.15]$$

$$= 1.5 \times 60\text{ cm} \times 0.10 = \mathbf{9\ cm.}$$

Hence, 9 cm depth of water is the net irrigation requirement.

Water depth required in the field

$$= \frac{\text{Net irrigation requirement}}{\text{Water application efficiency}}$$

$$= \frac{9\text{ cm}}{0.75} = \mathbf{12\ cm.}\quad \textbf{Ans.}$$]

CIVIL SERVICES COMPETITION (IAS)

This competition is open to all graduates including Engineering graduates. The age limits vary between 21 to 30 years as on 1st August of the year of exam.

In this competition, you would have to, first of all, appear in a screening test, called the **Preliminary Examination.** This exam. will consists of *objective type questions*, having the following marks :

(*i*)	*General Studies*	:	150 Marks
(*ii*)	*One subject, to be selected from out of 23 optionals, listed below, such as Civil Engineering (for you)*	:	300 Marks
		Total	450 Marks

List of optionals for Prelimes :

(i) Agriculture; (ii) Animal Husbandry & Veterinary Science; (iii) Botany; (iv) Chemistry; (v) Civil Engineering; (vi) Commerce; (vii) Economics; (viii) Electrical Engg; (ix) Geography; (x) Geology; (xi) Indian History; (xii) Law; (xiii) Mathematics; (xiv) Mechanical Engg; (xv) Medical Science; (xvi) Philosophy; (xvii) Physics; (xviii) Political Science; (xix) Psychology; (xx) Public Administration; (xxi) Sociology; (xxii) Statistics; and (xxiii) Zoology.

The syllabus (**revised wef year 2000**) prescribed for "General Studies" and "Civil Engineering" objective type papers, is given below :

Preliminary Exam
Paper I — General Studies (Max. Marks 150)

The paper on General Studies will include Questions covering the following field of knowledge

General Science.

Current events of national and international importance.

History of India and Indian National Movement.

Indian and World Geography

Indian Polity and Economy.

General Mental Ability

Questions on General Science will cover General appreciation and understanding of science including matters of everyday observation and experience, as may be expected of a well educated person who has not made a special study of any particular scientific discipline. In current events, knowledge of significant national and international events will be tested. In History of India, emphasis will be on broad general understanding of the subject in its social, economic and political aspects. Questions on the Indian National Movement will relate to the nature and character of the nineteenth century resurgence, growth of nationalism and attainment of Independence. In Geography, emphasis will be on Geography of India. Questions on the Geography of India will relate to physical, social and economic Geography of the country, including the main features of Indian agricultural and natural resources. Questions on Indian Polity and Economy will test knowledge of the country's political system and Constitution of India, Panchayati Raj, Social Systems and economic developments in India. On general mental ability, the candidates will be tested on reasoning and analytical abilities.

Paper II — Civil Engineering (Max. Marks 300)
PART-A

1. **Engineering Mechanics.** Units and dimensions, SI Units, Vectors, Concept of

Force, Concept of particle and rigid body. Concurrent, nonconcurrent and parallel forces in a plane, moment of force and Varignon's theorem, free body diagram, conditions of equilibrium, Principle of virtual work, equivalent force system.

First and Second Moment of area, Mass moment of Inertia.

Static Friction Inclined plane and bearings.

Kinematics and Kinetics : Kinematics in cartesian and polar co-ordinates, motion under uniform and non-uniform acceleration, motion under gravity. Kinetics of particle : Momentum and Energy principles, D Alembert's Principle, Collision of elastic bodies, rotation of rigid bodies, simple harmonic motion.

2. **Strength of Materials.** Simple Stress and Strain, Elastic constants, axially loaded compression members, Shear force and bending moment, theory of simple bending, Shear Stress distribution across cross-sections, Beams of uniform strength, Leaf spring, Strain Energy in direct stress, bending and shear.

Deflection of beams. Macaulay's method, Mohr's moment area method, Conjugate beam method, unit load method. Torsion of Shafts, Transmission of power, closecoiled helical springs, Elastic stability of columns : Euler's, Rankine's and Secant formulae. Principal Stresses and Strains in two dimension, Mohr's Circle. Theories of Elastic Failure, Thin and Thick cylinders : Stresses due to internal and external pressures-Lame's equation.

3. **Structural Analysis.** Analysis of pin jointed plane trusses, deflection in trusses. Three hinged and two hinged arches, rib shortening, temperature effects, influence lines in arches. Analysis of propped cantilevers, fixed beams, continuous beams and rigid frames. Slope deflection, moment distribution, Kani's method and Matrix method : Force and Displacement methods. Rolling loads and influence lines for determinate beams and pin jointed trusses.

PART-B

4. **Geotechnical Engineering.** Types of soil, field identification and classification, phase relationships, consistency limits, particle size distribution, classification of soil, structure and clay mineralogy.

Capillary water and structural water, effective stress and pore water pressure, Darcy's Law, factors affecting permeability, determination of permeability, permeability of stratified soil deposits.

Seepage pressure, quick sand condition, compressibility and consolidation, Terzaghi's theory of one dimensional consolidation, consolidation test. Compaction of soil, optimum moisture content, proctor Density.

Subsurface exploration, methods of boring, sampling, types of sampler, filed tests.

Shear strength of soils, Mohr-Coulomb failure theory, shear tests, Earth pressure at rest, active and passive pressures, Rankine's theory, Coulomb's wedge theory, earth pressure on retaining wall.

Bearing capacity, Terzaghi and other important theories, net and gross bearing pressure, Immediate and consolidation settlement.

Load carrying capacity of pile groups.

Stability of slope-Conventional method of slices, stability numbers.

5. **Transportation Engineering.** Highway alignment, choice of layout and capacity of highways, location survey, geometric design of highways-various elements, curves, grade separation and segregation of traffic, Intersection design, highway materials and testing subgrade and pavement components, types of pavements, road drainage, elements of airport engineering.

Railway engineering-elements of permanent track-rails, sleepers, ballast and rail fastenings, tractive resistance, elements of geometric design-gradients and grade compensation on curves, cant transition curves and vertical curves, stresses in railway tracks, points and crossings, signalling and interlocking, maintenance of railway track. Culverts and small bridges.

PART-C

6. **Fluid Mechanics.** Fluid properties, fluid statics, forces on plane and curved surfaces, stability of floating and submerged bodies.

Kinematics. Velocity, streamlines, continuity equation, accelerations irrotational and rotational flow, velocity potential and stream functions, flownet, separation.

Dynamics. Euler's equation along streamline, control volume equation, continuity, momentum, energy and moment of momentum equation from control volume equation, applications to pipe flow, moving vanes, moment of momentum, Dimensional analysis. Boundary layer on a flat plate, drag and lift on bodies. Laminar and Turbulent Flows. Laminar and turbulent flow through pipes, friction factor variation, pipe networks, water hammer, and surge tanks.

Open Channel Flow. Energy and momentum correction factors, uniform and non-uniform flows, specific energy and specific force, critical depth, Friction factors and roughness coefficients, flow in transitions, free overfall, weirs, hydraulic jump, surges, gradually varied flow equations, surface profiles, moving hydraulic jump.

PART-D

7. **Environmental Engineering**

Water supply. Estimation of surface and subsurface water resources, predicting demand for water, impurities of water and their significance, physical, chemical and bacteriological analysis, water borne diseases, standards for potable water.

Intake of water. pumping and gravity schemes, water treatment : principles of coagulation, floculation and sedimentation; slow-, rapid-, pressure-, filters; chlorination, softening, removal of taste, odour and salinity.

Water storage and distribution : storage and balancing reservoir types, location and capacity. Distribution systems : layout, hydraulics of pipe lines, pipe fittings, valves including check and pressure reducing valves, meters, analysis of distribution systems, leak detection, maintenance of distribution systems, pumping stations and their operations.

Sewerage systems. Domestic and industrial wastes, storm sewage-separate and combined systems, flow through sewers, design of sewers, sewer appurtenances, manholes, inlets, juctions, siphon. Plumbing in Public buildings.

Sewage characterisation. BOD, COD, solids, dissolved oxygen, nitrogen and TOC. Standards of disposal in normal water course and on land.

Sewage treatment. Working principles, units, chambers, sedimentation tank, trickling filters, oxidation ponds, activated sludge process, septic tank, disposal of sludge, recycling of waste water.

9. **Construction Management.** Elements and principles of Activity on Arrow (AOA) and Activity on Node (AON) networks and work breakdown structure. Interfaces. Ladder networks. Activity time. Time computations and floats. ATC and PTC trade-off. Work study and sampling. Scheduling principles-material schedules. ABC and EOQ analysis of inventory. Budgeting with barcharts. Working capital, PERT, probability of completion.

Elements of Engineering Economics, methods of appraisal, present worth, annual-cost, benefit-cost, incremental analysis. Economy of scale and size. Choosing between alternatives including levels of investments, Project profitability.

This preliminary examination is meant to serve as a screeining test only. The marks *obtained in the preliminary Exam by the candidates who are declared qualified for admission to Main Examination will not be counted for determining their final order of merit. The number of candidates to be admitted to the Main Examination will be about twelve to thirteen times the total approximate number of vacancies to be filled in various Services & Posts. Only those candidates who are declared by the commission to have qualified in the Preliminary Examination in a year will be eligible for admission to the Main Examination of that year, provided they are otherwise eligible for admission to the Main Examination.*

Main Examination

The main examination consists of one qualifying paper in *English* and another qualifying paper in *one of the Indian Languages* to be selected from the languages included in the eighth schedule of constitution, such as Hindi, Tamil, Bangali, Sanskrit or any other regional language. These two papers, each carrying 300 marks, will be of matriculation standard, and of qualifying in nature *i.e.* the *marks obtained in these papers will not be counted in your final ranking in the competition.*

Besides the above two qualifying papers (Paper I and II), there will be 7 other papers (Paper III to IX), full marks of which will count in your final ranking at this competition. These 7 papers will consists of ;

Compulsory Subjects

Paper III	Essay	200 marks
Paper IV	General Studies I	300 marks
Paper V	General Studies II	300 marks
Paper VI	Paper I of chosen Optional I	300 marks
Paper VII	Paper II of chosen Optional I	300 marks
Paper VIII	Paper I of chosen Optional II	300 marks
Paper IX	Paper II of chosen Optional II	300 marks
		2000 marks
	Interview and Personality Test	300 marks
	Grand Total	**2300 marks**

Note : *On the basis of merit list drawn out of 2000 marks of the Main Examination, cendidates will be summoned for Interview. The no. of condidates called for Interview will be about Twice the number of vacancies to be filled. The final select list will be drawn on the basis of merit for total marks obtained out of 2300 marks.*

Obviously, all the civil engineering students are expected to offer *'Civil Engineering'* subject as one of their two chosen Optionals. Hence, the subject will cover 600 marks out of the grand total of 2300 marks at this competition. You may offer 2nd optional as either "Geology" or "Mathematics" or any other subject of your interest.

The syllabuses (**revised wef year 2000**) for both the papers on *'General Studies'* as well as on the subject of *'Civil Engineering'* are given below for your ready reference.

A perusal of the syllabus of 'Civil Engineering' subject further reflects that **Paper I** will cover four subjects like *Theory of Structures, Structural Designs, Fluid Mechanics* and *Soil Mechanics.* **Paper II** will cover the subjects of *Construction Technology, Survey & Transportation, Hydrology, Water Resources, Irrigation,* and *Environmental Engineering.* Both the papers will thus cover virtually the entire field of civil engineering.

ESSAY

Candidates will be required to write an essay on a specific topic. The choice of subjects will be given. They will be expected to keep closely to the subject of the essay to arrange their ideas in orderly fashion, and to write concisely. Credit will be given for effective and exact expression.

GENERAL STUDIES (MAIN EXAM.)

Note. *The nature and standard of questions in the General studies papers will be such that a well-educated person will be able to answer them without any specialized study. The questions will be such as to test a candidate's general awareness of a variety of subjects, which will have relevance for a career in Civil Services.*

Syllabus for General Studies Paper I (Main Exam)

(*a*) *History of Modern India and Indian Culture.* The History of Modern India will cover history of the Country from about the middle of nineteenth century and would also include questions on important personalities who shaped the Freedom Movement and Social reforms. The part relating to Indian Culture will cover all aspects of Indian Culture from the ancient to modern times.

(*b*) *Geography of India.* In this part, questions will be on the physical, economic and social geography of India.

(*c*) *Indian Polity.* This part will include questions on the Constitution of India, Political system and related matters.

(*d*) *Current National issues and topics of social relevance.* This part is intended to test the Candidate's awareness of current national issues and topics of social relevance in the present-day India, such as the following.

Demography & Human Resource & related issues. Behavioural & Social issues & Social Welfare problems, such as child labour, gender equality, adult literacy, rehabilitation of the handicapped and other deprived segments of the society, drug abuse, public health, etc.

Law enforcement issues, human rights, corruption in public life, communal harmony etc. Internal Security and related issues.

Environmental issues, ecological preservation, conservation of natural resources and national heritage.

The role of national institutions, their relevance and need for change.

Syllabus for General Studies Paper II (Main Exam)

(*a*) *India and the World.* This part is intended to test candidate's awareness of India's relationship with the world in various spheres, such as the following :-

(*i*) Foreign Affairs (*ii*) External Security and related matters

(*iii*) Nuclear Policy (*iv*) Indians abroad

(*b*) *Indian Economy.* In this part, questions will be on the planning and economic development in India, economic & trade issues, Foreign Trade, the role and functions of I.M.F., World Bank, W.T.O. etc.

(*c*) *International Affairs & Institutions.* This part will include questions on important events in world affairs and on international institutions.

(*d*) *Developments in the field of science & technology, Communications and space.* In this part, questions will test the candidate's awareness of the developments in the field of science & technology, communications and space and also basic ideas of computers.

(*e*) *Statistical analysis, graphs and diagrams.* This part will include exercises to test the candidate's ability to draw common sense conclusions from information presented in statistical, graphical or diagrammatical form and to point out deficiencies, limitations or inconsistencies therein.

OPTIONAL SUBJECTS FOR MAIN EXAMINATION

Total number of questions in the question papers of optional subjects will be eight. All questions will carry equal marks. Each paper will be divided into two parts, viz. Part A and Part B, each part containing four questions. Out of eight questions, five questions are to be attempted. One question in each part will be compulsory. Candidates will be required to answer three more questions out of the remaining six questions, taking at least one question from each part. In this way, at least two questions will be attempted from each Part *i.e.* one compulsory question plus one more.

You have to choose 2 optionals for the Main Exam, out of the following subjects :

Optionals for Main Exam (2 optionals to be chosen from 50 subjects)

(*i*) Agriculture
(*ii*) Animal Husbandry and Veterinary Science
(*iii*) Anthropology
(*iv*) Botony
(*v*) Chemistry
(*vi*) Civil Engineering
(*vii*) Commerce and Accountancy
(*viii*) Economics
(*ix*) Electrical Engineering
(*x*) Geography
(*xi*) Geology
(*xii*) History
(*xiii*) Low
(*xiv*) Arabic
(*xv*) Bengali
(*xvi*) Chinese
(*xvii*) English
(*xviii*) French
(*xix*) German
(*xx*) Gujarati
(*xxi*) Hindi
(*xxii*) Kannada
(*xxiii*) Kashmiri
(*xxiv*) Konkani
(*xxv*) Malayalam
(*xxvi*) Manipuri
(*xxvii*) Marathi
(*xxviii*) Nepali
(*xxix*) Oriya
(*xxx*) Pali
(*xxxi*) Persian
(*xxxii*) Punjabi
(*xxxiii*) Russian
(*xxxiv*) Sanskrit
(*xxxv*) Sindhi
(*xxxvi*) Tamil
(*xxxvii*) Telgu
(*xxxviii*) Urdu
(*xxxix*) Management
(*xxxx*) Mathematics
(*xxxxi*) Mechanical Engineering
(*xxxxii*) Medical Science
(*xxxxiii*) Philosophy
(*xxxxiv*) Physics
(*xxxxv*) Political Science and International Relations
(*xxxxvi*) Psychology
(*xxxxvii*) Public Administration
(*xxxxviii*) Sociology
(*xxxxix*) Statistics
(*xxxxx*) Zoology

Since all the civil Engg. students are expected to offer "Civil Engineering" as one of their two optionals, we are giving below the syllabus of this subject :

Syllabus (*Revised wef year 2000*) for Civil Engineering Paper I (Main Exam.)

Part A — *Engineering Mechanics, Strength of Materials and Structural Analysis*

1. **Engineering Mechanics.** Units and Dimensions, SI Units, Vector, Concept of Force, Concept of particle and rigid body. Concurrent, Non Concurrent and parallel forces in a plane, moment of force and Varignon's theorem, free body diagram, conditions of equilibrium, Principle of virtual work, equivalent force system.

First and Second Moment of area, Mass moment of Inertia.

Static Friction, Inclined Plane and bearings. Kinematics and Kinetics :

Kinematics in Cartesian and Polar Co-ordinates, motion under uniform and non-uniform acceleration, motion under gravity. Kinetics of particle : Momentum and Energy principles, D' Alembert's Principle, Collision of elastic bodies, rotation of rigid bodies, simple harmonic motion, Flywheel.

2. **Strength of Materials.** Simple Stress and Strain, Elastic constants, axially loaded compression members, Shear force and bending moment, theory of simple bending, Shear Stress distribution across cross-sections, Beams of uniform strength, Leaf spring. Strain Energy in direct stress, bending & shear.

Deflection of beams : Meaculay's method, Mohr's Moment area method, Conjugate beam method, unit load method. Torsion of Shafts, Transmission of power, close coiled helical springs, Elastic stability of columns, Euler's, Rankine's and Secant formulae. Principal Stresses and Strains in two dimensions. Mohr's Circle, Theories of Elastic Failure, Thin and Thick cylinder : Stresses due to internal and external pressure - Lame's equations.

3. **Structural Analysis.** Castiglianio's theorems I and II, unit load method of consistent deformation applied to beams and pin jointed trusses. Slope deflection, moment distribution, Kani's method of analysis and Column Analogy method applied to indeterminate beams and rigid frames.

Rolling loads and Influence lines : Influence lines for Shear Force and Bending moment at a section of beam. Criteria for maximum shear force and bending Moment in beams traversed by a system of moving loads. Influence lines for simply supported plane pin jointed trusses.

Arches : Three hinged, two hinged and fixed arches, rib shortening and temperature effects, influence lines in arches.

Matrix methods of analysis : Force method and displacement method of analysis of indeterminate beams and rigid frames.

Plastic Analysis of beams and frames : Theory of plastic bending, plastic analysis, statical method, Mechanism method.

Unsymmetrical bending : Moment of inertia, product of inertia, position of Neutral Axis and Principle axes, calculation of bending stresses.

Part B — *Design of structures. Steel, Concrete and Masonry Structures*

1. **Structural Steel Design.** Structural Steel : Factors of safety and load factors. Rivetted, bolted and welded joints and connections. Design of tension and compression members, beams of built up section, rivetted and welded plate girders, gantry girders, stancheons with battens and lacings, slab and gussetted column bases. Design of highway and railway bridges : Through and deck type plate girder. Warren girder, Pratt truss.

2. **Design of Concrete and Masonry Structures.** Concept of mix design. Reinforced Concrete : Working Stress and Limit State method of design-Recommendations

of I.S. codes. Design of one way and two way slabs, stair-case slabs, simple and continuous beams of rectangular, T and L sections. Compression members under direct load with or without eccentricity, Isolated and combined footings.

Cantilever and Counterfort type retaining walls.

Water tanks : Design requirements for Rectangular and circular tanks resting on ground.

Prestressed concrete : Methods and systems of prestressing, anchorages, Analysis and design of sections for flexure based on working stress, loss of prestress.

Design of brick masonry as per I.S. Codes. Design of masonry retaining walls.

Part C. *Fluid Mechanics, Open Channel Flow and Hydraulic Machines*

1. **Fluid Mechanics.** Fluid properties and their role in fluid motion, fluid statics including forces acting on plane and curve surfaces. Kinematics and Dynamics of Fluid flow : Velocity and accelerations, streamlines, equation of continuity, irrotational and rotational flow, velocity potential and stream functions, flownet, methods of drawing flownet, sources and sinks, flow separation, free and forced vertices.

Control volume equation, continuity, momentum, energy and moment of momentum equations from control volume equation, Navier-Stokes equation, Euler's equation of motion, application to fluid flow problems, pipe flow, plane, curved, stationary and moving vanes, sluice gates, weirs, orifice meters and Venturi meters.

Dimensional Analysis and Similitude. Buckingham's Pi- theorem, dimensionless parameters, similitude theory, model laws, undistorted and distorted models.

Laminar Flow. Laminar flow between parallel, stationary and moving plates, flow through tube.

Boundary layer. Laminar and turbulent boundary layer on a flat plate, laminar sublayer, smooth and rough boundaries, drag and lift.

Turbulent flow through pipes : Characteristics of turbulent flow, velocity distribution and variation of pipe friction factor, hydraulic grade line and total energy line, siphons, expansion and contractions in pipes, pipe networks, water hammer in pipes and surge tanks.

2. **Open Channel Flow.** Uniform and non-uniform flows, momentum and energy correction factors, specific energy and specific force, critical depth, resistance equations and variation of roughness coefficient, rapidly varied flow, flow in contractions, flow at sudden drop, hydraulic jump and its applications, surges and waves, gradually varied flow, classification of surface profiles, control section, step method of integration of varied flow equation, moving surges and hydraulic bore.

3. **Hydraulic Machines and Hydropower.** Centrifugal pumps-Types, characteristics, Net Positive Suction Height (NPSH), specific speed. Pumps in parallel.

Reciprocating pumps, Air vessels, Hydraulic ram, efficiency parameters, Rotary and positive displacement pumps, diaphragm and jet pumps.

Hydraulic turbines, types classification, Choice of turbines, performance parameters, controls, characteristics, specific speed.

Principles of hydropower development. Type, layouts and Component works. Surge tanks, types and choice. Flow duration curves and dependable flow. Storage and pondage. Pumped storage plants. Special features of mini micro-hydel plants.

Part D — *Geo-technical Engineering*

Types of soil, phase relationships, consistency limits, particles size distribution, classifications of soil, structure and clay mineralogy.

Capillary water and structural water, effective stress and pore water pressure, Darcy's Law, factors affecting permeability, determination of permeability, permeability of stratified soil deposits.

Seepage pressure, quick sand condition, compressibility and consolidation, Terzaghi's theory of one dimensional consolidation, consolidation test.

Compaction of soil, field control of compaction. Total stress and effective stress parameters, pore pressure coefficients.

Shear strength of soils, Mohr Coulomb failure theory, Shear tests.

Earth pressure at rest, active and passive pressures, Rankine's theory, Coulomb's wedge theory, earth pressure on retaining wall, sheet pile walls, Braced excavation.

Bearing capacity, Terzaghi and other important theories, net and gross bearing pressure.

Immediate and consolidation settlement. Stability of slope, Total Stress and Effective Stress methods, Conventional methods of slices, stability number.

Subsurface exploration, methods of boring, sampling, penetration tests, pressure meter tests.

Essential features of foundation, types of foundation, design criteria, choice of type of foundation, stress distribution in soils, Boussinessq's theory, Newmarks's chart, pressure bulb, contact pressure, applicability of different bearing capacity theories, evaluation of bearing capacity from field tests, allowable bearing capacity, Settlement analysis, allowable settlement.

Proportioning of footing, isolated and combined footings, rafts, buoyancy rafts, Pile foundation, types of piles, pile capacity, static and dynamic analysis, design of pile groups, pile load test, settlement of piles, lateral capacity. Foundation for Bridges. Ground improvement techniques-preloading, sand drains, stone column, grouting, soil stabilisation.

Syllabus (*Revised wef year 2000*) for Civil Engineering Paper II (Main Exam.)

Part A — *Construction Technology, Equipment, Planning and Management*

1. **Construction Technology.** Engineering Materials : Physical properties of construction materials : Stones, Bricks and Tiles ; Lime, cement and Surkhi Mortars; Lime Concrete and Cement Concrete, Properties of freshly mixed and hardened concrete, Flooring Tiles, use of ferro-cement, fibre-reinforced and polymer concrete, high strength concrete and light weight concrete. Timber : Properties and uses; defects in timber; seasoning and preservation of timber. Plastics, rubber and damp-proofing materials, termite proofing, Materials, for Low cost housing.

Construction. Building components and their functions; Brick masonry : Bonds, jointing. Stone masonry. Design of Brick masonry walls as per I.S. codes, factors of safety, serviceability and strength requirements; plastering, pointing. Types of Floors & Roofs. Ventilators, Repairs in buildings.

Functional planning of buildings : Building orientation, circulation, grouping of areas, privacy concept and design of energy efficient building; provisions of National Building Code. Building estimates and specifications; Cost of works; valuation.

2. **Construction Equipment.** Standard and special types of equipment, Preventive maintenance and repair, factors affecting the selection of equipment, economical life, time and motion study, capital and maintenance cost.

Concreting equipments. Weigh batcher, mixer, vibration, batching plant, Concrete pump.

Earth-work equipment. Power shovel hoe, bulldozer, dumper, trailers, and tractors, rollers, sheep foot roller.

3. **Construction Planning and Management.** Construction activity; schedules, job layout, bar charts, organization of contracting firms, project control and supervision. Cost reduction measures.

Net work analysis. CPM and PERT analysis, Float Times, cashing of activities, contraction of network for cost optimization, up dating, cost analysis and resource allocation.

Elements of Engineering Economics, methods of appraisal, present worth, annual cost, benefit-cost, incremental analysis. Economy of scale and size. Choosing between alternatives including levels of investments, Project profitability.

Part B — *Survey and Transportation Engineering*

Survey. Common methods of distance and angle measurements, plane table survey, levelling traverse survey, triangulation survey, corrections, and adjustments, contouring, topographical map. Surveying instruments for above purposes. Techeometry. Circular and transition curves. Principles of photogrammetry.

Railways. Permanent way, sleepers, rail fastenings, ballast, points and crossings, design of turn outs, stations and yards, turntables, signals, and interlocking, level-crossing. Construction and maintenance of permanent ways : Super elevation, creep of rail, ruling gradient, track resistance, tractive effort, relaying of track.

Highway Engineering. Principles of highway planning, Highway alignments. Geometrical design : Cross section, camber, Super elevation, horizontal and vertical curves. Classification of roads : low cost roads, flexible pavements, rigid pavements. Design of pavements and their construction, evaluation of pavement failure and strengthening.

Drainage of roads : Surface and sub-surface drainage.

Traffic Engineering : Forecasting techniques, origin and destination survey, highway capacity. Channelised and unchannelised intersections, rotary design elements, markings, sign, signals, street lighting; Traffic surveys. Principle of highway financing.

Part C — *Hydrology and Water Resources Engineering*

1. **Hydrology.** Hydrological cycle, precipitation, evaporation, transpiration, depression storage, infiltration, overland flow, hydrograph, flood frequency analysis, flood estimation, flood routing through a reservoir, channel flow routing-Muskingam method.

Ground water flow. Specific yield, storage coefficient, coefficient of permeability, confined and unconfined aquifers, aquifers, aquitards, radial flow into a well under confined and unconfined conditions, tube wells, pumping and recuperation tests, ground water potential.

2. **Water Resources Engineering.** Ground and surface water resource, single and multipurpose projects, storage capacity of reservoirs, reservoir losses, reservoir sedimentation, economics of water resources projects.

3. **Irrigation Engineering.** Water requirements of crops : consumptive use, quality of water for irrigation, duty and delta, irrigation methods and their efficiencies.

Canals : Distribution systems for canal irrigation, canal capacity, canal losses, alignment of main and distributary canals, most efficient section, lined canals, their design, regime theory, critical shear stress, bed load, local and suspended load transport, cost analysis of lined and unlined canals, drainage behind lining.

Water logging : causes and control, drainage system design, salinity.

Canal structures : Design of cross regulators, head regulators, canal falls, aqueducts, metering flumes and canal outlets.

Diversion head work : Principles and design of weirs of permeable and impermeable foundation, Khosla's theory, energy dissipation, stilling basin, sediment excluders.

Storage works : Types of dams, design, principles of rigid gravity and earth dams, stability analysis, foundation treatment, joints and galleries, control of seepage.

Spillways : Spillway types, crest gates, energy dissipation.

River training : Objectives of river training, methods of river training.

Part D — *Environmental Engineering*

1. **Water Supply.** Estimation of surface and subsurface water resources, predicting demand for waters, impurities of water and their significance, physical, chemical and bacteriological analysis, waterborne diseases, standards for potable water.

Intake of water. pumping and gravity schemes. Water treatment : principles of coagulation, flocculation and sedimentation; slow-, rapid-, pressure-, filters; chlorination, softening, removal of taste, odour and salinity.

Water storage and distribution. storage and balancing reservoirs : Types, location and capacity. Distribution system : layout, hydraulics of pipe lines, pipe fittings, valves including check and pressure reducing valves, meters, analysis of distribution systems, leak detection, maintenance of distribution systems, pumping stations and their operations.

2. **Sewerage systems.** Domestic and industrial wastes, storm sewage-separate and combined systems, flow through sewers, design of sewers, sewer appurtenances, manholes, inlets, junctions, siphon. Plumbing in public buildings.

Sewage characterisation. BOD, COD, solids, dissolved oxygen, nitrogen and TOC. Standards of disposal in normal water course and on land.

Sewage treatment. Working principles, units, chambers, sedimentation tanks, trickling filters, oxidation ponds, activated sludge process, septic tank, disposal of sludge, recycling of waste water.

Solid waste. Collection and disposal in rural and urban contexts, management of long-term ill-effects.

3. **Environmental pollution.** Sustainable development. Radioactive wastes and disposal. Environmental impact assessment for thermal power plants, mines, river valley projects. Air pollution, Pollution control acts.

Past Years Questions of Civil Services Competition

The various questions that have been set during the last several years since 1979 in this exam. from the subject of Irrigation and Hydrology, are reproduced here. *You will be glad to notice that many of the numerical questions were directly set from this book.*

Year 1979 (*Civil Services*)
Paper I

Q. 5. *Describe with sketches where necessary how a weir based on Khosla's theory is designed. Discuss the limitations of this theory.*

Q. 8. *(b) A project involves construction of a canal of most economical section with side slopes 2 horizontal to 1 vertical has to discharge 15000 litres per sec with a slope of 10 cm in a kilometre. When unlined C = 45 and when lined C = 60. If the cost of per cub-metre of excavation is one third the cost per sq. metre of lining, which would be cheaper and what would be their dimensions ?*

Year 1980 (*Civil Services*)
Paper I

Q. 5. *Describe briefly various types of spillways and method used for dissipating the energy of the discharge from them.*

Paper II

Q. 11. *Wheat is to be grown in field having a field capacity equal to 27% and the permanent wilting point is 13%. Find the storage capacity in 80 cm depth of the soil, if* *the dry unit weight of the soil is 1.5 gm/cc. If the irrigation water is to be supplied when the average soil moisture falls to 18%, find the water depth required to be supplied to field if the field application efficiency is 80%, what is the amount of water needed at the canal outlet if the water lost in the water course and the field channel is 15% of the outlet discharge ?*

[**Note.** Please refer Solved Example 2.14. **This question was set from this book.**]

Q. 12. *An intense rain is assumed to be falling at a uniform rate of 5 cm per hr. for a period of 80 min. on a drainage basin of 550 hectares. The average infiltration capacity during the entire rain period has been worked out to be 1.4 cm per hr. Determine the maximum runoff rate, if the peak percentage based on 10 minutes interval from the distribution graph for this basin is 18%.* (60)

[**Note.** Please refer Solved Example 7.44. **This question was set from this book.**]

Q. 13. *(a) Find the maximum safe width for an elementary profile of a gravity dam of 20 m height. Specific gravity of the dam material is 2.25 and the uplift factor is 0.45.* (20)

(b) Enumerate atleast four types of spillways. Describe any two types in detail illustrated with sketches. (20)

(c) A flood of certain magnitude has a return period of 25 years. What is the probability of exceedence ? What is the probability that this flood may occur in the next 12 years ? (20)

[**Note.** Please refer Solved Example 7.52]

Q. 24. *(a) Discuss the following :*

(i) Wilting point ;

(ii) Evapotranspiration and net Irrigation requirements. (15)

(b) Draw the neat cross-sections of canal in

(i) cutting,

(ii) filing, and

(iii) partial cutting. (15)

(c) Draw a neat L-section of a glacis type fall with baffle wall and platform and clearly label various parts indicating slopes and energy line, etc. (15)

Q. 15. *(a) Briefly discuss the types of rivers.* (15)

(b) Explain with sketches the meandering ratio. (15)

(c) Explain with sketches the theory of river meandering. (15)

(d) Enumerate river training works. Discuss one of these with neat sketches. (15)

Year 1981 (*Civil Services*)

Paper I

Q. 6. Give a brief outline of the procedures for the design of the non-overflow section of a low gravity dam indicating clearly the forces (acting on the dam) being considered for the design. (30)

Paper II

Q. 9. Discuss the following terms bringing out their meaning, significance and write the mathematical equation if any :

(i) *Duty of crop*

(ii) *Delta of a crop*

(iii) *Optimum utilization of irrigation water*

(iv) *Consumptive use*

(v) *Net irrigation requirements ; and*

(vi) *Field capacity.* (60)

Q. 16. A pump is installed on a well to lift water and to irrigate rice crop, sown over a 3 hectares of land. If duty for rice is 864 hectares/cumec on the field and pump efficiency is 48% ; determine the minimum H.P. of the pump if the lowest well water level is 8.0 m below the highest portion of the field. Field channel losses are neglected. (60)

[**Note.** Please refer Solved Example 3.7. **This question was set from this book.**]

Q. 11. Given Q = 50 cumec ; Silt factor = 1.1, side slope = $\frac{1}{2}$: 1, using Laceys theory , determine :

(i) *Velocity ;*

(ii) *area of cross-section ;*

(iii) *Hydraulic radius ;*

(iv) *Perimeter, and*

(v) *Longitudinal slope.* (40)

[**Note.** Please refer Solved Example 4.6. **This question was set from this book.**]

(*b*) Discuss regime concept of Lacey. (20)

Q. 12. Results to determine the infiltration capacity equation in the exponential form are tabulated below :

Time in hours	*f in cm/hr*	$f-f_c$	$log_{10}(f-f_c)$
0	10.4	9.4	0.973 or + 0.973
0.25	5.6	4.6	0.663 or +0.663
0.50	3.2	2.2	0.342 or + 0.342
0.75	2.1	1.1	0.042 or + 0.042
1.00	1.5	0.5	$\bar{1}.699$ or (–) 0.301
1.25	1.2	0.2	$\bar{1}.301$ or –0.669
1.50	1.1	0.1	$\bar{1}.00$ or –1.00
1.75	1.0	0.0,	
2.00	1.0	0.0,	

Plot $log_{10}(f-f_c)$ against time and determine the infiltration exponential equation. Given that $log_{10}e = 0.4343$. (60)

[**Note.** Please refer Solved Example 7.13. **This question was set from this book.**]

Year 1982 (*Civil Services*)

Paper I

Q. 6. *The concrete floor of a head regulator is level with the channel bed (except for the short crest hump) and is 13 m long. The floor is provided with cut off walls at its upstream and downstream ends. The depth of upstream cutoff is 1.5 m (below the floor level) and that of the downstream wall is 2.0 m. Using Khosla's theory (see Fig. for definition, sketch and formula), determine the thickness of the floor at its mid-length and also at its junction with the upstream and downstream cutoff walls. The floor thickness may not be less than 30 cm any where. The upstream FSL is 1.5 m above the floor level. If the permissible exit gradient is 0.18, is the floor safe against failure by piping ?*

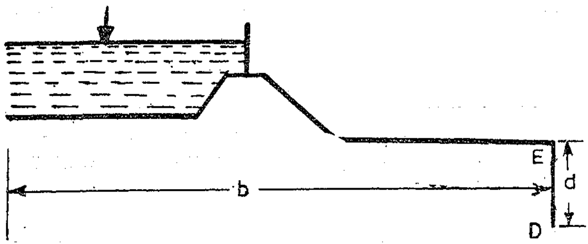

Fig. 31.11. Definition sketch for Khosla's theory for uplift pressure.

$$\phi_E = \frac{1}{\pi} \cos^{-1}\left(\frac{\lambda - 2}{\lambda}\right)$$

$$\lambda = \frac{1 + \sqrt{1 + \alpha^2}}{2}$$

$$\alpha = \frac{b}{d}.$$ (60)

[**Note.** Please refer Solved Example 11.4].

Paper II

Q. 9. *Write brief but relevant answers for any three parts :*

(a) Outlining the factors governing runoff, describe their interaction. Also describe briefly the methods for estimating runoff.

(b) Outlining the factors which lead to water-logging and salinity of soils in irrigated areas, discuss the respective remedial measures to reclaim them.

(c) Describe the stages of a river during its course. State the objectives of rive training. Also explain briefly how bunds and spurs function.

(d) Discuss the methods adopted to control seepage through and under-neath earth rock dams. Evaluate their performance.

Q. 10. *(a) Define the duty of a crop. Illustrate the relationship between duty and delta. Also describe how the efficiency of irrigation is determined.*

(b) Describe the procedure for determining the design discharge of an irrigation canal. Discuss why the kor demand of crops should be considered in place of average demand while computing the capacity.

(c) The transplantation of paddy takes 20 days and the total depth of water required by the crop is 25 cm on the field. During the transplantation period, there is about 10 cm of useful rain. Find the duty of irrigation water required for paddy during transplan-

tation period. Also find the duty of water at the head of water course and at the head of the distributary. Assume 25% losses of water in water courses and 15% losses from the distributary head to the water course head.

[**Note.** Please follow Example 3.5. **This question was set from this book by slightly modifying the numerals.**]

Q. 11. *(a) Describe hydrologic cycle and explain its importance.*

(b) Describing the method of determining the yield of a tubewell, discuss the factors contributing to the progressive reduction of its yield.

(c) Explain step by step, the method of construction of unit hydrograph from storm of unit duration stating the basic assumptions.

(d) Discuss general principles governing planned and optimal use of water resources.

Q. 12. *(a) Discuss the various design provisions which are intended to provide additional safety of earth-rock dams against earthquake forces.*

(b) Explain how cracking of embankments leading to piping failure become an important and difficult problem in the present day design of modern earth-rock dams.

(c) Explain how the treatment of foundations including abutments become relevant to the design of hydraulic structures of the most competitive types (namely arch dams and earth-rock dams).

(d) Stating the role of spillways, classify them. Also state the conditions for which each type is appropriate.

Year 1983 (*Civil Services*)

Paper I

Q. 6. (*a*) What is an "economical channel section" ? Work out the conditions for such a channel when the section is trapezoidal having bottom width *b*, depth *d* and side slopes l/n·

Part II

Question 9 is compulsory.

Q. 9. Write answers for any three sub-divisions :

(a) Define (i) Delta , (ii) Duty, and (iii) Base period and derive the relationship among them.

Also explain the influence of several factors which affect duty. (20)

(b) Explain the method of estimating maximum flood discharge in a river using unit hydrograph approach. (20)

(c) What is water-logging ? What are the ill-effects of water-logging? How will you reclaim a water-logged area ? (20)

(d) How do you differentiate between a high dam and a low dam ? Explain any two types of spillway in a masonry dam with sketches. (20)

Q. 10. *(a) A reservoir with a live storage capacity of 360 million cubic meters is able to irrigate an ayacut of 40,000 hectares with two fillings each year. If the crop season is 120 days, calculate the duty.* (20)

(b) Explain the isohyetal and the Theiesen's polygon method for finding out the average rainfall of a given basin. (20)

(c) Explain briefly the various factors which affect runoff. Mention the empirical formulae for the estimation of flood flows. (20)

Q. 11. *(a) What do you understand by a regime channel ? Compare the silt theories of Kennedy and Lacey.* (20)

(b) (i) Differentiate between a weir and a barrage. Explain with neat sketches their salient components.

(ii) List the advantages and disadvantages of a Butterss dam. (20)

(c) What are the forces that you will consider while designing a masonry dam in an earthquake region ? How will you account for these forces in the design ? Explain consolidation grouting. (20)

Q. 12. *(a) Discuss the object of the classification of river training work. Draw a practical section of a canal.* (20)

(b) Name the various types of cross-drainage works. Draw neat sketches to show the plan, the cross-section and sectional elevation of these. (20)

(c) What are different ways of aligning a canal ? Where will you use each of them ? Explain with suitable sketches. (20)

Year 1984 (*Civil Services*)

Paper I

Q. 2. *(b) Explain Lacey's regime channel, initial regime and final regime.*

Write the equations as per concept of Lacey for design procedure of a true regime channel carrying a fixed discharge and transporting a given silt grade in an unlimited incoherent alluvium. (20)

Paper II

Q. 9. *Write answers for any three subdivisions :*

(a) What is runoff ? How is it related to the rainfall ? What are the factors that influence the runoff from a catchment ? (20)

(b) Explain how Lacey's theory is an improvement over Kennedy's theory with reference to 'Regime' in channels. What are the steps involved in designing a channel through Lacey's theory ? (20)

(c) How will you reclaim waterlogged land ? Draw neat sketches of (i) carrier drains, and (ii) intercepting drains. (20)

(d) What is Retrogression ? Explain how river weirs are different from river barrages. Explain with neat sketches Syphon well drops and label various parts. (20)

Q. 10. *(a) What are different types of hydroelectric power plant ? Explain the various components of a high head hydroelectric project with a neat layout plan.* (30)

(b) What are the different types of earth dams ? Explain them with neat sketches. (30)

Q. 11. *(a) What are different types of irrigation ? Explain them. Define 'flow duty' and 'quantity duty'.* (15)

(b) Calculate the discharge flowing through a channel of trapezoidal section of bed width 18 m and depth 3 m with $\frac{1}{2}$ to 1 side slopes. The channel has a bed slope of 25 cm for every km and the coefficient of rugosity is 0.03. Given N = 0.9875 and D = 0.8760. (25)

(c) Describe ogee spillway and syphon spillway with neat sketches explaining how

they function. Also explain the general features of energy dissipation devices used in the toe of a spillway. (20)

Q. 12. *(a) List the factors to be considered before selecting a site for constructing a dam. Derive an expression for the elementary profile of a gravity dam in terms of base width and height of the dam.* (30)

[**Note.** Please refer Eqn. 19.23 and Article 19.6.]

(b) Explain the concept of Exit gradient. Also explain the different steps involved in the design of the apron of a weir on permeable foundation using Khosla's theory. (30)

Year 1985 (*Civil Services*)

Paper I

Q. 2. *(a) (i) Explain briefly the method of designing a canal using Lacey theory.*

(ii) Design an irrigation canal in alluvial soil according to Lacey silt theory ; given:

Lacey silt factor is 1, canal side slope is 1 horizontal to 2 vertical and full supply discharge is 10 m^3/sec.

[**Note.** Please refer Solved Example 4.9.]

Paper II

Question 9 is compulsory.

Q. 9. *Answer any three sub-divisions :*

(a) Define consumptive use of water by a crop and explain how it is determined under natural conditions. (20)

(b) Describe how a unit hydrograph is prepared from an isolated storm. List and evaluate the basic assumptions. (20)

(c) Explaining waterlogging and salinity of soils in irrigated areas, discuss the causative factors and reclamation process. (20)

(d) Explain why earth-rock dams are increasingly adopted in preference to other types of dams. (20)

Describe the nature of foundation problems in hydraulic structures and their treatment. Illustrate the answer citing case histories. (20)

Q. 10. *(a) The figures below represents streamflow in cumecs from a 1000 acre drainage area. Construct a unit hydrograph for this basin.*

Time (hrs)	2	4	6	8	10	*N noon*	2	4	6
Flow (cumecs)	5.1	6.5	7.4	10.2	8.8	7.4	5.9	5.4	4.8

[**Note.** Please refer Solved Example 7.39]. (25)

(b) Describing the isohyetal method for finding average rainfall over a drainage basin, bring out its merits relative to station average method. (15)

(c) Discuss the factors that affect the runoff from a catchment. (10)

(d) Describe the design consideration of under-sluices provided in diversion head works. (10)

Q. 11. *(a) Construct a mass diagram for the stream having the following monthly discharges during the 2 year period of record. What is the reservoir size required to provide a constant downstream flow of 3 cumecs?*

Month	Monthly discharge ha.m	
	In 1st year	In 2nd year
January	57.4	10.2
February	65.5	30.8
March	28.6	43.1
April	32.8	53.1
May	36.9	38.9
June	24.6	28.9
July	10.2	16.4
August	2.1	12.3
September	2.1	12.3
October	2.1	4.1
November	4.1	18.2
December	8.2	2.1

(30)

(b) Which slope (s) (upstream or downstream or both) of a zoned earth dam is (are) analysed for the three independent conditions ? Name the three conditions and state with reason the normal safety factor recommended for each condition. (9)

(c) State the design criteria for filter material. (6)

(d) Classify spillways stating the conditions favourable for each type. Evaluate the merits and demerits of syphon spillway. (15)

Q. 12. *The command area of a canal is planted with ragi. The base period for the crop is 120 days and delta is 50 cm. If 33% of water is lost in conveyance, compute the area which can be irrigated per 100 lps let into the canal from the reservoir. If the actual amount of evapotranspiration of the crop is 35 cm. compute the overall irrigation efficiency.* (20)

(b) Describe how the longitudinal section of an irrigation canal is fixed. (8)

(c) Discuss Lacey's theory of flow in alluvial canals. (10)

(d) Describe how the yield of a well is determined by a recuperation test. (10)

(e) Describe the method of analysis of gravity dam and demonstrate how the stability is enhanced by foundation treatment (grout curtain and drainage wells.) (12)

Year 1986 (*Civil Services*)

Paper I

Q. 5. *(a) What is a canal outlet ? Explain the requirements to be satisfied by a canal outlet. Distinguish between a hyper-proportional outlet and a sub-proportional outlet.* (30)

(b) Water flows over a concrete spillway at the rate of 300 cumecs. After flowing over the spillway it passes over a level concrete apron (n = 0.015). The velocity of water at the toe of the spillway is 15 m/sec. and the width of the apron is 50 m. The tail water depth is 3 m. Calculate the length of the apron to contain the jump. Also calculate the energy dissipated. (30)

Q. 6. *(a) Explain the effects of construction of a weir on the regime of a river. Explain with neat sketches the working of a silt excluder.* (30)

(b) Write an explanatory note on filter criteria for earthen dams. Explain the method of checking the stability of earth dam foundation against shear failure. (30)

Paper II

Q. 9. *Attempt any three sub-divisions :*

(a) Derive Seddon's law using both Chezy's equation and Manning's equation for the passage celerity of a flood wave in a wide rectangular open channel. (20)

(b) (i) What is meant by the basic profile of a low gravity dam ? (5)

(ii) Develop the basic profile of a low concrete gravity dam where the specific gravity of the concrete of the dam is 2.5, and uplift is credited with an intensity factor of 0.5 and an area factor also of 0.5. Allowable vertical compressive stress (in the presence of shear stresses — i.e. the vertical stress is not the principal stress necessarily) is 8.5 kg/cm^3. (15)

(c) Bring out features of the hydrological cycle indicating the interrelationships also. All major stages or phases should be clearly emphasized including the anomalies to be cautioned against. (20)

(d) What are the major components of a canal irrigation system ? What are the functions that each performs ? What are the main appurtenances in, across, or along each component ? (20)

Q. 10. *(a) (i) Mention any three objectives for which river training works are constructed. What are the different types of works or constructions adopted in this connection ?* (12)

(ii) Draw a typical plan view of a Bell's guide bund showing the flow direction, the angles and the nominal lengths also; and name the several parts and locations. (8)

(b) (i) Mention six different types of spillways. Also mention four different types of gates used on spillways. (5)

(ii) What are the several features that affect the hydraulic design of an ogee spillways ? (15)

(c) Design a channel by Lacey's theory for 40 cumec capacity. The side slopes may be assumed to be 1 : 1. The average size of the bed material may be taken as 0.8 mm. (20)

Q. 11. *(a)(i) A canal takes off from a reservoir to irrigate the areas as shown in the table. 40% of the water required for irrigation is assumed to be available directly from precipitation. Channel conveyance losses are 15%. Reservoir losses are 10%. What would be the capacity of the reservoir needed ? (The reservoir is to be filled only once a year).* (12)

Crop	*Base period, days*	*Duty of the field, ha/cumec*	*Area under crop, ha*
Wheat	*120*	*1800*	*500*
Sugarcane	*320*	*800*	*600*
Rice	*120*	*900*	*300*
Cotton	*200*	*1400*	*1200*
Bajra	*100*	*1200*	*500*

[**Ans.** 2890 ham]

(ii) What are the advantages of the sprinkler system of irrigation ? (8)

(b) Derive the Dupuit's equation for the centre-to-centre spacing of a circular tile drains battery below ground for alleviating water-logging. You can take L as the spacing between the drains forming the drainage system, a as the height of the pipe system above the impervious layer, b as the maximum height of the watertable above the impervious layer and q as the rate of discharge per unit area of land surface. (20)

(c) An unregulated stream provides the following volumes through each successive 4-day period over a 40-day duration at a possible reservoir site. What would be the reservoir capacity needed to ensure maintaining the average flow for these 40 days if

Day	0	4	8	12	16	20	24	28	32	36	40
Runoff volume, $m^3 \times 10^6$	0	9.6	5.4	2.3	3.5	2.3	2.2	1.4	6.4	12.4	10.9

the reservoir is full to start with? What is this average flow ? What would be the approximate quantity of water wasted in spillage in this case ? (20)

Q. 12. *(a) Discuss the several relative conditions that can occur below spillways by the comparative locations of the tail water rating curve and the jump height curve. What are the methods adopted for efficient energy dissipation in each case ? By what mechanism is energy dissipated in each method ?* (30)

(b) (i) The Muskingum method by McCarthy assumes the reach storage in a stream to be given by $S = K[xI + (I - x)O]$*, where K is the storage constant. Also, the basic routing equation written for discrete time is,*

$$\frac{I_1 + I_2}{2} t - \frac{O_1 + O_2}{2} t = S_2 - S_1$$

Derive from these the Muskingum equation and incidentally determine the coefficients therein. What is the sum of the coefficients ? (10)

(ii) The storage in a stream reach has been studied ; and x and K have been identified as 0.28 and 1.6 days. If the inflow hydrograph in the stream reach, as the flood starts coming in and passes, is given by the following table, compute the outflow hydrograph. (Plotting is not needed) :

Hours	0	6	12	18	24	30
I m^3*/sec*	35	55	92	130	160	140

(10)

[Note. Please refer Solved Example 13.3 in "Hydrology and Water Resources Engineering".]

Year 1987 *(Civil Services)*

Paper I

Q. 5. For the following data, make necessary hydraulic calculations for a vertical drop weir using the Bligh's theory :

Maximum flood discharge = *2800 cumecs*
HFL before construction = *285.0 m*
Minimum water level = *278.0 m*
Downstream bed level = *278.0 m*
F.S.L. of canal = *284.0 m*
Allowable afflux = *1 m*
Coefficient of creap = *12*
Permissible exit gradient = *1/6* (60)

Q. 6. *(a) Explain the different types of spillways used in dam construction. State briefly the design principles of an ogee spillway in sequence.* (30)

(b) Design an irrigation canal for a discharge of 15 cumec, $N = 0.225$, $m = 1$ and $\frac{B}{D} = 5.7$. Use the Kennedy theory. (30)

Paper II

Q. 9. *Attempt any three subdivisions :*

(a) Derive the basic probability of an N-year event defined in the conventional way ; indicate the definition also. Accordingly, derive the probability of a flood with a return period of 20 years, occurring in a particular 3-year period. (20)

(b) (i) What are the factors (list at least six) that affect the pattern of sediment deposition in a reservoir. (10)

(ii) A proposed reservoir has a capacity of 50 ha-m. The catchment area is 125 km^2 and the annual streamflow averages 12 cm of run-off. If the annual sediment production is 0.03 ha-m/km^2, what is the probable life of the reservoir before its capacity is reduced by 10% of its initial capacity by sedimentation ? The relationship between trap efficiency, n (%) and capacity-flow ratio, C/I, is as under :

C/I :	0.01	0.02	0.04	0.06	0.08	0.1	0.2	0.3	0.5	0.7
η *(%) :*	43	60	74	80	84	87	93	95	96	97

[**Note.** Please refer Solved Example 18.16]. (20)

(c) What are the several natural and man-made causes of water-logging ? What are the ill-effects due to water-logging? What are the several measures practicable for minimising water-logging effects ? (20)

(d) What are the purposes for which foundation treatment for hydraulic structures is undertaken ? What are the several features that are treated in this manner ? Write briefly on each. (20)

Q. 10. *(a) Classify the common methods of irrigation and indicate the suitability and advantages of each main method besides indicating how each method is practised.* (30)

(b) How are river training works classified ? What is the propose achieved in each of these classes of training works and how is it achieved? (15)

(c) Define the following : (i) Alkali soil, (ii) Alkaline soil, (iii) Leaching, Sodium absorption ratio. (15)

Q. 11. *(a) A multi-purpose reservoir for providing irrigation water, flood control and low-flow augmentation for water quality control is under consideration. The following curves have been generated by proper analysis : (i) Reservoir cost curve, (ii) Reservoir yield curve, (iii) Annual irrigation demand, (iv) Annual flood control benefits, (v) Water quality benefits from low-flow augmentation and (vi) Water requirement for low augmentation. Draw the general shape of each of these curves indicating the entities represented on the coordinate axes.* (25)

(b) A project has been assessed for different levels of investment and is to be evaluated for a 10 year life at 10% return on its capital. The consecutive levels of

investment and the corresponding net annual returns are assessed to be as under (all in lakhs of rupees) :

Investment :	500	600	700	800	900	1000
Annual returns :	100	110	122	132	141	149

Considering the appropriate aspects of evaluation, determine how large an investment should be made. SFF for 10 years at 10% = 0.06275. (20)

(c) Calculate the maximum discharge required at the outlet of a distributary having the following cropped area and duties of water : (15)

Crop	*Area (in ha)*	*Crop Season*	*Duty (in '000 ha/cumec)*
Sugarcane	200	*Throughout*	0.730
Other perennials	1000	*Throughout*	1.100
Hot weather fodder	3000	*Hot weather*	2.000
Rice	1500	*Kharif*	0.775
Other Kharif	1500	*Kharif*	1.500
Rabi	5000	*Rabi*	1.800

Q. 12. *(a) A concrete gravity dam has the following design features :*

Top of dam	= 200 m RL
Width at top	= 7 m
Bottom of top rectangular position	= 190 m RL
Downstream battery	= 0.7 h on 1 v
Upstream battery is below 150 m RL and has a value	= 1 h on 10 v
Drainage gallery at 10 m from u/s vertical face ; Uplift reduction at gallery	= 0.6
Tail water depth	= 5 m
Wt. of concrete	= 2.4 T/m^3
Water stands upto	= 195 m RL
Base of dam	= 100 m RL

Determine the vertical normal stresses at each end of the base when the reservoir is full as indicated. (30)

(b) What are the criteria for safe design of earth dams ? (15)

(c) A storm with a 15.0 cm precipitation produced a direct runoff of 8.7 cm. The time distribution of the storm is as follows :

Time from start hr.	1	2	3	4	5	6	7	8
Incremental rainfall in each hour, cm	0.6	1.35	2.25	3.45	2.7	2.4	1.5	0.75

Estimate the ϕ_{index} *of the storm.* (15)

[**Note.** Please refer Solved Example 7.26.]

Year 1988 (*Civil Service*)
Paper I

Q. 5. *(a) A concrete dam 30m high retains water to a maximum height of 25 m on upstream side. The upstream face is vertical for the upper 10 m of the dam and then sloping towards upstream at 1 horizontal to 10 vertical up to the base. The top width* *of the dam is 4 m for a height of 5 m and then splays in the downstream giving a total base width of 20 m. There is tail water for a depth of 5 m and the axis of drainage gallery is at 4 m from the heel. Assuming the specific gravity of concrete as 2.4, calculate the factor of safety against overturning and the stress at the toe and the heel under reservoir full condition.* (30)

(b) Describe briefly the function and design of a silt excluder provided in a diversion head work. Supplement your answer with neat sketches. (30)

Q. 6. *(a) Design the section of an unlined canal in a loamy soil to carry a discharge of 50 cum/sec with a permissible velocity of 1 m/sec. Assume the side slopes as 2 : 1 and B/D ratio as 6.0. Using Manning formula, calculate the bed slope of the canal, N = 0.0225.* (15)

(b) Discuss briefly the different types of failure of earth dams and measures to prevent them. (30)

(c) Explain the technical and financial justification for lining of existing canals. (15)

Paper II

(Part C — *Water Resources Engineering*)

Q. 9. *(Compulsory) Answer any three subdivisions :*

(a) What is runoff ? Discuss the factors influencing the runoff of a catchment area. (20)

(b) What is duty of water ? Explain the influence of several factors affecting duty. (20)

(c) Enumerate the different methods of river training. Describe the method of marginal embankments. (20)

(d) Discuss the factors influencing the selection of a site for a proposed dam. (20)

Q. 10. *(a) What is unit hydrograph ? How is it obtained ? Explain its use in the construction of flood hydrograph resulting from rainfalls.* (20)

(b) Explain flood routing through reservoirs. Describe stepwise the procedure adopted for flood routing computations by the trial and error method. (20)

(c) Write explanatory notes on the different types of irrigation. (20)

Q. 11. *(a) Explain the governing considerations for fixing up the alignment, the full supply level, and the full supply discharge of an irrigation canal.* (20)

(b) The gross command area for a distributary is 10,000 hectares, 75% of which can be irrigated. The intensity of irrigation for Rabi season is 60% and that for Kharif season is 30%. If the average duty at the head of the distributary is 2500 hectares per cumec for Rabi season, and 1000 hectares per cumec for Kharif season, determine the discharge required at the head of the distributary from average demand consideration. (20)

[**Note.** Please refer and follow Example 3.1 and determine the requisite discharge as 2.25 cumecs. **Ans.**]

(c) Explain the principal causes and the effects of water-logging in a canal irrigated farm. State the precautions and measures adopted to prevent water-logging of irrigated lands. (20)

Q. 12. *(a) State the general conditions of stability of gravity dams. Explain stepwise the procedure of analysing high gravity dams.* (20)

(b) Enumerate the different types of earth dams indicating the situation where each type is more suitable. Explain in sequence the steps involved in determining the stability of earth dams by the Swedish slip circle method. (20)

(c) State the governing considerations for the selection of different types of spillways. Explain the design principles of ogee spillway. (20)

Year 1989 (*Civil Services*)
Paper I

[**Note.** ***Due to revision in syllabus w.e.f. 1989, Paper I did not contain any question on Irrigation, as it contained questions on Structural Engg., Fluid Mechanics, and Soil Mechanics only, in 3 sections.***]

Paper II
(**Part C** — *Water Resources and Irrigation Engineering*)

Q. 9. *(Compulsory). Attempt any three sub-divisions :*

(a) (i) Explain briefly what you understand by the terms :

1. Design flood
2. Standard project flood
3. Probable maximum flood
4. Design storm. (10)

(ii) What are the recommended design floods for :

1. Spillways of major projects
2. Permanent barrages
3. Waterways of aqueducts
4. Pick-up weirs. (10)

(b) (i) Describe briefly the factors affecting the evaporation from water bodies. Describe a commonly used evaporimeter. (10)

(ii) An isolated 3 hour storm occurred over an area of 120 ha as below:

Partial area of catchment (ha)	*φ index (cm/h)*	*Rainfall (cm)*		
		1st hour	*2nd hour*	*3rd hour*
36	*0.90*	*0.6*	*2.4*	*1.3*
18	*1.10*	*0.9*	*2.1*	*1.5*
66	*0.50*	*1.0*	*2.0*	*0.9*

What is the total rainfall on the catchment in this storm ? Estimate the runoff from the catchment. If the φ index were to be remain at the same value, what runoff would be produced by a uniform rainfall of 3.3 cm in 3 hours uniformly spread all over the catchment ? (10)

[**Note.** Please refer Solved Example 7.28].

(c) Describe briefly the forces considered in the design of gravity dams: what combination of these forces is critical in the design of non-overflow section of the dam under reservoir empty condition ? (20)

(d) (i) Explain very briefly the following terms used in groundwater flow :

1. Specific yield
2. Storage coefficient
3. Barometric efficiency
4. Specific capacity. (10)

(ii) Write short notes on :

1. Irrigation water quality

2. Leaching. (10)

Q. 10. *(a) What are the advantages of lining a canal ? Explain how the benefit cost ratio for lining an existing canal can be estimated. Indicate clearly the assumptions, if any, involved.* (15)

(b) Write brief notes on :

(i) Bed load

(ii) Suspended load

(iii) Critical shear stress in sediment transport. (15)

(c) The following table gives the monthly inflow into and contemplated demand from a proposed reservoir :

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Monthly inflow $M.m^3$	50	40	30	25	20	30	200	225	150	90	70	60
Monthly demand $M.m^3$	70	75	80	85	130	120	25	25	40	45	50	60
Evapo-ration, cm	6	8	13	17	22	22	14	11	13	12	7	5
Rainfall cm	1	0	0	0	0	19	43	39	22	6	2	1

Assume the average reservoir area as 30 km^2. The runoff coefficient of the area flooded by the reservoir is 0.4. Estimate the minimum storage that is needed to meet the demand. (30)

[**Hint.** Follow Example 8.2 and compute the reqd. storage capacity = 133.08 ha. m, as per computations carried out in table given on next page. **Ans.**]

Q. 11. *(a) (i) Distinguish between :*

1. Hydrologic and hydraulic methods of flood routing.

2. Hydrologic storage routing and hydrologic channel routing. (10)

[**Hint.** Flow routing is a procedure by which we can estimate/trace the flow through a *hydrologic system* (like a river or a reservoir, or a canal), downstream of a given input point. This can be done either by adopting *hydrologic routing techniques* or by *hydraulic routing techniques.*

In **hydrological routing,** the flow is calculated as a *function of time alone at a particular location* ; whereas in a **hydraulic routing,** *the flow is calculated as a function of space and time both,* throughout the system.

Hydrologic storage routing has been adopted by us in Chapter 18, to compute the levels likely to be achieved in a reservoir due to entry of a flood hydrograph, and to work out the outflow hydrograph, spilling over the spillway. *Hydrologic channel routing* has similarly been used in Muskingum's method for determining the shape of flood hydrograph at a particular known point along a river channel downstream of a given input point upstream, as explained in Chapter 13 of "Hydrology and Water Resources Engineering".

Solution Table for Q. 10 (*c*) of 1989 (Civil Services)

Month	*Inflow in Mm^3*	*Evaporation cm*	*Rainfall in cm*	*Demand Mm^3*	*Evaporation loss $= \frac{30\ km^2 \times col.\ (3)}{100}\ m$ $= 0.3 \times col.\ (3)$ in $M.m^3$*	*Rainfall in Mm^3; only 60% rainfall is now counted, because 40% was already counted as runoff in the observed inflows before construction of dam $= \frac{0.6 \times col.\ (4)}{100}\ m \times 30\ km^2$ $= 0.18 \times col.\ (4)$*	*Adjusted inflow in $M.m^3$ col. (2) – col. (6) + col. (7)*	*Water reqd. from storage in $M.m^3$ col. (5) – col. (8) (only +ve values)*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Jan.	50	6	1	70	1.8	0.18	48.38	21.62
Feb.	40	8	0	75	2.4	0.00	37.60	37.4
March	30	13	0	80	3.9	0.00	26.10	53.9
April	25	17	0	85	5.1	0.00	19.90	5.10
May	20	22	0	130	6.6	0.00	13.70	6.30
June	30	22	19	120	6.6	3.42	26.82	3.18
July	200	14	43	25	4.2	7.74	203.54	Nil
August	225	11	39	25	3.3	7.02	228.72	Nil
Sept.	150	13	22	40	3.9	3.96	150.06	Nil
Oct.	90	12	6	45	3.6	1.08	87.48	2.52
Nov.	70	7	2	50	2.1	0.36	68.26	1.74
Dec.	60	5	1	60	1.5	0.18	58.68	1.32

Reqd. storage from reservoir $= \Sigma = 133.08\ Mm^3$. **Ans.**

The **hydraulic flood routing techniques,** such as those by the use of *Saint Venant Equations,* and *Dynamic wave routing,* involve complicated mathematics, and is generally used only when flows are to be analysed on a computer model. Such hydraulic routing models prove better than the hydrologic models in representing the actual unsteady non-uniform nature of flow in the channel, and also give reliable results even for routing *smaller flows,* such as for routing water in irrigation canals.]

Q. 11. *(a) (ii) Route the following flood through a river reach for which the Muskingum coefficients K and X are 22 h and 0.25 respectively. At time t = 0, the outflow discharge is 40 m³/s :*

Time (h)	*0*	*12*	*24*	*36*	*48*	*60*	*72*
Inflow (m^3/s)	*40*	*65*	*165*	*250*	*240*	*205*	*170*

(10)

[**Note.** Please refer Solved Example 13.4 in "Hydrology and Water Resources Engineering".]

Q. 11. *(b) Describe the salient features and design considerations of the hydraulic jump type energy dissipators used below overflow spillways.* (20)

Q. 11. *(c) Describe the functions of 'Distributary Head Regulators' and 'Cross Regulators'. Sketch a typical section of a Distributary Head Regulator and indicate the salient parts. List the design principles for a Distributary Head Regulator.* (20)

Q. 12. *(a) (i) A weir across an alluvial river has a horizontal floor of length 60 m and retains 6 m of water under full pond condition. If the downstream sheet pile is driven to a depth of 6 m below the average bed level, calculate the exit gradient. Further, assuming a porosity of 30% and the relative density of soil particles as 2.70, estimate the critical exit gradient and the factor of safety of the system with respect to the exit gradient.* (10)

(ii) Write explanatory notes on the following terms connected with a barrage :

(1) Scouring sluices

(2) Divide wall

(3) Downstream loose protection. (15)

Q. 12. *(b) List the various objectives of river training and indicate against each objective the methods of training that can be adopted to achieve the same.* (20)

Q. 12. *(c) List the essential requirements of an ideal irrigation outlet. Describe with the aid of sketches, the open flume semi-modular outlet.* (15)

Year 1990 (*Civil Services*)

Q. 9. *(Compulsory) Attempt any three sub-divisions :*

(a) Describe the salient characteristics of precipitation in India. (20)

(b) A certain crop is grown in an area of 3000 hectares, which is fed by a canal system. The data pertaining to irrigation are as follows :

Field capacity of soil	*= 26%*
Optimum moisture	*= 12%*
Permanent wilting point	*= 10%*
Effective depth of root zone	*= 80 cm*
Apparent relative density of soil	*= 1.4*

If the frequency of irrigation is 10 days and the overall irrigation efficiency is 22%, find :

(i) the daily consumptive use ; and

(ii) the water discharge in m^3/s required in the canal feeding the area. (30)

[**Hint.** Follow example 2.13 and 2.14, and determine :

Depth of water used by plants for growth, which is supplemented by irrigation after every 10 days

$$= \frac{\gamma d}{w} \text{ [Field capacity m.c.} - \text{Optimum m.c.]}$$

$$= \frac{1.4 \times 0.8 \text{ m}}{1} \left[0.26 - 0.12\right] = 0.1568 \text{ m} = 15.68 \text{ cm.}$$

(*i*) Daily water consumed by plants ; *i.e.*, daily consumptive use

$$= \frac{15.68}{10} \text{ cm} = 1.568 \text{ cm.} \quad \textbf{Ans.}$$

(*ii*) Total irrigation water required *i/c* losses in field and conveyance

$$= \frac{\text{N.I.R.}}{\eta_{irrigation}} = \frac{1.568}{0.22} \text{ cm/day} = 7.127 \text{ cm/day}$$

Field area $= 3000 \text{ ha} = 3000 \times 10^4 \text{ m}^2$

∴ Discharge required in irrigation canal

$$= \frac{7.127}{100} \times \frac{3000 \times 10^4}{24 \times 60 \times 60} \text{ m}^3/\text{s} = \mathbf{24.75\ m^3/s} \quad \textbf{Ans.}]$$

(c) Describe the causes and effects of water-logging in canal irrigated areas. Indicate the measures to be adopted to prevent water-logging. (20)

(d) Write short notes on :

(i) Reservoir sedimentation.

(ii) Silt ejectors.

(iii) Guide bunds.

(iv) Well-loss. (20)

Q. 10. *(a) For a river, the estimated flood peaks for two return periods by use of Gumbel's method are as follows :*

Return period (years)	*Peak flood (m^3/s)*
100	*485*
50	*445*

What flood discharge in this river will have a return period of 1000 years. (30)

[**Note.** Please refer Solved Example 7.57.]

(b) Write short notes on :

(i) Launching apron *(ii) Groynes*

(iii) Silt excluder *(iv) Recuperence test for a well*

(v) Piping failure of a weir floor *(vi) Tainter gate.* (30)

Q. 11. *(a) An impervious floor of a weir on permeable soil is 16 m long and has sheet piles at both the ends. The upstream pile is 4 m deep and the downstream pile is 5 m deep. The weir creates a net head of 2.5 m. Neglecting the thickness of the weir floor, calculate the uplift pressures at the junction of the inner faces of the pile with the weir floor, by using Khosla's theory.* (30)

[**Note.** Please refer Solved Example 11.3].

(b) Describe briefly the energy budget method of estimating evaporation from a lake. (20)

(c) Describe with the help of a neat sketch the salient features of a Sarda type canal fall. (10)

Q. 12. *(a) Write short notes on :*

(i) Maximum-Depth-Area-Duration Curves.

(ii) Probable Maximum Precipitation

(iii) Potential Evapotranspiration.

(iv) Infiltration process. (20)

(b) A commonly used shape for concrete lined canals, called the standard lined trapezoidal canal section, consists of a trapezoidal section with each of its two corners being rounded off by a circular arc of a radius equal to the full supply depth. Determine the dimensions of such a standard lined trapezoidal canal to carry a discharge of 200 m^3/s at a bed slope of 1 in 4000. The side slopes are 2 horizontal : 1 vertical, and Manning's n = 0.014. The limiting velocity in the canal is 2.0 m/s. (20)

[**Hint.** Follow exactly similar solved example 5.4 and determine

$$R = 2.66 \text{ m} ; \quad \cot\theta = 2 ; \quad \theta = 0.46 \text{ radians,}$$

$$A = 100 = y\,[B + 0.46\,y + 2y]$$

or $$B = \left[\frac{100}{y} - 2.46\,y\right] \qquad \ldots(i)$$

Also $$R = 2.66 = \frac{100}{P}, \text{ where}$$

$$P = B + 0.92y + 2y \times 2 = \frac{100}{2.66}$$

or $$B = 37.59 - 4.92y \qquad \ldots(ii)$$

Solving (*i*) and (*ii*)

$$\left.\begin{aligned} y &= 3.44 \text{ m} \\ B &= 20.7 \text{ m.} \end{aligned}\right] \quad \textbf{Ans.}$$

(c) Explain briefly a procedure for calculating the stability of slopes of an earth dam. What are the critical loading conditions at which the stability of an earthen dam is tested during design ? (20)

Year 1991 (*Civil Services*)

Q. 9. *Attempt any three sub-divisions.*

(a) Describe briefly the ground water resources of India and its utilization. (20)

(b) Explain how seismic forces are taken into account in the design of solid gravity dams. (20)

(c) (i) Describe briefly the dilution technique of stream flow measurement. (10)

(ii) A trapezoidal channel with side slopes 1.5 horizontal : 1 vertical is required to carry 15 m^3/s of flow with a bed slope of 1 in 4000. If the channel is lined, the Manning's coefficient n will be 0.014, and it will be 0.028 if the channel is unlined. Calculate the average boundary shear stress if hydraulically efficient lined channel is adopted. What percentage of earthwork is saved in a lined section-relative to an unlined section, when hydraulically efficient section is used in both the cases ? The freeboard can be assumed to be 0.75 m in both the cases and the lining can be assumed to be up to the top of the section. (10)

[**Note.** Please refer Solved Example 4.4]

(d) Write short notes on :

(i) Drip irrigation

(ii) Bed load

(iii) Meanders (20)

Q. 10. *(a) List the different types of spillway crest gates in common use. Describe with neat sketches the salient features of radial gates and vertical lift gates.* (30)

(b) (i) What are the assumptions in the unit hydrograph theory

(ii) The ordinates of 4-hour hydrograph of a catchment are given below :

Time (h)	0	4	8	12	16	20	24	28	32	36	40	44
Ordinate of 4-h U.H. (m^3/s)	0	20	60	150	120	90	70	50	30	20	10	0

Derive the flood hydrograph in the catchment due to the storm given below :

Time from start of storm (h)	0	3	8	12
Accumulated rainfall (cm)	0	5.0	5.8	8.8

The ϕ-index for the catchment can be assumed to be 0.25 cm/h and a constant base flow of 20 m^3/s be appropriate. (25)

[**Note.** Please refer Solved Example 7.37].

Q. 11. *(a) Explain briefly the concept of critical shear stress as used in sediment transport studies. Sketch and label the salient features of Shields curve relating to the critical shear stress. Show that in an unlined canal of hydraulic radius R and bed slope, S_0 constructed in a non-cohesive material, the minimum size d of the sand grain that will not be moved by the flow could be expressed as $d = 11\ R.S_0$.* (20)

(b) With reference to a water resources development project, explain briefly :

(i) Engineering economy study

(ii) Project formulation. (30)

[**Note.** Please refer chapter 20 in "Hydrology and Water Resources Engineering"].

(c) Explain briefly the guidelines currently used in India for selection of design floods for dams and barrages. (10)

Q. 12. *(a) A well is located in 30 m thick confined aquifer of permeability 35 m/day and storage coefficient of 0.004. If the well is pumped at the rate of 1500 litres per minute, calculate the drawdown at a distance of 40 m from the well after 20 hours of pumping.* (20)

[**Note.** Use Jacob's formula and compute drawdown as 0.94 m. **Ans.**]

(b) Describe the use of hydraulic jump as an energy dissipator on the downstream side of overflow spillways. (25)

(c) In a wide stream, a suspended load sample taken at a height of 0.30 m from the bed indicated a concentration of 1000 ppm of sediment by weight. The stream is 5.0 m deep and has a bed slope of 1/4000. The bed material can be assumed to be of uniform size with a fall velocity of 2.0 cm/s. Estimate the concentration of the suspended load at mid-depth. (15)

[**Note.** Please refer Solved Example 4.10].

Year 1992 (*Civil Services*)

Q. 9. *(Compulsory) Answer any three of the following :*

(a) Discuss the considerations to be made for selection of site of rain gauge stations.

How would you estimate the missing rainfall data at a rain gauge station for a particular rain storm by Normal Ratio method ? Under what conditions is it adopted ?

(20)

(b) Explain the terms duty, delta, and base period in connection with irrigation. Establish a relation between Duty of water, Delta and Base period.

Discuss the factors on which duty of water depends. (20)

(c) Discuss the relative advantages and disadvantages of a Barrage over a Weir. Explain the functions of Undersluices in a barrage. (20)

(d) Draw a typical cross-section of a masonry dam. Briefly explain the principle of design of this cross-section. Explain the functions of drainage gallery. (20)

Q. 10. *(a) What is unit hydrograph ? Discuss the assumptions involved in Unit Hydrograph Concept.* (20)

(b) Discuss in details the general procedure of deriving a unit hydrograph. Explain your answer with a neat diagram. (20)

(c) Name some statistical methods of forecasting peak flood discharge. Describe any one of these methods : (20)

Q. 11. *(a) Explain the terms :*

(i) Specific yield (ii) Coefficient of transmissibility, (iii) Storage coefficient, (iv) Infiltration gallery. (20)

(b) A well penetrates into an unconfined aquifer having a saturated depth of 15 m.

The discharge is 8000 litres/hour at 6 m drawdown. Assuming equilibrium flow conditions and a homogeneous aquifer, compute the discharge at 9 m drawdown. The radius of influence may be taken as equal in both cases. Deduce the formula that you would use. (20)

Solution. Using equation 16.17, we have

$$Q = \frac{\pi K (d^2 - h_w^2)}{2.3 \log_{10} \frac{R}{r_w}}$$

where $h_w = d - s$

where d = saturated depth of stratum

s = drawdown

h_w = water head in well.

$$\therefore \quad Q_1 = \frac{\pi K (d^2 - h_{w1}^2)}{2.3 \log_{10} \frac{R}{r_w}} \quad \text{and} \quad Q_2 = \frac{\pi K (d^2 - h_{w2}^2)}{2.3 \log_{10} \frac{R}{r_w}}$$

$$\therefore \quad \frac{Q_2}{Q_1} = \frac{(d^2 - h_{w2}^2)}{(d^2 - h_{w1}^2)} = \frac{d^2 - (d - s_2)^2}{d^2 - (d - s_1)^2}$$

Using given values of $Q_1 = 8000\ L/h$, $s_1 = 6$ m, $d = 15$ m and $s_2 = 9$ m, we get

$$Q_2 = \frac{15^2 - (15-9)^2}{15^2 - (15-6)^2} \times Q_1 = \frac{15^2 - 6^2}{15^2 - 9^2} \times 8000\ L/h$$

$$= \frac{21 \times 9}{24 \times 6} \times 8000\ L/h = 10{,}500\ L/h. \quad \textbf{Ans.}$$

(c) Describe briefly the ground water resources of India and its utilization. (20)

Q. 12. *(a) What are the different types of alignment of irrigation canals? Mention the situation where each type is suitable.* (15)

(b) Explain the phenomenon of hydraulic jump. Discuss its use in the design of hydraulic structures.

(c) Write short notes on :

(i) Bed load and suspended load.

(ii) Critical shear stress in sediment transport.

(iii) Guide-bunds.

(iv) Launching apron.

(v) Piping failure of a weir floor. (5 × 6)

Year 1993 (*Civil Services*)

Q. 9. *(Compulsory) Answer any three of the following :*

(a) What are the objectives of command area development ? Explain how these may be achieved. (20)

(b) (i) What is meant by consumptive use of water for a crop ? On what factors does this depend ? (10)

(ii) During a particular stage of the growth of a crop, consumptive use of water is 2.5 mm/day. Determine the interval in days between irrigations, and the depth of water to be applied when the amount of water available in the soil is 50% of the maximum depth of available water in the root zone, which is 80 mm. Assume irrigation efficiency to be 60%. (10)

[**Solution.** *Study Solved Example 2.13, and compute :*

Readily available moisture in root zone

$$= 50\% \times 80 \text{ mm} = 4 \text{ cm.}$$

Consumptive use = 2.5 mm/day = 0.25 cm/day

∴ 0.25 cm of water is consumed by crop in = 1 day

4 cm of water will be consumed by crop in

$$= \frac{1}{0.25} \times 4 = \mathbf{16\ days.}$$

Also, the depth of water to be recouped through irrigation = 4 cm.

Actual water required to be applied to the field

$$= \frac{\text{Water required to be recouped or absorbed}}{\text{Efficiency of irrigation application}}$$

$$= \frac{4 \text{ cm}}{60\%} = \frac{4 \text{ cm}}{0.6} \text{ cm} = \mathbf{6.67\ cm.} \quad \textbf{Ans.}$$

Hence, 6.67 cm depth of irrigation water shall have to be applied to the fields at an interval of 16 days. **Ans.**

(c) (i) Explain how maximum flood discharge can be obtained from frequency analysis of streamflow data. (8)

(ii) The records of annual rainfall at a rain gauge station expressed in mm in chronological sequence from 1981 to 1992 are given below :

360, 285, 557, 815, 273, 229, 707, 478, 309, 176, 285, 651

Using Hazen's method, estimate the maximum annual rainfall which has a recurrence interval of 10 years. (12)

[**Hint.** Follow Solved Example 7.8 and use Hazen's probability equation (eq. 7.139) as $T = \frac{N}{m - 0.5}$; *i.e.*

$$10 = \frac{12}{m - 0.5}$$

$m = 1.7$; Therefore choose the 1st severest storm

= **815 mm. Ans.]**

(d) Discuss the salient features of Khosla's method of design of weir on pervious foundation, against sub-surface flow. Point out the merits and limitations of the method. (20)

Q. 10. *(a) Discuss the common causes of failure of tubewells. Indicate the possible remedial measures against each of these. What are the criteria of failure of tubewells?* (30)

(b) Two identical tube-wells penetrating fully a 12 m thick aquifer are located at 180 m apart. The tubewells have diameter of 30 cm, radius of influence of 300 m, and the coefficient of permeability of aquifer is 10^{-3} *m/sec. Compute :*

(i) Discharge of tube-well when only one is working with a drawdown of 5 m.

(ii) Percentage decrease in discharge of the well, if both are working with a drawdown of 5 m. (30)

[**Solution.** (*a*) Discharge of single tube-well is given by eqn. (16.20) as :

$$Q_1 = \frac{2\pi KHs}{2.3 \log_{10} \dfrac{R}{r_w}}$$

$$= \frac{2 \times 3.14 \times 10^{-3} \times 12 \times 5}{2.3 \log_{10} \dfrac{300}{0.15}} = \mathbf{0.0496\ m^3/s} \quad \textbf{Ans.}$$

(*b*) Discharge of each identical tube-well, when both are working, is given by eqn. (16.24) as :

$$Q_2 = \frac{2\pi KHs}{2.3 \log_{10} \left(\dfrac{R^2}{r_w \cdot B} \right)}$$

$$= \frac{2 \times 3.14 \times 10^{-3} \times 12 \times 5}{2.3 \log_{10} \left(\dfrac{300^2}{0.15 \times 180} \right)} = \mathbf{0.0465\ m^3/s.}$$

Percentage decrease in discharge

$$= \frac{0.0496 - 0.0465}{0.0496} \times 100 = \mathbf{6.3\%.} \quad \textbf{Ans.]}$$

Q. 11. *(a) What are the true regime conditions in an alluvial channel as stipulated by Lacey ?*

(ii) A stable channel is to be designed for a discharge of 40 m^3*/sec and silt factor of unity. Calculate the dimensions of the channel using Lacey's regime equations. Also calculate the dimensions of the channel if it were to be designed on the basis of Kennedy's method with critical velocity ratio equal to unity, and the ratio of bed width to depth of flow the same as obtained from Lacey's method.* (40)

[**Hint.** Follow *Solved Example 4.8*, and design the channel dimensions on Lacey's theory to be y = **1.84 m**, and b = **25.92 m. Ans.** Then, design channel dimensions on the basis of Kennedy's theory by using $\frac{B}{D}$ ratio as equal to

$\frac{25.92}{1.84} = 14.09$, and by following *Solved Example 4.6*, to compute **D = 1.53 m** and **B = 21.50 m. Ans.**]

(b) Write short notes on :

(i) Sprinkler irrigation *(ii) Drip irrigation*
(iii) Canal lining *(iv) Silt ejector.* (20)

Q. 12. *(a) Explain with sketches the various channel patterns of a river. Discuss the influence of these patterns on planning of a hydraulic structure.* (20)

(b) What are the objectives of river training ? Describe the following river training methods indicating their merits and demerits :

(i) Spurs *(ii) Guide banks*
(iii) Revetments. (20)

Year 1994 *(Civil Services)*

Q. 9. *(Compulsory) Answer any three sub divisions.*

(a) (i) How is the inconsistency of rainfall data of a rain gauge station ascertained ? Discuss briefly the technique and also enumerate the possible causes for such inconsistency.

(ii) What are monolayer films ? How effective are they in retarding evaporation from reservoirs. (20)

(b) (i) 800 m^3 of water is applied to a farmer's rice field of 0.6 hectares. When the moisture content in the soil falls to 40% of the available water between the field capacity (36%) of soil and permanent wilting point (15%) of the soil crop combination, determine the field application efficiency. The root zone depth of rice is 60 cm. Assume porosity = 0.4.

[**Note.** Please refer Solved Example 2.15].

(ii) Differentiate between "Potential Evapotranspiration" and "Actual Evapotranspiration". Do the characteristics of soil and available moisture content affect them ? If yes, how ? (20)

(c) (i) In what manner does seepage endanger the safety of a structure on permeable foundation ? How will you ensure the safety of structures against seepage effects.

(ii) Sketch the typical cross-section of channel, when it is (i) Fully in filling (ii) Partly in filling and partly in cutting. (20)

(d) (i) In a silt excluder for a barrage, why the tunnels in general are of different lengths ? Explain.

(ii) Give a typical layout of the Hydropower development "shortcircuiting long reaches of a circuitous river with steep slope".

(iii) Find the base width of elementary profile of a gravity dam from considerations of no tension. (20)

Q. 10. *(a) Compare the characteristics of Instantaneous unit Hydro-graph (IUH) with the characteristics of Conventional unit Hydrograph. Can S-curve hydrograph be used to derive an IUH of a catchment ? If so, how ?*

(b) The ordinates of a 6-hour unit hydrograph for a basin are given below :

Time (hours)	0	3	6	9	12	18	24
6-h unit hydrograph ordinates (m^3/s)	0	150	250	450	600	800	700
Time (hours)	30	36	42	48	54	60	66
6-h unit hydrograph ordinates (m^3/s)	600	450	325	200	100	50	0

A storm had three successive 6 hour interval of rainfall magnitudes of 3.0, 5.0 and 4.0 cm respectively. Assuming a ϕ-index of 0.20 cm/hr and a base flow of 30 m^3/s, determine the resulting hydrograph of flow. (40)

[**Hint.** Follow similar Solved Example 7.35].

Q. 11. *(a) What are "partially penetrating wells". Discuss their characteristics.* (10)

(b) A 30 cm well completely penetrates an unconfined aquifer of depth 40 m. After a long period of pumping at a steady rate of 1500 lpm, the drawdown in two observation wells 25 m and 75 m from the pumping well were found to be 3.5 m and 2.0 m, respectively. Determine the transmissibility of the aquifer. What is the drawdown at the pumping well ? Derive the equation used. (30)

[**Hint.** Derive and use Thiem's equation (*i.e.* eq. 16.9) for unconfined aquifers. Then to solve the given numerical example, assume the water table to be at the top of the aquifer, *i.e.* the depth of aquifer being equal to the saturated depth (d). Then using the eq. (16.9) we have

$$K = \frac{2.3\, Q \log \frac{r_2}{r_1}}{\pi\,(h_2^2 - h_1^2)} = \frac{2.3 \times \left(\frac{1.5}{60}\right) \text{m}^3/\text{s} \times \log_{10} \frac{75}{25}}{\pi\,[(40-3.5)^2 - (40-2)^2]}$$

$$= 0.781 \times 10^{-4} \text{ m/s}$$

$$T = K.d = 0.781 \times 10^{-4} \times 40$$

$$= \mathbf{3.126 \times 10^{-4}\ m^2/sec} \quad \textbf{Ans.}$$

Now, to determine drawdown, in main well s_w, use r_w in place of r_1, and h_w in place of h_1 in the above equation, as :

$$K = 0.781 \times 10^{-4} = \frac{2.3 \times 0.025 \text{ m}^3/\text{s} \times \log_{10} \frac{75}{0.15}}{\pi\,[36.5^2 - h_w^2]}$$

or $\quad h_w = \mathbf{13.55\ m}$ **Ans.**]

(c) What are the different steps necessary to create an Engineering project ? Enumerating conservation purposes, differentiate between single purpose and multipurpose projects. (20)

[**Hint.** Please refer article 21.1 & 21.2 in "Hydrology and Water Resources Engineering — 1998 ed.]

Q. 12. *(a) Describe various modes of sediment transport in an alluvial channel.*

Design a Lacey's regime channel, flowing through material of average diameter 0.328 mm, for the following data :

Culturable commanded area = 1,00,000 hectare

Intensity of irrigation :

Rabi = 40%

Kharif = 30%

Outlet discharge factor :

Rabi = 1,800 hec/cumec

Kharif = 800 hec/cumec

Assume conveyance losses to be 10%. (30)

[**Hint.** Area irrigated in Rabi = 40,000 hec

$$\therefore\ Q \text{ for Rabi} = \frac{40{,}000\,\text{hec}}{1800\,\text{hec/cumec}} = 22.2\ \text{m}^3/\text{s}$$

$$\text{Similarly } Q \text{ for Kharif} = \frac{30{,}000\,\text{hec}}{800\,\text{hec/cumec}} = 37.5\ \text{m}^3/\text{s}$$

Hence, design the channel on Lacey's theory for Q = 37.5 m^3/s and silt factor $f = 1.75\sqrt{d_{mm}} = 1.75\sqrt{0.328} = 1.0$, by following the solved example 4.8, and compute $b = 25.06$ m, $y = 1.8$ m and $S = 1$ in 6110 for a channel having side slopes of $\frac{1}{2}H : IV$. **Ans.**].

(c) What are the objectives of river training ? Describe the following river training methods :

(i) Spurs *(ii) Guide banks.* (20)

Year 1995 (*Civil Services*)

Q. 9. *(Compulsory). Answer any three subdivisions :*

(a) In a basin six rain gauge stations are reporting rainfall. In a year the annual rainfall recorded by the gauges are as follows :

Station	A	B	C	D	E	F
Rainfall (cm)	41	51	32	55	50	68

For 8% error in estimation of the mean rainfall, calculate the optimum number of rain gauge stations in the basin. Give criteria to install them, if there number is more than the existing number. (20)

[**Hint.** Follow Example 7.3 and compute :

$$\bar{p} = \frac{41 + 51 + 32 + 55 + 50 + 68}{6} = 49.5\ \text{cm}$$

$$\overline{p^2} = \frac{\Sigma P^2}{n} = \frac{41^2 + 51^2 + 32^2 + 55^2 + 50^2 + 68^2}{6} = 2575.83$$

$$\sigma = \sqrt{\frac{n}{n-1}\left[\overline{p^2} - (\bar{p})^2\right]} = \sqrt{\frac{6}{5}\left[2575.83 - (49.5)^2\right]}$$

$$= \sqrt{150.7} = 12.276$$

$$C_v = \frac{100\,\sigma}{\bar{p}} = \frac{100 \times 12.276}{49.5} = 24.80$$

$$N = \left(\frac{C_v}{E}\right)^2 = \left(\frac{24.80}{8}\right)^2 = 9.61 \textbf{ Say 10 No.}$$

∴ Optimum No. of rain gauges = **10 No.** **Ans.**

4 additional gauges are, thus, required to be installed in the given catchment. *These additional gauges should be distributed in the different zones (caused by isohyets) in proportion to their areas.* This will ensure even distribution of the gauges over the entire basin. **Ans.**]

Q. 9. *(b) What are cross-drainage works ? The type of cross-drainage work on the main canal at a drainage can be changed by suitably changing the alignment of main canal. Explain giving schematic sketch.* (20)

Q. 9 *(c) What information is needed to route a flood through a reservoir? Discuss the salient features of the outflow hydrograph as it differs from the inflow hydrograph.* (20)

Q. 9 *(d) "Seismic forces are taken into account in the design of solid gravity dams". If the statement is correct, explain how ?* (20)

Q. 10 *(a) Briefly discuss the limitations of unit hydrograph theory.* (10)

Q. 10 *(b) The IUH (Instantaneous Unit Hydrograph) of a drainage basin is a triangle with base 36 hours and a peak of 20 m^3/s at 8 hours from the start. Determine 2 hour unit hydrograph* (20)

[**Hint.** Instantaneous Unit Hydrograph is a unit hydrograph (containing 1 cm effective rainfall) of infinitely small duration. It is only a theoretical concept, and is explained in author's another book titled "Hydrology and Water Resources Engg" under article 9.11.

The ordinates of a I.U.H. at D hr interval can be used to work out ordinates of unit hydrograph of D hr duration, by averaging the two adjoining coordinates. Say for example, mean of cordinates of IUH at 0 hr and D hr will represent the ordinate of U.H. at D hr. Similarly, the mean of the ordinates of IUH at D hr. and $2D$ hr. will give the ordinate of the U.H at $2D$ hr. Hence, to work out ordinates of U.H. of 2 hr duration, the ordinates of IUH at 2 hr interval are first of all written down in col (2) of the solution table (Figs worked out from shape of IUH triangle).

Solution Table for Q. 10 (*b*)

Time (1)	*Ordinates of IUH at 2 h interval* (2)	*Ordinates of 2 h Unit hydrograph (Computed by averaging)* (3)	
0	0	0	
2	5	2.5	(a.v of 0 + 5)
4	10	7.5	(av. of 5 and 10)
6	15	12.5	(av. of 10 and 15)
8	20	17.5	(av. of 15 and 20)
10	18.57	19.28	
12	17.15	17.85	
14	15.73	16.43	
16	14.30	15.01	
18	12.87	13.58	
20	11.44	11.15	
22	10.00	10.72	
24	8.57	9.28	
26	7.14	7.85	
28	5.71	6.43	
30	4.28	5.00	
32	2.85	3.56	
34	1.43	2.14	
36	0	0	

The ordinates of unit graph are finally written down in Col (3) using averaging method clarified in the table **Ans.**]

Q. 10. *(c) The following flood hydrograph was recorded in a drainage basin due to a storm having three successive 6 hour interval of rainfall magnitudes of 2.9 cm, 4.9 cm, and 3.9 cm respectively. Assume base flow = 20 m^3/s, and storm loss = 0.15 cm/hour, determine a 6 hour unit hydrograph*

Time hours	*0*	*3*	*6*	*9*	*12*	*15*	*18*	*21*
Flood graph ord (m^3/s)	*20*	*50*	*92*	*140*	*199*	*202*	*204*	*144*
Time (hours)	*24*	*27*	*30*	*33*				
Flood graph ord (m^3/s)	*84.5*	*45.5*	*29.0*	*20.0*				

[**Hint.** This question is the reverse type of solved examples like 7.38 and can be solved by assuming ordinates of 6 hr unit graph as *a, b, c, d, e, f,* etc. and then computing the flood graph caused by three successive effective rainfalls amounting to (*i*) $2.9 - 0.15 \times 6 = 2$ cm: ; (*ii*) $4.9 - 0.15 \times 6 = 4$ cm ; and (*iii*) $3.9 - 0.15 \times 6 = 3$. cm, respectively. The second rainfall to occur at 6 hr lag, and third one at 12 hr lag. The additive hydrograph ordinates will equal the flood graph ordinates *minus* base flow. The computations are given below in the table.

Solution Table for Question 10 (*c*) of Year 1995

Time (hr)	*Assumed ordinates of U.H. of 6 hr m^3/s*	*Flood graph ordinate caused by effective of rainfall of 2.9 – 0.9 = 2 cm*	*Flood graph ordinate caused by effective rainfall = 4.9 – 0.9 = 4 cm at a lag of 6 hr*	*Flood graph ordinate caused by eff. rainfall = 3.9 – 0.9 = 3 cm at a lag of 12 hr*	*Σ Total flood graph (3) + (4) + (5) = Given value of flood graph ordinate — base flow of 20 m^3/s*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	
0	0	0			$0 = 0$
3	a	$2a$			$2a = 30^*$; $a = 15$
6	b	$2b$	0		$2b = 72^{**}$; $b = 36$
9	c	$2c$	$4a$		$2c + 4e = 120$; $c = 30$
12	d	$2d$	$4b$	0	$2d + 4b = 179$; $d = 17.5$
15	e	$2e$	$4c$	$3a$	$2e + 4c + 3a = 182$; $e = 8.5$
18	f	$2f$	$4d$	$3b$	$2f + 4d + 36 = 184$; $f = 3$
21	g	$2g$	$4e$	$3c$	$2g + 4e + 3c = 124$; $g = 0$
24			$4f$	$3d$	$4f + 3d = 64.5$
27			$4g$	$3e$	$4g + 3e = 25.5$
30				$3f$	$3f = 9$
33				$3g$	$3g = 0$

* 50 – 20 = 30
** 92 – 20 = 72

The required ordinates of unit graph are thus finally worked out at 3 hr interval between 0 to 21 hrs, as :

0, 15, 36, 30, 17.5, 8.5, 3, 0 m^3/s. **Ans.**]

Q. 11. *(c) A 30 cm diameter well completely penetrates a confined aquifer of permeability 45 m/day. The length of the strainer is 20 m. Under steady state of pumping, the drawdown at the well was found to be 3.0 m, and the radius of influence was 300 m. Calculate the discharge. With increase in diameter of well by 50%, what will be the increase in % of discharge ? Derive the equation used* (30)

[**Hint.** For confined stratum, eqn. (16.20) is applicable, which states :

$$K = \frac{2.3\, Q \log_{10} \dfrac{R}{r_w}}{2\pi\, H.S}$$

$$\text{where } K = 45 \text{ m/day} = \frac{45}{24 \times 3600} \text{ m/s}$$

$$= 0.052 \times 10^{-2} \text{ m/s}$$

$$R = 300 \text{ m}$$

$$r_w = 0.15 \text{ m}$$

$$H = 20 \text{ m}$$

$$s = 3.0 \text{ m}$$

$$\therefore \quad Q = \frac{2 \cdot \pi H.S.K}{2.3 \log_{10} \frac{R}{r_w}} = \frac{2 \times 3.14 \times 20 \times 3 \times 0.052 \times 10^{-2}}{2.3 \times \log_{10} \frac{300}{0.15}}$$

$$= 0.02581 \text{ m}^3/\text{sec} = 25.81 \text{ L/sec} \quad \textbf{Ans.}$$

If well dia increases by 50%, then r_w will become $= 1.5\, r_w$; then

$$Q' = \frac{2\pi\, H.S.\, K}{2.3 \log \frac{R}{1.5\, r_w}}$$

$$\therefore \quad \frac{Q'}{Q} = \frac{\log_{10} \frac{R}{r_w}}{\log_{10} \frac{R}{1.5\, r_w}}$$

$$\%\text{ age increase in discharge} = \frac{Q' - Q}{Q} \times 100 = \left(\frac{Q'}{Q} - 1\right) 100$$

$$= \left[\frac{\log_{10} \frac{300}{0.15}}{\log_{10} \frac{300}{0.15 \times 1.5}} - 1\right] 100 = \left[\frac{\log_{10} 2000}{\log_{10} \frac{2000}{1.5}} - 1\right] 100$$

$$= \left[\frac{3.3010}{3.1249} - 1\right] 100 = \mathbf{17.61\%} \quad \textbf{Ans.]}$$

Q. 11. *(b) Write short explanatory notes on :*

(i) Flood frequency analysis

(ii) Guide bunds and Launching aprons (30)

Q. 12. *(a) Design a cement plaster lined irrigation channel ($n = 0.012$) for 30 m^3/s discharge at a slope of 22.5 cm/km. Take the side slope as $1\frac{1}{2}$ H : 1 V.*

[**Hint.** This question can be solved by following the solved example 5.4, and by assuming a limiting velocity of say 1.5 m/sec in the channel]

Q. 12. *(b) Calculate the seepage through an earth dam resting on an impervious foundation for the relevant data given below*

Height of the dam	*= 60.0 m*
Upstream slope	*= 2.75 : 1 (H : V)*
Downstream slope	*= 2.50 : 1 (H : V)*
Free board	*= 2.5 m*
Crest width	*= 8.0 m*
Length of drainage blanket	*= 120.0 m*

Coefficient of permeability of the embankment material

$$X\text{- direction} = 4.0 \times 10^{-7} \text{ m/s}$$

$$Y\text{-direction} = 1 \times 10^{-7} \text{ m/s}$$ (20)

[**Hint.** Exactly similar question has appeared in Engg services 1995 Exam, which has been solved on page there itself. Students may follow through, and compute

$$q = \mathbf{35.24 \times 10^{-7}\ m^3/sec.\ m}$$

$$= \mathbf{305\ l\ per\ day\ per\ m\ width\ of\ dam} \quad \textbf{Ans.}$$

Q. 12. *(c) Why is it necessary to control sediment entering a canal ? Describe the working of a silt ejector giving neat sketches. On what basis is it designed ?* (20)

Year 1996 *(Civil Service)*

Q. 9. *(Compulsory) Answer any three sub divisions.*

(a) What are the causes of infertility of water-logged areas ? Derive an expression to determine the spacing of drains in open drainage system. Under what conditions this system may be recommended as an antiwater logging measure. (20)

(b) Sketch a 'runoff cycle'. Discuss direct runoff and base flow components of the cycle in details (20)

(c) Find the base width of the elementary profile of a gravity dam from the considerations of no tension, and safety in sliding. Assume reservoir full condition. (20)

(d) Define critical shear stress for a sediment bed. Discuss the use of Shield's diagram to calculate the value of critical shear stress if sediment and fluid properties are known. (20)

Q. 10. *(a) Define a unit hydrograph. Enumerate steps to develop a unit hydrograph from a given flood hydrograph for a catchment. The peak of a flood hydrograph due to a 6 hour storm is 470 m^3/s. The average depth of rainfall is 8.0 cm. Assume an infiltration loss of 0.25 cm/hour and a constant base flow of 15 m^3/s. Estimate the peak discharge of a 6 hour unit hydrograph for the catchment.* (35)

[**Hint.** For subjective part, please refer text. For numerical question, the effective rainfall is $= 8.0 - 6 \times 0.25 = 6.5$ cm. The U.H. will be obtained by dividing the ordinates a flood graph by 6.5. Hence, the peak of U.H.

$$= \frac{\text{Peak of F. graph} - \text{Base flow}}{6.5}$$

$$= \frac{470 - 15}{6.5} = 70 \text{ m}^3/\text{s}$$

Add constant base flow of 15 m^3/s

∴ Peak discharge of U.H. of 6 hr duration

$$= 70 + 15 = \mathbf{85\ m^3/s} \quad \textbf{Ans.]}$$

Q. 10. *(b) How would you determine a 2 hour synthetic unit hydrograph by Snyder's method ? Discuss the situations in which this method is used* (25)

[**Hint.** Please refer article 9.9 in author's another book titled "Hydrology and Water Resources Engineering"]

Q. 11. *(a) In a frequency analysis of rainfall based on years of data of 10 minutes storm, the following values were obtained :*

Arithmetic mean of data = 1.65 cm

Standard deviation = 0.45 cm

Find using Gumbel's extreme value distribution the recurrence interval of a storm of ten minute duration and depth equal to 3 cm. (20)

[**Hint.** Use Eq. (7.142) as

$$X_{(T)} = \bar{X} + K \cdot \sigma$$

or $$3 = 1.65 + K \times 0.45$$

$$K = 3$$

Use eq. (7.148) as

$$K = \frac{y_{(T)} - 0.577}{1.2825} \text{ for } N \to \alpha$$

Since the analysed data is for a number of years, it can be presumed to be for an infinite no. of yrs ; *i.e.* $N \to \alpha$

Hence, $$3 = \frac{Y_{(T)} - 0.577}{1.2825}$$

$$Y_{(T)} = 4.4245$$

Finally use eq. (7.146) as

$$Y_{(T)} = -\left[\ln \ln \frac{T}{T-1}\right] \quad \text{or} \quad -4.4245 = \ln \ln \frac{T}{T-1}$$

or $$\frac{T}{T-1} = 1.012052 \quad \text{or} \quad \frac{T-1}{T} = 0.98809$$

or $T = 83.97$; say **84 yrs Ans**]

Q. 11. *(b) Draw a schematic sketch of a diversion headworks with canals taking off from both sides. Indicate the functions of undersluices portion and canal head regulator.* (25)

Q. 11. *(c) Discuss the use of hydraulic jump, as an energy dissipation device in the design of hydraulic structures* (15)

Q. 12. *(a) Explain the terms :*

(i) Specific yield *(ii) Specific capacity*

A well penetrates into an unconfined aquifer having a saturated depth of 100 m. The discharge is 250 litres per minute at 12 m draw down. Assuming equilibrium flow conditions and a homogeneous aquifer, estimate the discharge at 18 m drawdown. The radius of influence may be taken as equal in both cases. Derive the formula used (30)

[**Hint.** Please refer solved example 16.3. **This question was set from this book]**

Q. 12. *(b) Write short notes on :*

(i) Piping failure of a weir floor and remedial measures

(ii) Spherical flow in a well (30)

Year 1997 *(Civil Services)*

Q. 9. *(Compulsory). Answer any three sub divisions*

(a) Explain briefly interception, transpiration and consumptive use. A 3-hour storm occurs over a 63 sq. km area. From the following data, estimate the rainfall excess for the entire area and its hourly distribution :

Sub area	*φ Index*	*Hourly rain*		
	cm/hr	*1st*	*2nd*	*3rd*
14.0	2.0	1.5	5.0	0.8
21.0	3.5	1.5	5.0	0.9
28.0	1.0	1.7	6.0	1.5

(20)

[**Hint.** Follow similar solved Example 7.28, and determine.

Total rainfall excess (runoff) = Σ (partial runoff volumes)

or $R = R_1 + R_2 + R_3$

$$R_1 = 14 \text{ km}^2 [0 + (5.0 - 2.0) + 0] = 42 \text{ km}^2 \cdot \text{cm}$$

$$R_2 = 21 \text{ km}^2 [0 + (5.0 - 3.5) + 0] = 31.5 \text{ km}^2 \cdot \text{cm}$$

$$R_3 = 28 \text{ km}^2 [(1.7 - 1.0) + (6.0 - 1.0) + (1.5 - 1.0)]$$

$$= 28 \text{ km}^2 [0.7 + 5 + 0.5] = 173.6 \text{ km}^2 \cdot \text{cm}$$

$$\therefore \quad R = R_1 + R_2 + R_3 = 42 + 31.5 + 173.6 = 247.1 \text{ km}^2 \cdot \text{cm}$$

∴ Total runoff as volume from 63 km^2 area = 247.1 $\text{km}^2 \cdot \text{cm}$

∴ Total runoff as depth $= \frac{247.1}{63}$ cm = **3.92 cm** **Ans.**

Hourly values of total runoff can also similarly be computed by considering hourly values separately rather than in consolidated form as below :

$$\text{Total runoff in 1st hour} = \frac{14 \times 0 + 21 \times 0 + 28\,(1.7 - 1.0)}{63}$$

$$= \mathbf{0.31 \text{ cm}} \quad \ldots(i)$$

$$\text{Total runoff in 2nd hour} = \frac{14 \times (5.0 - 2.0) + 21\,(5.0 - 3.5) + 28 \times (6.0 - 1.0)}{63}$$

$$= \frac{14 \times 3 + 21 \times 1.5 + 28 \times 5.0}{63}$$

$$= \mathbf{3.39 \text{ cm}} \quad \ldots(ii)$$

$$\text{Total runoff in 3rd hour} = \frac{14 \times 0 + 21 \times 0 + 28\,(1.5 - 1.0)}{63}$$

$$= \frac{28 \times 0.5}{63} = \mathbf{0.22 \text{ cm}} \quad \ldots(iii)$$

Total runoff = (*i*) + (*ii*) + (*iii*)

= 0.31 + 3.39 + 0.22 = **3.92 cm** (*O.K*) **Ans.**

(b) Write a note on the main elements of water resources development. Enumerate the steps followed in planning. (20)

(c) Explain the various causes of water logging. Describe various methods adopted as anti-water logging measures. (20)

(d) Describe in brief various types of groynes used for river training. Draw a section of a groyne. (20)

Q. 10. *(a) What do you understand by infiltration index ? How do you determine it?* (15)

(b) Describe with the help of a neat sketch any three methods of separation of base flow from the hydrograph of runoff indicating the situations under which you advocate them. (20)

(c) The following are the ordinates of a 3 hour unit hydrograph. Derive the ordinates of a 6 hour unit hydrograph and plot the same.

Time (hr.)	*3 hr. UGO (cumec)*	*Time (hr.)*	*3 hr. UGO (cumec)*
0	0	15	9.4
3	1.5	18	4.6
6	4.5	21	2.3
9	8.6	24	0.8
12	12.0	27	0.0

(25)

[**Hint.** Follow exactly similar solved Example 7.33]

Q. 11. *(a) A 30 cm well penetrates 50 m below the static watertable. After a long period of pumping at a rate of 1800 lpm, the draw-downs in the wells at 15 m and 45 m from the pumped well were 1.7 m and 0.8 m respectively. Find the transmissibility of the aquifer. What is the draw-down in the pumped well ?* (30)

[**Hint.** Follow exactly similar solved Example 16.5]

(b) Derive an expression for discharge from a well fully penetrating a confined aquifer. (15)

(c) What do you understand by 'priming' and 'depriming' ? Describe any three devices used for early priming in Saddle Siphon Spillway. (15)

Q. 12. *(a) What is berm ? Why is it provided in canals ? Using Lacey's theory, design an irrigation channel for the following data :* (30)

Discharge Q = 50 cumec

Silt factor f = 1

[**Hint.** Follow solved Example 4.8]

Q. 12. *(b) Write short notes on :*

(i) Bed forms in alluvial channels

(ii) Silt excludes

(iii) Divide wall and fish ladder. (30)

Year 1998 (*Civil Services*)

Q. 9. *(Compulsory). Answer any three sub divisions :*

(a) Rainfall intensities in mm/h at half-hour intervals during a 4-hr storm were : 5,

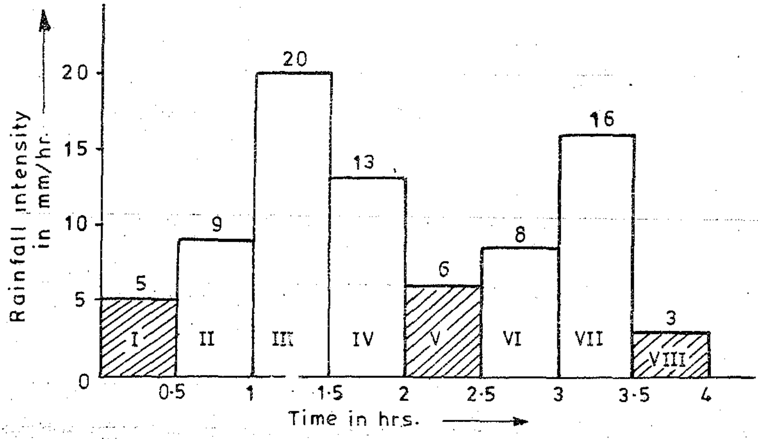

Fig. 31.12

9, 20, 13, 6, 8, 16 and 3 mm/hr. If the corresponding observed runoff is 27.45 million m^3 from a basin having an area of 1830 km^2, determine the ϕ_{index} for the storm. (20)

[**Solution.** Follow Solved Example 7.26, and compute as follows : Plot rainfall hyetograph as shown below.

$$\text{Total runoff } (Q) = \frac{27.45 \times 10^6 \text{ m}^3}{(1830 \times 10^6) \text{ m}^2} = \frac{27.45}{1830} \times 1000 \text{ mm} = \mathbf{15\ mm}$$

$$\text{Total rainfall}(P) = 0.5 \text{ hr } [5 + 9 + 20 + 13 + 6 + 8 + 16 + 3] \frac{\text{mm}}{\text{hr}}$$

$$= \mathbf{40\ mm}$$

$$W_{index} = \frac{P - Q}{t_r} = \frac{(40 - 15) \text{ mm}}{4 \text{ hr}} = \mathbf{6.25\ mm/hr}$$

Since ϕ_{index} has to be somewhat more than W_{index}, we can conclude that ϕ_{index} would be a little more than 6.25 mm/hr. When this is so, evidently, the Ist, Vth and VIIIth (half hr) rainfalls would become ineffective in producing excess rain, because the rain intensity in those periods would be less than ϕ_{index}.

In other words, the period (t_e) during which excess rain occurs, would be only $4 - 1.5 = 2.5$ hr. In that case, using Eq. (7.102), we have

$$\phi_{index} = \frac{\text{Total in filtration during the period of excess rainfall}}{\text{Period of excess rainfall}}$$

$$= \frac{\text{Total infiltration} - \text{Infiltration during the time when no excess rain occurs}}{t_e}$$

$$= \frac{25 \text{ mm} - 0.5\,[5 + 6 + 3]}{2.5 \text{ hr}}$$

$$\therefore \ \phi_{index} = \frac{25 - 0.5 \times 14}{2.5} = \frac{25 - 7}{2.5} = \frac{18}{2.5} = 7.2 \text{ mm/hr.}$$

With this computed value of ϕ_{index}, no other period excepts the periods marked as II, VI & VIII (already accounted) become infructous to yield excess rain. Hence, the computations done do not need further revision. Hence, ϕ_{index} = **7.2 mm/hr Ans.**

Q. 9. *(b) Distinguish between*

(i) Drainage divide and ground water divide

(ii) Consumptive and non-consumptive uses of water (20)

Q. 9. *(c) Briefly explain water-logging and its ill-effects.* (20)

Q. 9. *(d) Draw a sketch of a composite earth dam showing its components. Also state the functions of these components.* (20)

Q. 10. *(a) During a recuperation test, the water level in an open well depressed by 2.5 m during pumping and it recuperated 2 m in 100 minutes. Find :*

(i) Yield from a well of 4 m diameter under a depression head of 2.4 m; and

(ii) Diameter of a well to yield 12 l/s under a depression head of 2.4 m. (20)

[**Hint.** Follow exactly similar Solved Example 16.10]

Q. 10. *(b) Describe the zone method of design of high gravity dams.* (20)

Q. 10. *(c) What is a silt excluder ? Explain its working with the help of neat sketches.* (20)

Q. 11. *(a) The ordinates of a 3-hr unit hydrograph are as follows :*

Time (hr.)	*3-hr unit graph ordinates (m^3/s)*
0	0
3	3
6	8
9	15
12	13
15	10
18	6
21	2
24	0

Assuming a constant base flow of 15 m^3/s and an average storm loss of 0.20 cm/hr, obtain the ordinates of the resultant hydrograph for three successive storms of 3.6, 6.0 and 4.2 cm, each of 3 hours duration. (20)

[**Hint.** Follow exactly similar Solved Example 7.38]

(b) Describe various methods used for energy dissipation below spillways. (20)

(c) Compare Kennedy's and Lacey's silt theories. Which of them would you prefer for designing an irrigation channel ? Why ? (20)

Q. 12. *(a) Explain the terms 'duty' and 'delta'. State the different factors that affect duty.* (20)

(b) Draw a neat sketch of a syphon aqueduct and state the conditions under which it is recommended. (20)

Q. 12. *(c) Write short notes on :*

(i) Reservoir sedimentation ; and (ii) River training. (20)

Year 1999 (*Civil Services*)

Questions 9 is compulsory

Q. 9. Answer any three sub-divisions

(*a*) *Define a flood plain. Briefly describe and discuss structural and non-structural measures of flood control.* (20)

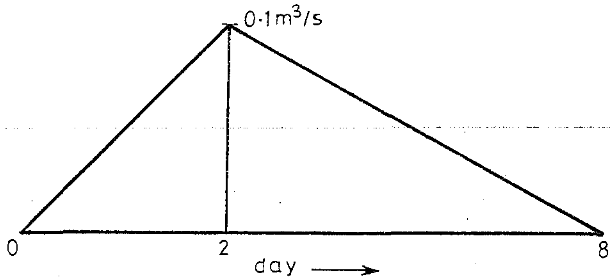

Fig. 31.13

(*b*) *Define a unit hydrograph. What are its assumptions ?*

The unit hydrograph of a drainage basin for unit duration of 1 hour and effective rainfall of 1 cm/hour is given in the form of a triangle with the base as 8 days and peak flow of 0.1 m³/sec occurring on the second day. Estimate the area of the drainage basin.

[**Solution.** Area of unit hydrograph = 1 cm of rain on catchment of A sq. m.

$$\text{Area of U. graph} = \frac{1}{2} \times 0.1 \frac{\text{m}^3}{\text{s}} \times 8 \text{ days}$$

$$= \frac{1}{2} \times 0.1 \frac{\text{m}^3}{\text{s}} \times (8 \times 24 \times 60 \times 60) \text{ . s}$$

$$= \frac{1}{2} \times 0.1 \times 8 \times 24 \times 3600 \text{ m}^3$$

or $$\frac{1}{2} \times 0.1 \times 8 \times 24 \times 3600 \text{ m}^3 = \left(\frac{1}{100} \text{ m}\right) \times A \text{ (m}^2)$$

or $$A = 345.6 \times 10^4 \text{ m}^2 = 345.6 \text{ ha}$$ **Ans.**]

(*c*) *What are reservoir routing and channel routing ? What are the shortcomings of the Muskingum method of flood routing ?* (20)

[**Hint :** Please refer chapter on Flood Forecasting in "Hydrology and water Resources" by the same author.]

(*d*) *What are the important features for the design of cross-drainage works ? Sketch a typical siphon aqueduct.* (20)

Q. 10. (*a*) (*i*) *State and discuss the various factors affecting run off from a drainage basin.*

(*ii*) *How will you test the consistency of the rainfall record of a station, if the annual precipitation data of a group of stations including the one in question are available for a long period ?* (20)

Q. 10. (*b*) *At a certain point in an unconfined aquifer of 4 km² area, the water-table was at an elevation of 120.0 m. Due to natural recharge in a wet season, its level rose to 121.2 m A volume of 2 million cubic metres of water was then pumped out of the aquifer, causing the water-table to reach a level of 119.2 m. Assuming the water-table in the entire aquifer to correspond in a similar way, estimate*

(*i*) *the specific yield of the aquifer; and*

(*ii*) *volume of recharge during the wet season.* (20)

[**Solution.** Water pumped in lowering W.T. by 121.2 – 119.2 = 2 m is 2M.m³.

Vol of Aquifer drained in lowering W.T. by 2m

$$= \text{Area} \times 2 \text{ m depth} = (4 \times 10^6 \text{ m}^2) \times 2 \text{ m} = 8 \text{ M.m}^3$$

(*i*) Sp. yield of the aquifer (Eq. 16.8)

$$= \frac{\text{Vol. of water drained by gravity drainage}}{\text{Total vol. of aquifer drained}}$$

$$= \frac{2 \text{ M.m}^3}{8 \text{ M.m}^3} = 0.25 = 25\% \quad \textbf{Ans.}$$

(*ii*) During rainy season, the W.T. rose by 121.2 – 120 = 1.2 m. Since 2m lowering of W.T. equals 2 M.m³ of water withdrawal, 1.2 m rise will be equal to **1.2 M.m³ of recharge. Ans.**]

Note. This question was earlier set at AMIE Exam., 1994 (Summer) and its solution was available in Author's another book titled "Hydrology and Water Resources Engg."

Q. 10. (*c*) *Briefly discuss different methods of economic evaluation of water resources projects. What is meant by project-induced economic growth ?* (20)

Q. 11. (*a*) *State the method of images as used in the analysis of ground-water flow.*

A 0.5 m diameter well fully penetrates a 30 m thick unconfined aquifer of hydraulic conductivity 20 m/day. Due to continuous pumping, if a drawdown of 1.0 m is registered in the well, what is the rate of pumping when the well is located at a distance of 50 m from a perennial stream ?

[**Hint.** Pl refer solved example 16.9] (30)

Q. 11. (*b*) *What are the factors affecting the evaporation process ? Briefly describe the Penman approach of estimating reservoir evaporation.* (15)

Q. 11. (*c*) *What is the purpose of providing drainage in an irrigated system ? What are the effects of poor drainage on soil and plants.* (15)

Q. 12. (*a*) *Enumerate the various forces acting on a gravity dam. Also indicate their points of application. Why are construction joints provided in a dam ?* (20)

Q. 12. (*b*) *Briefly describe and discuss the various methods of lining irrigation canals. Give a cross-section of a lined canal.* (20)

Q. 12. (*c*) *Suggest a suitable device for energy dissipation at the toe of a spillway with the following data :*

Discharge per unit width	*= 10 cumecs.*
Depth of water at the toe	*= 80 cm*
Margin of safety to be adopted against sweep out	*= 7%*
Tail water depth	*= 6.0 m*

(20)

[**Hint.** Here $y_1 = 0.8$ m ; T.W.D. = 6 m ; $q = 10$ m^3/s

Using Eq. (10.4) as :

$$y_2 = -\frac{y_1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2q^2}{gy_1}}, \text{ we get}$$

$$y_2 = -\frac{0.8}{2} + \sqrt{\frac{0.8^2}{4} + \frac{2 \times 100}{9.81 \times 0.8}} = 4.664 \text{ m.}$$

With 7% margin for sweep out caused by jumping water on tail water, y_2 becomes equal to $1.07 \times 4.664 = 4.99$ m.

Since tail water depth = 6m, is much more than $y_2 = 4.99$ m, the jump to be formed at the toe of the spillway shall be drowned out by tail water, and proper energy dissipation will not occur.

Hence, the point of jump formation will have to be raised by providing a *sloping glacis* as shown in fig. 21.31 (b_1) - allowing the jump to form on the apron at RL above the river bed by as much as TWD$-y_2 = 6 - 4.99 = 1.01$ m. Alternatively a *roller bucket* as shown in Fig. 21.31 (b_2) may be provided for energy dissipation. **Ans.**]

Year 2000 (*Civil Services*)

(Max. 3 Questions can be solved from this section)

Section B

Q. 5. *is compulsory in five parts :*

Q. 5(*a*). *Briefly discuss the factors affecting run off from a drainage basin* (12)

Q. 5(*b*). *Describe the chemical constituents which affect the suitability of water for irrigation.* (12)

Q. 5(*c*). *How will you estimate the benefits of*

(*i*) *on irrigation project ; and* (*ii*) *a flood control project* (12)

Q. 6.(*a*). *Define storage coefficient and transmissibility coefficient of an aquifer.*

A well is 30 cm in diameter and fully penetrates 50 m below the static water-table. After 36 hours of pumping at a steady state rate of 4 m^3/minute the water level in a test well 200 m apart is lowered by 1.2 m; and in a well 40 m away, the draw down is 2.7 m. What is the transmissibility of the aquifer ? (20)

[**Hint.** Pl. follow exactly similar Solved Question 16.5.]

Q. 6(*c*). *Briefly discuss the causes of water logging in irrigated areas. Describe the procedure for the design of the drainage for water-logged soils.* (20)

Q. 7(*a*). *Describe methods of measuring rainfall and snowfall of a basin. How is consistency of rainfall data determined.* (20)

Q. 7(*c*). *Describe salient features of meandering of rivers in alluvial plains. Describe suitable methods of training such rivers.* (20)

Q. 8(*a*). *Briefly describe Lacey's theory of transportation of silt in channels*

Design an irrigation channel in alluvial soil according to Lacey's Regime theory. The following data are given :

Full supply discharge = 15 cumecs *Lacey's silt factor = 1.0 ;*

Channel side slopes = 1/2 : 1. (20)

[**Hint.** Pl refer exactly *Similar Solved Example* 4.9]

Q. 8(*c*). *Briefly discuss various methods of determining flood frequency analyses. Develop a computer program to determine flood frequency by any one method.* (20)

Year 2001 (*Civil Services*)

Section B. (*Max. 3 questions can be solved from this section*)

Q. 5. *is compulsory in five parts from Irr. & Env. Engg. side.*

Q. 5 (*a*). *What is the difference between a 'confined aquifer' and an 'unconfined aquifer' ? Define and describe Darcy's law of flow of water through permeable soils.* (12)

Q. 5 (*b*). *What is the water requirements of crops ? What is the meaning of the terms 'Duty' and 'Delta' in connection with crop water requirements ? What are the factors affecting duty ? What is average 'delta value' in millimetres for sugarcane ?* (12)

Q. 5 (*c*). *What are the various types of cross drainage works ? What is the purpose of these C. D. Works ? Describe the use of syphon in cross drainage works.* (12)

Q. 6 (*a*). *What are the various surface water sources used for irrigation ? How is the storage capacity of a large reservoir fed by a river for a large irrigation project determined ?* (20)

Q. 6 (*b*). *For reducing seepage of water through the body of an earthen dam, what provisions are made ? What is piping in earthen dams ? How is it prevented ?* (20)

Q. 6 (*c*). *Discuss hydrological cycle and water budget. How can we determine yield from a catchment for various uses from natural rainfall ?* (20)

Year 2002 (Civil Services - Paper II)

Section - B. (*Maximum of 3 Questions can be solved from this section as against a total of 5 Questions*).

Q5 is compulsory in five parts from this section from Irrigation and Environment Engg side.

Q5. (*a*) *List the different types of canal lining in common use. Draw a neat sketch of a typical cross-section of a canal carrying a discharge of 60 m^3/s and lined with brick in cement mortar. Mark the salient features on the sketch.* (12)

Q5. (*b*) (*i*) *What are the basic premises of unit hydrograph theory ? What are the limitations of unit hydrographs ?*

(*ii*) *A 6-hour unit hydrograph is triangular in shape and has a peak ordinate of 10 m^3/s. The base is 72 hours with 12 hours of time up to the peak. What is the area of the catchment represented by this unit hydrograph.* (12)

[**Hint :** Vol. of water contained in $U \cdot H$

$$(1 \text{ cm})\, A\,(m^2) = \frac{1}{2} \times 72\, hrs \times 10 \frac{m^3}{s}$$ where A is catchment area in m^2.

or $$\left(\frac{1}{100}\text{ m}\right) A\,(m^2) = \frac{1}{2} \times (72 \times 3600)\, s \times 10 \frac{m^3}{s}$$

or $$A = (36 \times 36000 \times 100)\, m^2 = 12960 \times 10^4\, m^2 = 12960 \text{ hectares} \quad \text{Ans.]}$$

Q5. (*c*) *In Khosla's theory, how is the exit gradient of a weir in permeable foundation estimated ? Using the theory, how can the factor of safety of a weir design against piping be estimated ?* (12)

[**Hint :** Exit gradient at downstream end of a weir having depth of d/s cut off $= d$ is given by equation (11.4) as :

$$G_E = \frac{H}{d} \frac{1}{\pi \sqrt{\lambda}}$$

where $$\lambda = \frac{1 + \sqrt{1 + \alpha^2}}{2} \text{ and } \alpha = \frac{b}{d}\ ;$$ where b = Total floor length

$$F \cdot S = \frac{1}{\text{Exit gradient}}.$$

Q5. (*f*) *Write the Shield's curve for incipient motion of sediment. Mark clearly the ordinate and abscissa of this curve and level the salient features.*

[**Hint :** Please refer article 4.5 and Fig. 4.4]

Q6. (*b*) *In the context of sediment transport in alluvial channels, describe briefly the following :*

(*i*) *Bed load,* (*ii*) *Bed forms and* (*iii*) *Regime channel* (20)

Q6. (*c*) *List the different methods of application of irrigation water to farm land. In a system which relies on supply of water through field channels, indicate methods of achieving high efficiency of water use.* (20)

Q7. (*a*) (*i*) *Write the Rouse's equation for distribution of suspended sediment in the vertical of a channel and label all the terms.*

In a wide alluvial channel having suspended sediment load, the depth of flow is 2.8 m. If a suspended load sampler indicated a concentration of 700 ppm at a point 30 cm below water surface, estimate the concentration at a point 10 cm above the bed in the same vertical. The exponent in Rouse's equation can be assumed as 0.4. (20)

[**Solution.** Rouse's equation is given by equation (4.40) as :

$$\frac{c}{c_a} = \left[\frac{a\,(D - y)}{y\,(D - a)}\right]^{\frac{w_o}{KV*}} \qquad \text{...(Eqn. 4.40)}$$

In the given question, the exponent $\frac{w_o}{KV*}$ is given as equal to 0.4.

Hence, the equation becomes :

$$\frac{c}{c_a} = \left[\frac{a\,(D - y)}{y\,(D - a)}\right]^{0.4}$$

where c_a is known concentration at a distance 'a' from the bed c is concentration at distance y from load.

Here $D = 2.8$ m.

$c_a = 700$ ppm, $a = (2.8 - 0.3) = 2.5$ m

$c = ?$ $y = 0.1$ m

$$\therefore \quad \frac{c}{700 \text{ ppm}} = \left[\frac{2.5\,(2.8-0.1)}{0.1\,(2.8-2.5)}\right]^{0.4} = \left[\frac{2.5 \times 2.7}{0.1 \times 0.3}\right]^{0.4} = (225)^{0.4} = 8.727$$

or $c = 6109$ ppm Ans.

Q7. (*c*) *Explain the difference between hydraulic routing and hydrological routing of a flood. Describe method of routing of flood wave through a reservoir with uncontrolled spillway outlet ?* (20)

[**Hint :** Please see article 18.10].

Q8. (*a*) *Describe the principle used in the development of Ogee spillway profile. Describe the discharge characteristics of Ogee spillways with vertical upstream face under free flow condition.* (20)

[**Hint :** Please see articles 21.6.2 & 21.6.4 to 21.6.6.]

Q8. (*c*) *Discuss the problem of reservoir sedimentation ? What is the impact of sedimentation on the performance of a multipurpose reservoir ? What remedial measures can be adopted to reduce the rate of siltation ?* (20)

[**Hint :** Please see article 18.12 & 18.12.5.]

Year 2003 (*Civil Services Paper II*)

Q5. (*a*) **Compulsory :** *Briefly state the various steps needed for planning an irrigation project.* (12)

Q5. (*b*) *List the objectives of various of water resources development in the context of the lesser developed countries.* (12)

Q5. (*c*) *Briefly describe the basic methods of applying irrigation water to fields describing the situations when each method is useful.* (12)

Q6. (*a*) *In a lake of 70.8 ha surface, the inflow was 1.5 m³/s in a certain 30 day month. The dam on the lake regulated the outflow (discharge) from the lake to 1.25 m³/s in that month. If the recorded precipitation in that month was 7.62 cm and the storage volume increased by an estimated 6,50,000 m³, what is the estimated evaporation in m³ and cm ? Assume that no water infiltrates out of the bottom (and sides) of that lake.* (20)

[**Hint.** Inflow = 1.5 m^3/s ; Outflow = 1.25 m^3/s

Increase in storage (rate) = 0.25 m^3/s

Increase in storage in the month of 30 days

$$= 0.25 \times (30 \times 24 \times 3600) \text{ m}^3 = \mathbf{6{,}48{,}000\ m^3}.$$

Precipitation = 7.62 cm

Precipitation volume = 7.62 cm × Lake area of 70.8 ha

$$= \frac{7.62}{100} \text{ m} \times (70.8 \times 10^4 \text{ m}^2) = \mathbf{53{,}950\ m^3}.$$

Total gross storage $= 6{,}48{,}000 + 53{,}950 = 7{,}01{,}950 \text{ m}^3$.

Actual net increase in storage = 6,50,000 cum

Total loss of water volume from the lake

$$= 7,01,950 - 6,50,000 = 51,950 \text{ cum}$$

Since loss due to infiltration is Nil, the total loss is the loss due to evaporation

= 51,950 cum. Ans.]

Q7. (*a*) *Assuming the initial infiltration rate of 10 mm/h and final infiltration rate of 5 mm/h and the constant value (describing the rate of decay of the difference between the initial and final infiltration rates) as 0.95 h^{-1}, calculate the total infiltration depth for a storm lasting 6 h.* (20)

[**Hint.** Please refer Solved Example 7.13 (*a*).]

Q8. (*a*) (*iii*) *Briefly state the criteria for selection of gravity dam site.* (10)

Year 2004 (*Civil Services Paper II*)

Q5. (*a*) *Why are canal falls provided in irrigation channels ? With the help of sketches, describe and illustrate a trapezoidal notch fall, labelling all the salient features and their functions in flow management and safety.* (12)

(*b*) *What is meant by river training ? What are its objectives ? What are the in-situ features that help in this context ?* (12)

(*c*) *Estimate the depth and frequency of irrigation required for a certain crop, given :*

Root zone depth	:	*90 cm*
Field capacity	:	*22%*
Wilting point	:	*12%*
Apparent sp. gr. of soil	:	*1.5*
Consumptive use	:	*22 mm/day*
Efficiency of irrigation	:	*60%*

Assume 50% depletion of available moisture as the indiator to begin application of irrigation water.

[**Solution.** Please follow similar solved example 2.14 and compute as :

Available moisture = Field capacity m.c. – Wilting point m.c.

$$= 22\% - 12\% = 10\%$$

Since irrigation water is to be supplied on 50% depletion of available moisture, we have

Readily available moisture = 50% × 10% = 5%

It means that irrigation water will be supplied as soon as m.c. falls to 17% from 22%. Thus, m.c. will be allowed to vary between 22% to 17%.

Depth of irrigation water required to raise m.c. from 17% to 22%

$$= \frac{\gamma_d \cdot d}{\gamma_w}\left[\text{Field capacity m.c.} - \text{Optimum m.c.}\right]$$

$$= \frac{\gamma_w \cdot G_a^* \cdot d}{\gamma_w}\left[22\% - 17\%\right]^*$$

d = depth of root zone = 90 cm

$$= 1.5 \times 90 \text{ cm } [5\%] = \frac{1.5 \times 90 \times 5}{100} = \mathbf{6.75\ cm}$$

Water depth reqd in the field

$$= \frac{6.75 \text{ cm}}{0.6} = 11.25 \text{ cm.} \quad \textbf{Ans.}$$

Depth of water available to plants for evapotranspiration = 6.75 cm

Consumptive use = 2.2 cm/day

2.2 cm of water depth is utilised by plants in = 1 day

$\therefore$ 6.75 cm of water depth will be utilised by plants in $= \frac{1}{2.2} \times 8.75$ day

= 3.07 days.

Hence, 11.25 cm water depth will be supplied to fields at every 3 days, which represents the irrigation frequency. **Ans.**

Q6. *(a) For a station 1, the recorded annual 24-hr maximum rainfall are given below. Compute the necessary data to estimate : (a) 24 hr maximum rainfall with a specified return period ; and (b) probability of a rainfall of not less than a specified depth occurring in 24 hours at station 1. Indicate the above features on a sketch (not necessarily plotted to exact data) prescribing the coordinate parameters.*

1 Year	1960	61	62	63	64	65	66	67	68	69
2 Rainfall, cm	14.2	13.1	7.5	14.9	12.4	14.2	7.0	16.1	8.3	9.2

1 Year	70	71	72	73	74	75	76	77	78	79	80
2 Rainfall cm	7.0	13.4	7.5	14.0	15.2	6.5	9.7	13.1	8.8	14.7	11.2

Solution. Please follow similar solved example 7.9 and compute Recurrence interval (T) values for all the given precipitations arranged in decreasing order, as shown in table below, using Eq. $T = \frac{N}{m}$, where N = Total no. of years of record = 21, and m is the ranking of storm :

* G_a is apparent sp gravity, which is the sp gravity of dry soil.

Solution Table for Q6 (a) of Year 2004

Year	*Maximum 24 hr rainfall in cm (arranged in decreasing order)*	*Ranking of storm (m)*	*Recurrence interval (T) in yrs.* $T = \frac{N}{m} = \frac{21}{col. (3)}$
(1)	*(2)*	*(3)*	*(4)*
1967	16.1	1	21.00
1974	15.2	2	10.5
1963	14.9	3	7.00
1979	14.7	4	5.25
1960	14.2	5	4.20
1965	14.2	6	3.50
1973	14.0	7	3.00
1971	13.4	8	2.63
1977	13.1	9	2.33
1961	13.1	10	2.10
1964	12.4	11	1.91
1980	11.2	12	1.75
1976	9.7	13	1.62
1969	9.2	14	1.50
1978	8.8	15	1.40
1968	8.3	16	1.31
1972	7.5	17	1.24
1962	7.5	18	1.17
1970	7.0	19	1.11
1966	7.0	20	1.05
1975	6.5	21	1.00

A graph can now be plotted between values of T (on log scale on x-axis) and values of rainfall (cm) on log scale on Y-axis using log-log graph paper. (Refer Fig. 7.30).

(*b*) To find probability of a rainfall of not less than a specified depth, say D cm, we can read out Recurrence interval (T) value for the given rainfall depth from the plotted graph. The inverse of this T value will give the required probability value p $\left(\because\ p = \frac{1}{T}\right)$.]

Q6. (b) *Draw a schematic diagram (in plan view) of a barrage on an alluvial river, with provision for overflow and fish passage, for diversion of flow into a main canal, including for sediment extraction. On the diagram, label the several features and the schematic flow paths.*

Q7. (a) *Ordinates of a 4-hr unit hydrograph (u.h.g.) on a catchment are tabulated. Derive the ordinates of a 2-hr u.h.g. for the same catchment.*

Time (hr)	0	4	8	12	16	20	24	28
Ordinate of 4-hr u.h.g. (m^3/s)	0	23	54	60	25	14	6	4

(20)

[**Hint.** Please follow similar solved example 7.52.]

Q8. (a) *In a subsurface pipe drainage system, it is desired to keep the highest level of the water table at 1.5 m below the ground surface. The depth of impervious layer from land surface is 10.0 m and the depth of the drain below the land surface is 2.0 m. The mean annual rainfall in the area is 96 cm ; and the coefficient of permeability is 6 × 10⁻⁶ m/s. Design the spacing the the drain pipes.* (20)

Solution. Please follow similar solved example 6.2 and compute as under :

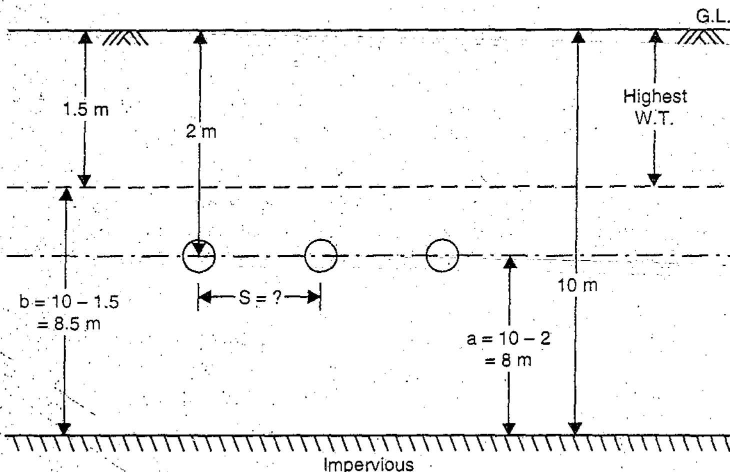

Fig. 31.14

From Fig. 31.14, we have

$a = 10 - 2 = 8$ m

$b = 10 - 1.5 = 8.5$ m

$K = 6 \times 10^{-6}$ m/s

P_{AA} = Annual rainfall = 96 cm = 0.96 m

$S = ?$

We have to use eqn. (6.9) as :

$$q = \frac{4K}{S}\left[b^2 - a^2\right]$$

Where q is the infiltration discharge into the ground, which should be removed by the drains in m³/sec.

Assuming that 1% of the average annual rainfall of the considered place, shall be removed by the tile drains in 24 hours (a common assumption), we get

$$q = \frac{P_{AA} \times 1\%}{24 \times 60 \times 60} \times (S \times 1) \text{ cumec/m length of drains}$$

or $$q = \frac{0.01 \times 0.96 \text{ m}}{24 \times 60 \times 60} \times \left[S \times 1\right] \text{ m}^3\text{/s per m length of drains} \quad ...(i)$$

Also $$q = \frac{4 \times 6 \times 10^{-6}}{S}(8.5^2 - 8^2) \quad ...(ii)$$

Equating (*i*) and (*ii*), we get

$$\frac{4 \times 6 \times 10^{-6} \times 8.25}{S} = \frac{0.01 \times 0.96 \times S}{24 \times 3600}$$

or $$S^2 = \frac{4 \times 6 \times 10^{-6} \times 8.25 \times 24 \times 3600}{0.01 \times 0.96} = 1782 \text{ m}^2$$

or $$S = \mathbf{41.21 \text{ m.}} \quad \textbf{Ans.}$$

Q. 8. (b) (i) In single as well as multiple purpose water resources projects, how are benefits classified ? Give brief explanation for each ; also indicate the distinction between ''with/without'' and ''before/after'' considerations.