128. In problem 125, what is the probability that the T year flood may occur in any one of the next N years.

129. The probability that a T year flood occurs in any year is

(a) $\frac{1}{T}$ ☐ (b) $\left(\frac{1}{T}\right)^2$ ☐

(c) $\log\left(\frac{1}{T}\right)$ ☐ (d) e^{-T}. ☐

130. In the channel routing by the Muskingum method, the values of the routing constants c_0 and c_1 are − 0.2 and 0.5 respectively. The value of the third routing constant c_2 is

(a) 0.5 ☐ (b) − 0.2 ☐

(c) − 0.5 ☐ (d) 0.7. ☐

131. Which of the following is not one of the physiographic factors affecting the runoff from a basin

(a) size of the basin ☐ (b) slope of the main stream ☐

(c) antecedent precipitation ☐ (d) drainage net work. ☐

132. The relationship between the reduced variate y and the return period T is given by

(a) $1-\frac{1}{T}=e^{-e^{-y}}$ ☐ (b) $\frac{1}{T}=e^{-e^{-y}}$ ☐

(c) $1+\frac{1}{T}=e^{-e^{-y}}$ ☐ (d) $\frac{1}{T}=1+e^{-e^{-y}}$. ☐

133. The most commonly used method for reservoir routing is

(a) Muskingum method ☐ (b) Snyders method ☐

(c) Chow's method ☐ (d) Pul's method. ☐

134. The place which records highest annual rainfall in India

(a) Trivandrum ☐ (b) Bombay ☐

(c) Chirrapunji ☐ (d) Goa. ☐

135. Enveloping curve is a method

(a) to determine the peak flood ☐ (b) to determine the infiltration capacity ☐

(c) to estimate the interception ☐ (d) to route the flood through a reservoir. ☐

136. The average atmospheric pressure expressed in millibars is

(a) 10.13 ☐ (b) 101.3 ☐

(c) 1013 ☐ (d) 10130. ☐

137. The average atmospheric pressure expressed in dynes/cm^2 is

(a) 100 ☐ (b) 1000 ☐

(c) 10^5 ☐ (d) 10^6. ☐

138. Relative humidity may be defined as the ratio of

(a) the actual vapour pressure to the saturation vapour pressure ☐

(b) the saturation vapour pressure to the actual vapour pressure ☐

(c) the vapour pressure deficit to the saturation vapour pressure ☐

(d) the saturation vapour pressure to the vapour pressure deficit. ☐

139. Isohyets are

(a) lines joining points of equal rainfall intensity ☐

(b) lines joining points of equal storm duration ☐

(c) lines joining points of equal relative humidity ☐
(d) lines joining points of equal rainfall depth. ☐

140. The moisture useful for plant growth is
(a) capillary water ☐ (b) gravity water ☐
(c) hygroscopic water ☐ (d) all the above. ☐

141. Darcy's law gives the velocity of flow in
(a) openchannels ☐ (b) pipes ☐
(c) porous medium ☐ (d) pumps. ☐

142. Which of the following cannot be used as a humidity measuring device ?
(a) Hydrometer ☐ (b) Dry and wet bulb themometers ☐
(c) Phychrometer ☐ (d) Hygrometer. ☐

143. The number of rain gauges required in a given area to estimate the average depth of rainfall with a given accuracy
(a) is more if the rainfall is non-uniformly distributed ☐
(b) is less if the rainfall is non-uniformly distributed ☐
(c) is more if the rainfall is uniformly distributed ☐
(d) is independent of the variability of rainfall. ☐

144. The site selected for measurement of snowfall should be
(a) horizontal ☐
(b) open to snowfall and in isolation ☐
(c) sheltered against winds and drifting snow ☐
(d) all the above. ☐

145. The ordinate of the instantaneous unit hydrograph is proportional to
(a) the ordinate of S-curve hydrograph ☐
(b) the slope of S-curve hydrograph ☐
(c) inverse of the ordinate of S-curve hydrograph ☐
(d) inverse of the slope of S-curve hydrograph. ☐

146. S-curve hydrograph derived its name because
(a) it has the deformed S-shape ☐ (b) it is proposed by Snyder ☐
(c) it gives the storage of runoff ☐ (d) none of the above. ☐

147. S-curve hydrograph can be used only
(a) to obtain unit hydrograph of longer duration from unit hydrograph of shorter duration ☐
(b) to obtain unit hydrograph of shorter duration from unit hydrograph of longer duration ☐
(c) to obtain unit hydrograph of any duration from unit hydrograph of any given duration ☐
(d) to obtain a synthetic unit hydrograph. ☐

148. A S-curve hydrograph is derived from a D-hour unit hydrograph of a basin with a drainage area of A sq km. The equilibrium discharge ordinate in the S-curve is given by
(a) $\frac{27.8A}{D}$ m^3/s ☐ (b) $\frac{2.78A}{D}$ m^3/s ☐
(c) $\frac{278A}{D}$ m^3/s ☐ (d) $\frac{0.278A}{D}$ m^3/s. ☐

149. The ordinate of a direct runoff hydrograph are measured at Δt-hour intervals and summed up as ΣQ. The area of the catchment is A sq km. Then the depth of runoff d in cm is given by

(a) $\frac{0.36 \Delta t \Sigma Q}{A}$ ☐ (b) $\frac{0.036 \Delta t \Sigma Q}{A}$ ☐

(c) $\frac{0.36 A \Sigma Q}{\Delta t}$ ☐ (d) $\frac{0.036 A \Sigma Q}{\Delta t}$. ☐

150. The trap efficiency of a reservoir is a function of

(a) age of the reservoir ☐ (b) the reservoir capacity ☐

(c) total inflow ☐ (d) (reservoir capacity/total inflow). ☐

151. The standard time at which the daily rainfall is recorded in India is

(a) 7.30 A.M. ☐ (b) 8.30 A.M. ☐

(c) 9.30 A.M. ☐ (d) 5.30 P.M. ☐

152. A spillway is designed for a 5 year flood. What is the probability that the design flood occurs at least once in the next 5 years

(a) 0.2 ☐ (b) 0.8 ☐

(c) 0.672 ☐ (d) 0.5. ☐

153. The two parameters sufficient to describe the symmetrical normal distribution are

(a) mean and standard deviation ☐ (b) mean and range ☐

(c) range and variance ☐ (d) mean and kurtosis co-efficient. ☐

154. If the permeability of a porous medium is not same in all the directions then it is known as

(a) thinotropic ☐ (b) isoentropic ☐

(c) isotropic ☐ (d) anisotropic ☐

155. Which of the following is preferred for measuring the velocity of flow in a natural stream

(a) Pitot tube ☐ (b) Hot-wire anemometer ☐

(c) Current meter ☐ (d) Rod float. ☐

156. The theory of infiltration was enunciated by

(a) Sherman ☐ (b) Dalton ☐

(c) Darcy ☐ (d) Horton. ☐

157. Rainfall simulation are used for the determination of

(a) rainfall ☐ (b) interception ☐

(c) evaporation ☐ (d) infiltration. ☐

158. To which category does the Symon's rain gauge belong ?

(a) tipping-bucket ☐ (b) ordinary rain gauge ☐

(c) syphon ☐ (d) weighing. ☐

159. The type of recording rain gauge used in India is

(a) weighing type ☐ (b) float type ☐

(c) tipping-bucket type ☐ (d) none of the above. ☐

160. The Thiessen weights of the four influencing rain gauge stations of a catchment area are 0.1, 0.2, 0.3 and 0.4. If the rainfalls recorded at these gauges are 40, 30, 20 and 10 mm respectively what is the average depth of rainfall over the basin

(a) 20 mm ☐ (b) 30 mm ☐

(c) 40 mm ☐ (d) 10 mm. ☐

161. The isohyets drawn for a storm yielded the following data :

Isohyet in mm	45—55	55—65	65—75	75—85
Area between isohyets in km²	100	200	300	400

The average depth of rainfall is equal to

(*a*) 50 mm ☐ (*b*) 60 mm ☐

(*c*) 70 mm ☐ (*d*) 80 mm. ☐

162. It is predicted that a storm yielding a maximum daily rainfall of 20 cm has a return period of 5 years. Then the place will receive a maximum daily rainfall of 20 cm

(*a*) one in every five years ☐ (*b*) on the average once in 5 years ☐

(*c*) four times in every five years ☐ (*d*) none of the above. ☐

163. The depth of flow in a stream at a vertical is 10 m. The velocities measured at 2 m and 8 m depth are 0.6 m/s and 0.4 m/s respectively. What is the average velocity for the vertical ?

(*a*) 1 m/s ☐ (*b*) 0.25 m/s ☐

(*c*) 0.5 m/s ☐ (*d*) 0.75 m/s. ☐

164. The water balance equation for a catchment area in terms of rainfall (P), runoff (R), evaporation (E) and storage (S) is written as

(*a*) $R = P - E \pm \Delta S$ ☐ (*b*) $R = P + E \pm \Delta S$ ☐

(*c*) $R = E - P \pm \Delta S$ ☐ (*d*) $P = E - R \pm \Delta S$. ☐

165. In the Muskingum channel routing equation, the sum of the three routing constants C_0, C_1 and C_2 should be equal to

(*a*) 1/3 ☐ (*b*) 2/3 ☐

(*c*) 1 ☐ (*d*) 3. ☐

166. The units of the constant K in the Muskingum storage equation are

(*a*) m/s ☐ (*b*) m^3/s ☐

(*c*) hr ☐ (*d*) m^3. ☐

167. The units of the constant *x* in the Muskingum storage equation are

(*a*) m ☐ (*b*) m/s ☐

(*c*) m^3/s ☐ (*d*) no units. ☐

168. For channel routing, the Muskingum storage equation is given by

(*a*) $K[xI + (1 - x)Q]$ ☐ (*b*) $K[xQ + (1 - x)I]$ ☐

(*c*) $K[xQ + (1 - x)Q]$ ☐ (*d*) $K[xI + (1 + x)Q]$. ☐

169. The ratio of the total number of streams draining the basin to the basin area is known as

(*a*) drainage density ☐ (*b*) stream density ☐

(*c*) drainage efficiency ☐ (*d*) all the above. ☐

170. The ratio of the total lengths of the streams draining the basin to the basin area is known as

(*a*) drainage density ☐ (*b*) stream density ☐

(*c*) drainage efficiency ☐ (*d*) stream efficiency. ☐

171. If A and L denote the area of the basin and the length of the main stream, the form factor of the basin is given by

(a) $\frac{A}{L}$ ☐ (b) $\frac{A}{L^2}$ ☐

(c) $\frac{L}{A}$ ☐ (d) $\frac{L}{A^2}$. ☐

172. A storm produced an intensity of 30 mm/hr for a period of 6 hours. If the area of the basin is 800 km^2 and average infiltration rate is 5 mm/hour, what is the volume of runoff produced by the storm in hectare-metres ?

(a) 12000 ☐ (b) 120 ☐

(c) 12 ☐ (d) 1.2. ☐

173. I.M.D. stand for

(a) Indian Mining Department ☐ (b) Indian Mineral Deposits ☐

(c) India Meteorological Department ☐ (d) International Monetary Debt. ☐

174. The strange's table gives the relationship between

(a) temperature and evaporation ☐ (b) rainfall and infiltration ☐

(c) rainfall and runoff ☐ (d) runoff and area of the basin. ☐

175. The responsibility of gauging the major rivers in the country lies with

(a) central ground water board ☐ (b) central water commission ☐

(c) central board of irrigation and power ☐ (d) central water agency. ☐

ANSWERS

1. (c)	2. (b)	3. (a)	4. (d)	5. (a)	6. (b)
7. (c)	8. (d)	9. (c)	10. (d)	11. (a)	12. (d)
13. (d)	14. (d)	15. (a)	16. (c)	17. (b)	18. (c)
19. (a)	20. (d)	21. (a)	22. (c)	23. (b)	24. (d)
25. (b)	26. (b)	27. (d)	28. (c)	29. (a)	30. (a)
31. (b)	32. (b)	33. (b)	34. (b)	35. (c)	36. (a)
37. (b)	38. (b)	39. (a)	40. (c)	41. (c)	42. (b)
43. (c)	44. (d)	45. (a)	46. (b)	47. (c)	48. (c)
49. (c)	50. (b)	51. (c)	52. (d)	53. (b)	54. (c)
55. (a)	56. (b)	57. (a)	58. (a)	59. (b)	60. (a)
61. (b)	62. (b)	63. (b)	64. (d)	65. (b)	66. (a)
67. (d)	68. (c)	69. (d)	70. (a)	71. (a)	72. (b)
73. (a)	74. (b)	75. (b)	76. (a)	77. (c)	78. (a)
79. (d)	80. (b)	81. (c)	82. (b)	83. (b)	84. (a)
85. (a)	86. (a)	87. (d)	88. (c)	89. (c)	90. (a)
91. (a)	92. (a)	93. (b)	94. (b)	95. (c)	96. (a)
97. (d)	98. (b)	99. (d)	100. (c)	101. (b)	102. (b)
103. (c)	104. (a)	105. (a)	106. (b)	107. (b)	108. (a)
109. (b)	110. (b)	111. (d)	112. (b)	113. (d)	114. (b)

115. (*a*)	**116.** (*c*)	**117.** (*b*)	**118.** (*c*)	**119.** (*d*)	**120.** (*b*)
121. (*a*)	**122.** (*c*)	**123.** (*b*)	**124.** (*c*)	**125.** (*a*)	**126.** (*a*)
127. (*b*)	**128.** (*b*)	**129.** (*a*)	**130.** (*d*)	**131.** (*c*)	**132.** (*a*)
133. (*d*)	**134.** (*c*)	**135.** (*a*)	**136.** (*c*)	**137.** (*d*)	**138.** (*a*)
139. (*d*)	**140.** (*a*)	**141.** (*c*)	**142.** (*a*)	**143.** (*a*)	**144.** (*d*)
145. (*b*)	**146.** (*a*)	**147.** (*c*)	**148.** (*b*)	**149.** (*a*)	**150.** (*d*)
151. (*b*)	**152.** (*c*)	**153.** (*a*)	**154.** (*d*)	**155.** (*c*)	**156.** (*d*)
157. (*d*)	**158.** (*b*)	**159.** (*b*)	**160.** (*a*)	**161.** (*c*)	**162.** (*b*)
163. (*c*)	**164.** (*a*)	**165.** (*c*)	**166.** (*c*)	**167.** (*d*)	**168.** (*a*)
169. (*b*)	**170.** (*a*)	**171.** (*b*)	**172.** (*a*)	**173.** (*c*)	**174.** (*c*)
175. (*b*).					

5

Water Resources Engineering

(Including Irrigation, Open Channel Flow and Water Power)

I. INTRODUCTION

The process of artificially supplying water to soil for raising the crops is called Irrigation. As the rainfall is highly non-uniformly distributed in space and is confined to about 4 months in monsoon at many places and as it is basically an agricultural country, Irrigation is essential in India.

There are two types of irrigation : Flow irrigation where the water is supplied to the fields by gravity and lift irrigation where water is lifted up to ground level and then it is made to flow by gravity.

The methods of applying water to the crops are basically of three types. They are surface irrigation, sub-surface irrigation and sprinkler irrigation.

In the surface irrigation water is applied on the ground surface which infiltrates and then it is absorbed by plants.

In the sub-surface irrigation water is supplied directly to the root zone of the crops.

In the sprinkler irrigation water is applied in the form of spray (resembling rain).

In the surface irrigation methods we have flooding, furrows and contour farming. In the controlled flooding the various methods are free flooding, border strips, basin flooding, zig-zag method etc.

Irrigation water should have acceptable quality. Presence of excessive salts make water saline and unsuitable for irrigation.

If total salt content in water exceeds 2000 ppm, it is not suitable for irrigation.

Boron is the most toxic element. If its concentration exceeds 2 ppm it is harmful to the crops.

The ratio of weight of water present in the soil to the weight of dry soil is called the moisture content.

When all the pores in the soil are occupied by water, the soil is said to be saturated. The moisture content at saturation condition is called the saturation capacity.

When a saturated sample is drained some water will move out under gravity and the remaining water is held in the soil against gravity by the capillary forces.

The moisture content of the soil after it is drained under gravity is called the field capacity. The difference between saturation capacity and field capacity indicates the superfluous water or the gravity water. The gravity water is not available for plant growth.

The plant roots extract moisture from soil and the moisture in the soil will be continuously depleted. The moisture content at which plants can no longer extract sufficient water from the soil for their growth is called permanent wilting point or wilting co-efficient. The difference between the field capacity and the permanent wilting point is the available water. For healthy growth of the crop the moisture in the soil should be maintained at or slightly below the field capacity.

When a soil sample is ovendried its moisture content will be zero. If it is now kept in atmosphere, it will absorb some moisture from the atmosphere which is held in soil due to chemical forces. This water is known as hygroscopic water and it can not be removed from the soil unless by heating.

The consumptive use or the evapotranspiration is the amount of water required (usually expressed as the depth over a given area) to meet the transpiration needs for the healthy growth of plants and also the evaporation from the surrounding soil.

Not all the rain which falls on the ground can be utilised by the plants because most of it runs off. The portion of rainfall which is effectively used by the plant to meet its consumptive need is called the effective rainfall.

Net irrigation requirement = Consumptive use – effective rainfall

$$NIR = CU - ER$$

Field irrigation requirement = Net irrigation requirement
+ Field application losses such as runoff percolation and evaporation

$$FIR = NIR + \text{field application losses}$$

Gross irrigation requirement = Field irrigation requirement + conveyance losses

$$GIR = FIR + \text{Conveyance losses}$$

$$\text{Water application efficiency} = \frac{NIR}{FIR} \times 100$$

$$\text{Water conveyance efficiency} = \frac{FIR}{GIR} \times 100.$$

It is obvious that the sprinkler irrigation has the maximum water application efficiency and also maximum water conveyance efficiency.

Sprinkler irrigation, though involves large initial expenditure, is suitable when the land is highly undulating. In such cases, contour farming is also adopted when the irrigation is done by flooding.

Duty may be defined as the number of hectares of a particular crop which can be irrigated by continuous supply of 1 cumec of water throughout the base period of the crop. Duty is denoted by D while the base period in days is denoted by B.

If the volume of water supplied to the crop throughout its base period is spread over the area of the crop the depth it would occupy is called delta denoted by Δ, expressed in Ha-m/Ha or simply m.

The relationship between duty and delta is given by $\Delta = \frac{8.64\,B}{D}$.

The value of duty depends on the place where it is measured. The duty measured on the field will be high, while the duty measured at the head of the canal is less owing to conveyance losses.

The total area which can be irrigated by a canal system is called the gross commanded area (G.C.A.). This G.C.A. less the unfertile barren land and the other areas of habitation represents the culturable commanded area (C.C.A.). The area on which the crop is actually grown is called culturable cultivated area.

$$\text{C.C.A.} = \text{G.C.A.} - \text{the unfertile and inhabited area}$$

$$\text{Intensity of irrigation} = \frac{\text{Culturable cultivated area}}{\text{C.C.A.}}$$

Crops which are sown at the beginning of south-west monsoon are called Khariff crops. Crops which are sown in autumn are called Rabi crops.

Crop ratio is defined as the ratio of the area irrigated in Rabi season to the area irrigated in Khariff season.

The crops which increase the nitrogen content of the soils and hence the fertility are called leguminious crops.

Rice, maize, jowar, pulses and groundnut come under Khariff crops.

Gram, wheat, tobacco and potato come under Rabi crops. Cotton is a long duration crop which a base period of about 8 months.

Sugarcane is a perennial crop whose base period is spread over almost the entire year.

Reserviors are formed by damming the rivers to store water for using the same in dry periods. Certain storage in the reservoir is earmarked to accommodate the silt that is likely to be trapped after the reservoir is formed such storage is called the dead storage. All the sluices which draw water from the reservoir for various uses should have their sill levels above the dead storage level.

Suitable sites for locating reservoir are selected after thorough topographic, geological and Hydrologic investigations.

The storage available at a potential site between any two successive contours with areas A_1 and A_2 and with an elevation difference h can be found out from one of the following equations :

$$V = \frac{h}{2}(A_1 + A_2) \qquad \text{(Trapezoidal formula)}$$

$$V = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1 A_2}) \qquad \text{(Cone formula)}$$

The trap efficiency of the reservoir is a function of the ratio of the capacity of the reservoir to the inflow rate. As this ratio increases the trap efficiency also increases.

The structure built across a stream to form a reservoir is called a dam.

A dam is said to be overflow dam when water is allowed to flow over it otherwise it is called non-overflow dam.

Depending on the material used, the dams are known as either rigid dams or non-rigid dams.

Gravity dams, arch dams, buttress dams, steel dams and timber dam come under the category of rigid dams.

Earth dams and rockfill dams come under the category of non-rigid dams.

A gravity dam resists all the external forces by its own self weight. It is more permanent than others and requires least maintenance but requires good foundations.

An archdam resists the water thrust by arch action and transmits the reaction force to the two abuttments. It is perferred in narrow gorges where the hillocks of the valley are very strong. Idukki dam in Kerala is an example of the Arch dam in India.

Earth dams are cheap to construct and require no skilled labour. They generally utilise the material available at the site. They can be built on any type of foundation with proper design.

The water pressure on a gravity dam is given by

$P = \frac{WH^2}{2}$, where H is the height of water stored and it acts horizontally at a height of $\frac{H}{3}$ above the base.

The uplift pressure on the base will have an intensity of WH at *u/s* face and WH' at the *d/s* face where H' is the tail water. If a drainage gallery is provided the intensity at the line of the gallery will be taken as

$$w[H' + \tfrac{1}{3}(H - H')].$$

The height of the wave h_w is computed using Molitor's formula. Then the wave pressure is given by

$P_w = 2w\,h_w$ and acts at a height of $\frac{3}{8}h_w$ above the still water surface.

The other forces include self-weight ice pressure, silt pressure, wind pressure and earthquake pressure.

The factor of safety against over turning is defined as the ratio of the sum of all the restoring moments taken about the toe. It should always be more than 1.5.

The shear friction factor ensures stability against sliding. It is given by

$$\text{S.F.F.} = \frac{\mu\Sigma(V-U)+bq}{\Sigma H}$$

where q is the shear strength of the joint, V is the total vertical downward forces, U is the total up lift force, H is the total horizontal force and μ is the co-efficient of friction. Its value should be between 1.5 and 4.0 depending on the loading condition.

To prevent cracking, the design should ensure that no tension develops. This is guaranteed if the resultant falls within the middle third of the base or eccentricity is less than one-sixth of the base. That is, $e \le \frac{b}{6}$.

The maximum normal stress on the base is given by

$$p_n = \frac{V}{b}\left(1+\frac{6e}{b}\right).$$ This occurs at the toe.

The maximum principal stress is given as

$\sigma = p_n \sec^2 \phi$, where ϕ is the angle made by the *d/s* face with the vertical.

The elementary profile of gravity dam is a right-angled triangle. It is modified to suit to the particle conditions.

The height of the dam is large, the stresses developed on the base will also increase and therefore the base width may be increased (by making the *u/s* face inclined instead of vertical) to keep the stress within permissible limits.

A low gravity dam is the dam in which the maximum compressive stress is less than the allowable stress when the *u/s* face is vertical. The limiting height of low gravity dam is given by

$$H = \frac{f}{w(S+1)}$$

where f is the allowable stress, w is the unit weight of water and S is the specific gravity of the dam material.

Drainage gallaries in gravity dams are provided to intercept the seepage through the body of the dam and drain off, to facilitate the drilling and grouting of foundations, to give access to the instrumentation installed and to relieve the uplift pressures.

Construction joints in gravity dams are provided to facilitate the construction work to be carried out in stages.

Construction joints are provided to prevent cracks due to shrinkage produced by temperature changes. The construction joints are properly keyed to permit the transfer of shearing stresses and are properly sealed by water stops to prevent leakages.

Arch dams are two types : constant radius arch dam in which the radius of the arch is constant and constant angle arch dams (a special variety of variable arch dam) in which the central angle of the arch is constant.

For constant angle arch dam the best central angle is 133° 34′. At this angle the volume of concrete is minimum.

The dams which combine the features of arch dams and buttress dams are called multiple arch buttress dams. The Meer Alam dam near Hyderabad, A.P. is of this type.

Based on method of construction, the earth dams are known as rolled fill dams or hydraulic fill dams.

Based on materials used, the rolled fill dams are further divided into homogeneous embankment type, zoned embankment type and Diaphragm type.

In homogeneous type, the top flow line intersects the *d/s* face which is not at all desirable. To overcome this difficulty a horizontal filter is provided on the *d/s* side.

In the zoned embankment type the central portion is made of highly impervious material like clay called the core and to give stability to the core pervious material is dumped on either side which are called shells.

In the diaphragm type dam the central impervious portion is a very thin wall.

The split-up of earth dam failures is as follows :

Hydraulic failures = 40%

Seepage failures = 30%

Structural failures = 30%

Toe drain, horizontal drain and chimney drain are the devices which are used to relieve the pore pressure in the body of the dam and increase the stability.

Impervious cutoff, cutoff trench, upstream impervious blanket and relief wall are the devices which are used to control the seepage through the foundation of the earth dams.

The top flow line, also known as the phreatic line in the earth dam section has the shape of a parabola. If its focal distance is s, the discharge per unit length of the dam is then given as $q = Ks$, where K is the permeability of the dam material. Alternatively if a flow net is drawn.

$$q = KH = \frac{N_f}{N_d}$$

where N_f is the number of flow channels, N_d is the number of equipotential drops and H is the height of water stored. If the dam material is an isotropic with K_x and K_y as the permeability in the x and y directions. The equivalent permeability for the transformed isotropic section is given as

$$K' = \sqrt{K_x K_y}.$$

Flownets may also be constructed using the electrical analogy method. The upstream face is an equipotential line.

The failure of the slopes in an earth dam occurs along a circle known as the slip circle. The stability analysis of slopes is done by Sweedish slip circle method or by Bishop's method, the former being the most generally accepted.

Since the base of the earth dam is large because of flat side slopes normally the stability analysis of foundation against shear is not required. But when the foundation consists of fine, loose cohesionless material or unconsolidated clays and silts it may be necessary to carry out the stability analysis of the foundations.

Any storage reservoir should be provided with arrangements to discharge the surplus water to the *d/s* side safely. The component in the storage headworks which serves this purpose is called the spillway.

Based on the utility the spillway may be called a main spillway or an emergency spillway.

Emergency spillway is an additional safety measure which comes into operation only when unprecedented floods arrive. Its sill is normally kept at or above the Full Reservoir level.

The various types of spillways are ogee spillway, chute spillway, side channel spillway, tunnel or conduit spillway, morning glory spillway, or shaft spillway, and siphon spillway.

Ogee spillway is most commonly used. Its shape conforms to the nappe over a rectangular weir. Its discharge equation is also same as that of rectangular weir. The pressures on the ogee spillway are atmospheric only when the head of the flow is equal to the design head. If the head is more than design head negative pressures will be developed on the ogee spillway and the discharge increases. In the ogee spillway the discharge is proportional to $H^{3/2}$.

In the siphon spillway the discharge takes place under the siphonic action. The discharge is proportional to $H^{1/2}$. But the head in this case is the difference in head race and tail race water levels.

The water discharged over the spillway will have a lot of kinetic energy. Unless this energy is dissipated and its velocity reduced it may erode away the river bed at the foot of spillway and cause danger to the structure.

The commonly used energy dissipators are the hydraulic jump type, the rollers bucket, and the ski-jump bucket.

For a given discharge the normal depth of flow in the river *d/s* of the spillway may not be same as the depth of flow required for the formations of the jump. If it is less than required the jump will be pushed *d/s* and if it is more, the jump will be pushed *u/s*.

The stilling basin where the hydraulic jump occurs is therefore, designed to suit to the tail water conditions at the site.

For example, the floor may be depressed or the sloping glacis may be provided etc.

In order to contain the jump within the stilling basin and to reduce the length of the jump some appurtenance like end sill, chute block and baffle piers may be used.

When the river bed consists of hard rock and if the tail water depth is less than the depth required for the formation of the jump, the ideal choice would be the ski-jump energy dissipator.

Gates are provided over the spillways to increase the useful storage without much of additional cost. Judicious operation of gates can increase the usefulness of the reservoir manifold.

Various types of gates are Radial gates, needle, flash boards, stop logs, vertical lift gates, bear trap gates, rolling gates and drum gates.

Radial gate is also known as a tainter gate.

Stoney gate is a type of vertical lift gate.

Weir is an obstruction of small height built across a river to raise water level and divert water into the canal.

Barrage also has the same purpose but its crest will be almost at the river bed level and the raising of water level is done by the gates.

The other components of diversion headworks are divide wall, scouring sluices fish ladder, head regulator, and silt excluder.

The divide wall prevents the cross currents and the flow parallel to the weir and thereby eliminates the formation of vortices and deep scour. It also provides a still packet of water in front of the head regulator.

The purpose of the fish ladder is to allow the migration of fish from *u/s* to *d/s* and *vice versa*.

The scour sluices (also known as under sluices) maintain deep channel in front of the head regulator and dispose of heavy silt from time to time. They also carry a part of the flood.

Head regulator allows water into canal under controlled and regulated conditions.

Silt excluder is meant to prevent the entry of silt into canal.

The weirs are to be generally founded on permeable river beds. Therefore the foundation floor thickness of weirs should be sufficient to resist the uplift pressures.

If H is the percolation head and L is the length of seepage path (also known as the percolation length) the hydraulic gradient is H/L.

According to Bligh's theory the safe creep length is given by L = CH, where C is called the co-efficient of creep.

In the Bligh's creep theory the vertical and horizontal creeps are given the same weightage and the hydraulic gradient is uniform everywhere throughout the creep length. Therefore in this theory the *d/s* cutoff has no special significance except to increase the creep length.

In the Lane's weighted creep theory the horizontal creep is given a weightage of 1 while the vertical creep is given a weightage of 1.5.

Both Bligh's theory and Lane's weighted creep theory fail to recognize the importance of exit gradient.

According to Khosla's potential flow theory the hydraulic gradient of the seepage flow is not same throughout. In the case of a simple floor with negligible thickness the seepage pressure head varies as a sine curve and the hydraulic gradient at the exit is infinity. Also the outer faces of end piles are more effective than the inner faces in dissipating the uplift pressure.

The *d/s* sheet pile is essential to contain the exit gradient and prevent undermining.

There will be mutual interference of the piles on the uplift pressures. The effect of *d/s* pile is to increase the uplift pressure at the *u/s* pile.

At the end of solid apron on the *d/s* of the foundation an inverted filter and a launching apron (also known as talus, which is made of rough stones in two or three layers) are provided.

The inverted filter relieves the uplift pressure while the launching apron protects the *d/s* pile from scour holes. Talus may also be provided at the *u/s* end of the solid apron.

Whatever, care we may take, some silt may still find its way into the canal at head regulator.

Silt extractor or silt ejector is the device which is constructed at distance away from the head regulator to remove the silt from the canal.

Based on the alignment the canals are classified as contour canal, ridge (or watershed) canal and side slope canal.

As the name suggests the ridge canal runs along the ridge line of the watershed and it has command area on both sides. It is not having any cross drainage works.

Contour canal runs along a contour and it has commad area only on one side.

Side slope canal is normal to the contours and it has steep bed slope.

A canal which is designed to carry water round the year is called a perennial canal.

A canal which feeds two or more canals is called a feeder canal.

The order of the network of an irrigation canal system is Main canal—Branch canal—Major distributory—Minor distributory—Water course.

The discharge in the minor distributory is less than $\frac{1}{4}$ m^3/s.

Canals draw a fair share of silt from the river. When these canals are not lined and when they run in alluvium soils, they must be so designed that they do not either silt or scour.

Kennedy and Lacey have proposed silt theories to design the canals for non-silting and non-scouring conditions.

According to Kennedy's theory the silt is kept in suspension only due to the eddies generated from the bed. The critical velocity is given by $V_0 = 0.55\ D^{0.64}$ where D is the depth of flow. He made use of the Kutter's equation for finding the mean velocity. Design becomes unique only when B/D ratio is known. Otherwise different designs exist for different bed slopes. The silt supporting capacity is proportional to $V_0^{0.25}$.

According to Lacey's theory the silt is kept in suspension due to the eddies generated from both bed and also sides. The relevant equations are

$$V^2 = \frac{2}{5} f R$$

$$V = 10.8\ R^{2/3}\ S^{1/3}$$

$$P = 4.75\sqrt{Q}$$

$$R = 0.47\left(\frac{Q}{f}\right)^{1/3}$$

$$f = 1.76\sqrt{m_r}$$

where V is the velocity, R is the scour depth, f is the silt factor, P is the perimeter, Q is the discharge, S is the slope, all under regime condition, and m_r is the mean diameter of the silt particles in mm.

Generally the canal section will be such that a part of it will be in excavation and the remaining in embankment. If the volume of excavation is just equal to the volume of soil to form the embankment on either side, it will be most economical. Accordingly, the depth which satisfies the above condition is called the balanced depth of cutting.

Berm is a narrow strip of land at the ground level between the inner toe of the bank and top edge of the cutting.

Free board is the level difference between top of the bank and full supply level (F.S.L.).

Borrow pits are required when the volume of filling exceeds the volume of cutting.

When the volume of excavation is in excess of filling, spoil banks are formed.

Counter berm (or back berm) is provided on the outside of the canal bank to contain the hydraulic gradient line within the bank.

When the water table raises very near to the root zone of the crop affecting the fertility of the soil and the yield of the crop, the soil is said to be water logged. The land will be water logged when the water table is within 1.5 m to 2.1 m below ground level.

The reasons for water logging are excessive irrigation, in adequate surface drainage, seepage from canal system, obstruction to drainage etc.

It can be remedied by providing efficient surface drainage and subsurface drainage, restricting the irrigation, reducing the seepage from canals etc.

Seepage loss is the major loss in the irrigation canals. This loss can be minimised by lining the canals. It also acts as anti-water logging measure besides reducing the evaporation losses and eliminating the weed growth. The various types of lining are : concrete lining, Brick lining, soil cement lining, shotcrete lining, Precast concrete lining, cement motar lining asphaltic lining etc.

An outlet is a small structure which allows water from the distributing channel to a water course or field channel.

If the discharge in the outlet depends on the difference in water levels in the distributing channel and field channel, it is called a non-modular outlet.

If the discharge in the outlet depends only on the fluctuations of the water level in the distributing channel and is independent of the fluctuations in water levels of the field channel, it is called a semi-modular or flexible outlet.

If the discharge in the outlet remains constant irrespective of the fluctuations in the water level in distributing channel and field channel, it is called rigid module or flexible outlet.

$$F = \text{Flexibility} = \frac{dq/q}{dQ/Q}$$

q = The discharge through the outlet

Q = The discharge in the distributing channel

when F = 1, it is called the proportional outlet

F > 1, it is called the hyper proportional outlet

F < 1, it is called the sub-proportional outlet

$$S = \text{Sensitivity} = \frac{\left(\frac{dq}{q}\right)}{\left(\frac{dG}{D}\right)}$$

where G is the gauge reading such that G = 0, when $q = 0$

D is the depth of water in the distribution channel.

For rigid module sensitivity is zero.

Submerged pipe outlet is an example of non-modular outlet.

Pipe outlet discharging freely into atmosphere, Kennedy's gauge outlet, open flume outlet come under the category of semi-modules.

Gibb's module is an example of rigid module.

When the natural ground slope is steeper than the design slope canal falls are provided. Canal fall would lower the water level and dissipate the energy associated with the drop.

Types of falls : ogee fall, rapid fall, stepped fall, Notch fall Vertical drop fall, Glacis type of fall, cylinder fall (or syphon well drop).

If the discharge can be measured at the fall it is called a meter-fall otherwise non-meter fall.

Sarda fall is a vertical drop fall. It uses rectangular crest when $Q < 14\ m^3/s$ and trapezoidal crest when $Q > 14\ m^3/s$.

Montague fall is a glacis type fall.

Canal regulators are required to direct water from main canal to branch canal or branch canal to major distributory etc. and also to maintain proper levels in the canals to achieve this objective.

The regulator at the head of the off-taking canal is called the head regulator. The regulator on the parent channel just below the off-take point is called cross regulator.

Sometimes a bridge can be combined with regulator.

A canal escape is a structure constructed on an irrigation canal for the purpose of wasting some of its water.

Cross drainage works are required whenever a canal crosses a natural drain during its course.

When the canal runs above the drain it is called an aqueduct. When there is a sufficient head room between bottom of the canal trough and the high flood level (H.F.L.) in the drain it is called a simple aqueduct. When the bottom of canal trough is below the H.F.L. it is called a syphon aqueduct.

When the drain runs above the canal it is called a superpassage. If the F.S.L. is above the river bed level but below H.F.L. it is called a canal syphon.

When canal and drain cross each other at same level it is called a level crossing.

When the section of the canal including the earthen banks is not altered while it passes over the drain, it is called type I aqueduct.

When the outer slopes of the banks are supported by walls and the flow section is not altered it is called type II aqueduct. The type II syphon aqueduct is also called an under tunnel.

When the canal section is flumed it is called the type III aqueduct.

River training works are required to direct and guide the river flow, to make the river course stable and reduced bank erosion and to pass the flood discharges safely.

The important river training works are guide banks, Groynes or spurs, Levees or embankments and pitched islands etc.

Guide banks are provided to guide the stream near a structure so as to confine it in a reasonable width of the rivers. Guide bank is also known as Bell's bund.

Groynes, which are also known as spurs, are the structures constructed in a transverse direction to the river flow and extend into the river. They are provided to protect the river bank and train the flow along a certain course.

In a repelling groyne the axis of the groyne makes an obtuse angle with the direction of flow.

The axis of an attracting groyne makes an acute angle with the river flow direction.

The axis of a deflecting groyne is normal to the river flow.

In the case of Denehy's groyne, the head has the shape of T, while the shape of Hockey spur resembles the hockey stick.

Levee is an earthen dike constructed parallel to the river. It is also known as marginal bund.

If the depth of flow in a open channel at a section does not change with time the flow is said to be steady. Otherwise, it is called unsteady flow.

The steady flow in open channels is of two types : Uniform flow and Varied (or non-uniform) flow.

The varied flow can be varied into three categories : gradually varied flow, rapidly varied flow, spatially varied flow.

In uniform flow the depth of flow is same along the channel.

In a gradually varied flow the depth of flow either increases or decreases along the channel very gradually.

In a rapidly varied flow the depth of flow changes very rapidly along the channel.

In a spatially varied flow, the discharge either increases of decreases along the channel.

The hydraulic jump is an example of rapidly varied flow, while the flow in a side channel spillway is an example of spatially varied flow.

The velocity in uniform flow in open channels is given by

$$V = C\sqrt{RS} \text{ Chezy's}$$

$$V = \frac{1}{n} R^{2/3} S^{1/2} \text{ Manning's}$$

where C is the Chezy's co-efficient, n is the Manning's rugosity co-efficient

S is the bed slope

$$R = \frac{A}{P} = \text{the hydraulic radius}$$

A = Area of flow

P = Wetted perimeter

The hydraulic depth D is given as the ratio $\frac{A}{T}$, where T is the top width.

The specific energy is the energy measured w.r.t. channel bottom as the datum

$$E = y + \frac{V^2}{2g}.$$

For a given discharge, the specific energy will be minimum when the flow is critical. The corresponding depth of flow is called the critical depth, denoted by y_c.

When the depth of flow y is less than y_c the flow is super-critical and when $y > y_c$ it is subcritical.

The specific energy increases as the depth of flow increases in sub-critical flow where as in super-critical flow it decreases.

The Froude number of the flow, F is given by $F = \frac{V}{\sqrt{gD}}$

where V is the velocity and D is the hydraulic depth. For critical flow ; F = 1, when F < 1 the flow is sub-critical and if F > 1, the flow is supercritical.

For a given specific energy there are two possible depth of flow one in super-critical regime and the other in sub-critical regime. These two depths are called the alternate depths.

For a given specific energy, the discharge will be maximum when the flow is critical.

In a sub-critical flow, if the width of the channel is reduced, the depth of flow decreases and the reverse happens in super- critical flow.

In a sub-critical flow, if a hump is placed the depth of flow over the hump is less than the *u/s* depth of flow and the reverse is true in super-critical flow.

The specific force at a section is given by

Specific force $= \frac{Q^2}{gA} = A\bar{z}$

where $\bar{z}$ is the depth to the centroid of the section from the free surface.

The two depths of flow one in super-critical regime and the other in sub-critical regime for which the specific force is same are called the conjugate depths.

For a given discharge, the specific force will be minimum when the flow is critical.

For a given specific force, the discharge is maximum when the flow is critical.

When the flow is critical, $\frac{V^2}{2g} = \frac{D}{2}$. For rectangular channels since $D = y$, the velocity head equals half the depth of critical flow. In triangular channels at critical flow the velocity head is one-fourth the depth of flow.

The section of the open channel is the most efficient when the wetted perimeter is minimum for the given area.

In the best rectangular section $B = 2y$.

In the best triangular section the bottom angle is 90°.

In other words, the best rectangular and triangular sections are half of a square.

In the best trapezoidal section the top width is twice the length of the inclined side, the side slope is 60°, and it is half of a regular hexagon.

If y_1 and y_2 are the depth before and after the jump, and F_1 is the Froude number of the flow before the jump,

$$\frac{y_2}{y_1} = \frac{1}{2}[-1 + \sqrt{1 + 8F_1^2}].$$

Loss in jump, $$\Delta E = \frac{(y_2 - y_1)^2}{4y_1y_2} = \frac{(V_1 - V_2)^3}{2g(V_1 + V_2)}$$

$$y_1y_2(y_1 + y_2) = 2y_c^3$$

Height of jump, $h_j = y_2 - y_1$

Length of jump $L_j = (5 \text{ to } 7)\, h_j$

$F_1 = 1$ to 1.7 undular jump

$F_1 = 1.7$ to 2.5 weak jump

$F_1 = 2.5$ to 4.5 oscillating jump

F_1 = 4.5 to 9.0 steady jump

F_1 > 9.0 strong jump.

Efficiency of the jump $= \frac{E_2}{E_1} = \frac{E_1 - \Delta E}{E_1}$.

The depth of flow to carry a given discharge under uniform flow conditions over a given slope is called the normal depth y_n.

If $y_n < y_c$ it is steep slope, $y_n = y_c$ it is critical slope, $y_n > y_c$ it is mild slope.

The gradually varied flow in open channels is created by placing obstructions in the uniform flow, by terminating the channel abruptly, by changing the bed slope suddenly etc.

The dynamic equation of gradually varied flow is given by

$$\frac{dy}{dx} = \frac{S_o - S_f}{1 - \frac{Q^2 T}{g A^3}}, \text{ where } S_f \text{ is the energy slope.}$$

when $\frac{dy}{dx}$ is positive the profile is called back water curve and

when $\frac{dy}{dx}$ is negative the profile is called drawdown curve.

Three types of profiles are possible on any slope. For example, M_1, M_2, M_3 and S_1, S_2, S_3 on mild and steep slopes respectively.

Drawdown curves can occur only in second zone.

Backwater curves can occur only in first and third zones.

A rectangular channel is said to be wide if B > 10y. For wide rectangular channels, the hydraulic radius is approximately equal to the depth of flow. That is, $R \simeq y$. With this condition, if Manning's equation is used for velocity.

$$\frac{dy}{dx} = S_o \frac{1 - \left(\frac{y_n}{y}\right)^{10/3}}{1 - \left(\frac{y_c}{y}\right)^3}$$

and if Chezy's equation is used

$$\frac{dy}{dx} = S_o \frac{1 - \left(\frac{y_n}{y_c}\right)^3}{1 - \left(\frac{y_c}{y}\right)^3}.$$

The section factor for uniform flow is $AR^{2/3}$, or $A\sqrt{R}$ depending on whether Manning's or Chezy's equation is used.

The section factor for critical flow is $A\sqrt{D}$.

In circular channels, maximum velocity occurs if $y = 0.81\ d$ where d is the diameter of the channel.

Maximum discharge according to Chezy's equation occurs when $y = 0.95\ d$ and according to Manning's equation when $y = 0.938\ d$.

The hydraulic jump is also known as a standing wave. The depth of flow after the jump is called the sequent depth. For a given initial depth y_1, the sequent depth is always less than the alternate depth y_2. This the because of losses in the hydraulic jump.

The flow over a chute spillway is generally supercritical.

The potential energy possessed by water when it is stored in reservoirs can be utilized to run the turbines which in turn activate generators and produce electricity. Such an arrangement is called a hydrcelectric plant. The power produced in such plants is known as water power or hydro power.

The load (that is the demand for power) on a hydroplant is not uniform. It is a variable with the peak load occurring somewhere in the evening hours.

The graph showing the variation of load with time is called a load curve.

The ratio of the average load to peak load is called load factor.

The installed capacity of the plant will be in excess of the peak load.

The difference between installed capacity and peak load is called the reserve capacity.

The ratio of the average load to the installed capacity is called the capacity factor.

The capacity factor is always less than load factor.

Higher load factor and higher capacity factor indicate the better utilisation of the plant capacity.

A graph plotted between the load and the percentage time such load is equalled or exceeded is called a load duration curve.

The storage provided to take care of the hourly fluctuations is called pondage. The enlarged water body above the intake which serves this purpose is called a forebay.

Booms are provided to deflect and divert the ice and debris from intake to spillway.

Trash racks are provided to prevent the entry of trash into intakes.

Water hammer is produced in penstock pipes due to sudden changes in the discharge.

Surge tanks are provided to reduce the water hammer pressures in penstock pipes. They should be located as nearer to the turbine as possible.

II. OBJECTIVE TYPE QUESTIONS

1. Contour bunding is practiced in

(*a*) plain areas ☐ (*b*) hilly areas ☐

(*c*) water logged areas ☐ (*d*) dried-up tanks. ☐

2. Which of the following has the maximum water application efficiency ?

(*a*) Surface irrigation ☐ (*b*) Lift irrigation ☐

(*c*) Sprinkler irrigation ☐ (*d*) Furrow irrigation. ☐

3. The soil moisture useful for plant growth is

(*a*) gravity water ☐ (*b*) hygroscopic water ☐

(*c*) capillary water ☐ (*d*) all the above. ☐

4. The field capacity is the moisture content present in the soil

(*a*) when it is completely saturated ☐

(*b*) when all the gravity water is removed from it after saturation ☐

(*c*) when the oven dry sample absorbs moisture from atmosphere ☐

(*d*) none of the above. ☐

5. The field capacity of an irrigation soil depends on
   (a) both porosity and pore size ☐ (b) only on porosity ☐
   (c) only on pore size ☐ (d) porosity and depth of root zone. ☐
6. Available soil moisture is the difference between
   (a) saturation capacity and field capacity ☐
   (b) saturation capacity and permanent wilting point ☐
   (c) field capacity and permanent wilting point ☐
   (d) saturation capacity and temporary wilting point. ☐
7. The moisture content of the soil below which plants cannot extract sufficient water for their requirements is called
   (a) field capacity ☐ (b) saturation capacity ☐
   (c) temporary wilting point ☐ (d) permanent wilting point. ☐
8. Soil moisture deficiency is the difference between
   (a) saturation capacity and the existing soil moisture content ☐
   (b) field capacity and the existing soil moisture content ☐
   (c) permanent wilting point and the existing moisture content ☐
   (d) temporary wilting point and the existing moisture content. ☐
9. Basin irrigation is a method of irrigation in which
   (a) water is applied to straight ditches parallel to a row of trees ☐
   (b) sewage effluent is used instead of fresh water ☐
   (c) water lifted by pumps is stored in large basins and then applied to fields ☐
   (d) a basin is formed around each tree or a group of trees and water is applied to these basins. ☐
10. The field capacity and dry unit weight of an irrigation soil are 25% and 1.5 g/cc respectively. If the root zone depth is 0.8 m. What is the depth of water required to bring the existing soil moisture of 15% to the field capacity
    (a) 6 cm ☐ (b) 12 cm ☐
    (c) 18 cm ☐ (d) 24 cm. ☐
11. For an irrigation field lying in a sandy undulating terrain, the most desirable method of applying water is
    (a) basin flooding ☐ (b) furrow irrigation ☐
    (c) free flooding ☐ (d) sprinkler irrigation. ☐
12. When the water table is within the root zone depth and is detrimental to the plant life, the land is said to be
    (a) super saturated ☐ (b) water logged ☐
    (c) over nourished ☐ (d) none of the above. ☐
13. Which of the following may lead to water logging of the fields ?
    (a) poor drainage ☐
    (b) excessive seepage from nearby reservoirs and canals ☐
    (c) over irrigation ☐
    (d) all the above. ☐

14. Water present in the soil which cannot be removed except by heating is called
(*a*) gravity water ☐ (*b*) capillary water ☐
(*c*) hygroscopic water ☐ (*d*) free water. ☐

15. Effective rainfall for a crop may be defined as
(*a*) the portion of the rainfall which is utilized by crops ☐
(*b*) the total rainfall ☐
(*c*) the total rainfall minus the total run off ☐
(*d*) none of the above. ☐

16. Consumptive use of a crop is defined as the
(*a*) total amount of water applied to the crop during its life period ☐
(*b*) total amount of water applied minus the total rainfall during its life period ☐
(*c*) total amount of water utilised by the crop for its evapo-transpiration requirements ☐
(*d*) total amount of water used in the plant metabolism. ☐

17. A climatic region lacking enough water for agriculture without artificial irrigation is called
(*a*) arid zone ☐ (*b*) dry zone ☐
(*c*) desert zone ☐ (*d*) none of the above. ☐

18. If B is the base period in days, D is the duty in hectares/cumec and Δ is the delta of the crop in *m*, the relation between them is given by
(*a*) $D = 8.64\ B\Delta$ ☐ (*b*) $\Delta = 8.65\ BD$ ☐
(*c*) $\Delta = \frac{0.864\ B}{D}$ ☐ (*d*) $\Delta = \frac{8.64\ B}{D}$. ☐

19. The duty at the field of a crop is 100 hectares/cumec. If the canal losses are 25%, what is the duty at the head of the canal ?
(*a*) 750 ☐ (*b*) 1250 ☐
(*c*) 250 ☐ (*d*) 800. ☐

20. The time factor of a canal is defined as the ratio of
(*a*) the number of days of irrigation period to the number of days the canal has run ☐
(*b*) the number of days the canal has run to the number of days of irrigation period ☐
(*c*) the duty at the head of canal to the duty at the field ☐
(*d*) the number of days the canal has run at its capacity. ☐

21. The capacity factor of a canal is defined as the ratio of
(*a*) the mean discharge in the canal to the peak discharge ☐
(*b*) peak discharge to the average discharge ☐
(*c*) the peak discharge to the ayacut irrigated by the canal ☐
(*d*) the ayacut irrigated to the peak discharge. ☐

22. The duty of water at the outlet is also known as
(*a*) time factor ☐ (*b*) capacity factor ☐
(*c*) full supply co-efficient ☐ (*d*) outlet factor. ☐

23. The canal has to irrigate 12000 hectares of rice with a duty of 1000 hectares/cumsc. For what discharge should the canal be designed if the capacity factor is 0.8 and the time factor is 0.75
(*a*) 9.6 m^3/s ☐ (*b*) 9 m^3/s ☐
(*c*) 20 m^3/s ☐ (*d*) 12.8 m^3/s. ☐

24. Crop ratio is defined as the ratio of area irrigated
    (*a*) in Rabi season to Kharif season ☐
    (*b*) in Kharif season to Rabi season ☐
    (*c*) under perennial crop to non-perennial crops ☐
    (*d*) under perennial crop to total area. ☐
25. The Kharif crop is sown
    (*a*) at the end of south-west monsoon ☐ (*b*) at the end of north-east monsoon ☐
    (*c*) the beginning of south-west monsoon ☐ (*d*) in mid summer. ☐
26. Which of the following is not a Rabi crop
    (*a*) sugar cane ☐ (*b*) groundnut ☐
    (*c*) wheat ☐ (*d*) potato. ☐
27. Nitrogen content in the soil can be increased by raising one of the following crops in crop rotation
    (*a*) garden crop ☐ (*b*) aquatic crop ☐
    (*c*) leguminous-crop ☐ (*d*) perennial crop. ☐
28. The average Δ of rice crop is nearer to
    (*a*) 40 cm ☐ (*b*) 80 cm ☐
    (*c*) 120 cm ☐ (*d*) 160 cm. ☐
29. Net irrigation requirement of a crop is given as
    (*a*) consumptive use + field losses ☐
    (*b*) consumptive use + conveyance losses ☐
    (*c*) consumptive use + field losses + conveyance losses ☐
    (*d*) consumptive use – effective rainfall. ☐
30. The field irrigation requirement is computed as
    (*a*) consumptive use + field application losses ☐
    (*b*) net irrigation requirement + field application losses ☐
    (*c*) net irrigation requirement + conveyance losses ☐
    (*d*) consumptive use + conveyance losses. ☐
31. The gross irrigation requirement is given by
    (*a*) consumptive use + conveyance losses ☐
    (*b*) field irrigation requirement + conveyance losses ☐
    (*c*) net irrigation requirement + conveyance losses ☐
    (*d*) consumptive use + field application losses. ☐
32. The depth of root zone for rice is generally about
    (*a*) 8 cm ☐ (*b*) 12 cm ☐
    (*c*) 16 cm ☐ (*d*) 10 cm. ☐
33. The most commonly adopted method of irrigation for cereal crops is
    (*a*) furrow ☐ (*b*) basin flooding ☐
    (*c*) check flooding ☐ (*d*) sub-surface irrigation. ☐
34. The intensity of irrigation is defined as the ratio of
    (*a*) culturable commanded area to gross commanded area ☐
    (*b*) gross commanded area to culturable commanded area ☐

(*c*) culturable cultivated area to culturable commanded area ☐
(*d*) culturable cultivated area to gross commanded area. ☐

35. The heavy crop among the following is
(*a*) hemp ☐ (*b*) sugar cane ☐
(*c*) tobacco ☐ (*d*) cotton. ☐

36. Identify the correct pair of crop and harvesting time from the following :
(*a*) Tobacco—December ☐ (*b*) Rice—July ☐
(*c*) Potato—February ☐ (*d*) Gram—April. ☐

37. Which of the following is leguminous crop ?
(*a*) rice ☐ (*b*) sugar cane ☐
(*c*) groundnut ☐ (*d*) hemp. ☐

38. What type of crop is the sugar cane
(*a*) Kharif ☐ (*b*) Rabi ☐
(*c*) Hot weather ☐ (*d*) Perennial. ☐

39. The most desirable alignment of an irrigation canal is along
(*a*) the ridge line ☐ (*b*) a contour line ☐
(*c*) the valley line ☐ (*d*) a straight line. ☐

40. The type of canal meant for diversion of flood waters of river is
(*a*) ridge canal ☐ (*b*) inundation canal ☐
(*c*) perennial canal ☐ (*d*) permanent canal. ☐

41. An irrigation canal which is designed to irrigate all round the year may be called
(*a*) permanent canal ☐ (*b*) continuous canal ☐
(*c*) perennial canal ☐ (*d*) all weather canal. ☐

42. Canals which are excavated directly from the rivers with or without head regulator are called
(*a*) natural canals ☐ (*b*) ditch canals ☐
(*c*) seasonal canals ☐ (*d*) innudation canals. ☐

43. The canals meant for the purpose of draining off water from water logged areas are called
(*a*) seepage canals ☐ (*b*) percolation canals ☐
(*c*) drains ☐ (*d*) ditch canals. ☐

44. The cone formula to comput the storage volume V between two contours with an elevation difference of *h m* is given by
(*a*) $V = \frac{h}{2}(A_1 + A_2)$ ☐ (*b*) $V = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1A_2})$ ☐
(*c*) $\frac{h}{3}(A_1 + 2A_2)$ ☐ (*d*) $V = \frac{h}{3}(2A_1 + A_2)$. ☐

45. Dead storage in a reservoir is provided
(*a*) to meet the emergency needs ☐
(*b*) to mitigate the floods ☐
(*c*) to accommodated the silt trapped in the reservoir ☐
(*d*) to increase the useful life period. ☐

46. Which of the following is a non-rigid dam ?
(*a*) gravity dam ☐ (*b*) earth dam ☐
(*c*) arch dam ☐ (*d*) buttress dam. ☐

47. Which of the following is a rigid dam
(*a*) gravity dam ☐ (*b*) earth dam ☐
(*c*) rockfill dam ☐ (*d*) coffer dam. ☐

48. The external forces acting on a gravity dam are resisted by
(*a*) transfering the thrust to the abutlments ☐ (*b*) the cantilever beam bending action ☐
(*c*) the self weight of the dam ☐ (*d*) none of the above. ☐

49. Arch dams are generally preferred in
(*a*) wide rivers with good foundation at shallow depth ☐
(*b*) wide rivers with weak foundation ☐
(*c*) narrow gorges with strong abuttments ☐
(*d*) reservoirs where provision is made for future increase in capacity. ☐

50. The famous arch dam in India is at
(*a*) Bhakra ☐ (*b*) Khadakvasla ☐
(*c*) Nagarjuna Sagar ☐ (*d*) Idikki. ☐

51. Beaver dam is a type of
(*a*) earth dam ☐ (*b*) steel dam ☐
(*c*) timber dam ☐ (*d*) buttress dam. ☐

52. The type of dam which requires lest maintenance is
(*a*) steel dam ☐ (*b*) gravity dam ☐
(*c*) timber dam ☐ (*d*) rockfill dam. ☐

53. If h_w is the height of the wave, the maximum intensity of wave pressure occurs at a height of (measured above still water surface)
(*a*) $\frac{h_w}{2}$ ☐ (*b*) $\frac{h_w}{4}$ ☐
(*c*) $\frac{h_w}{8}$ ☐ (*d*) $\frac{h_w}{16}$. ☐

54. If w is the specific weight of water and h_w is the height of the wave, the total wave pressure is equal to
(*a*) $2w\,h_w^2$ ☐ (*b*) $4w\,h_w^2$ ☐
(*c*) $8w\,h_w^2$ ☐ (*d*) $16w\ h_w^2$. ☐

55. The head water and tail water depths in a gravity dam are H and H'. The intensity of up lift pressure at the line of drainage gallery is then given by
(*a*) $w[H' + \frac{1}{3}(H - H')]$ ☐ (*b*) $w/3\,(H + H')$ ☐
(*c*) $w[H - \frac{1}{3}(H - H')]$ ☐ (*d*) $w[H + \frac{2}{3}(H - H')]$. ☐

56. The lower limit of factor of safety against overturning in a gravity dam is
(*a*) 1.25 ☐ (*b*) 1.75 ☐
(*c*) 2.0 ☐ (*d*) 1.5. ☐

57. If p_n is the normal stress at the toe, and ϕ is the angle made by the downstream face with the vertical the maximum principal stress at the toe of the gravity dam for no tail water condition is given by
(a) $p_n \tan^2 \phi$ ☐ (b) $p_n \sec^2 \phi$ ☐
(c) $p_n \cot^2 \phi$ ☐ (d) $p_n \operatorname{cosec}^2 \phi$. ☐

58. A low gravity dam is one in which
(a) the height of water stored is less than 30 m ☐
(b) the resultant just passes through the down stream middle third point ☐
(c) the maximum principal stress is less than the allowable crushing strength and the upstream face is entirely vertical ☐
(d) the height of the dam is less than 5 times the top width. ☐

59. If the allowable crushing strength is f, w is the unit weight of water and S is the specific gravity of the dam material, the limiting height of the low gravity dam is given by
(a) $H = \frac{f}{w(S+1)}$ ☐ (b) $H = \frac{f}{w(S-1)}$ ☐
(c) $H = \frac{f}{(w+S+1)}$ ☐ (d) $H = \frac{f}{(w+S-1)}$. ☐

60. The type of dam which can be raised easily, if required, is
(a) gravity dam ☐ (b) earth dam ☐
(c) arch dam ☐ (d) none of the above. ☐

61. For no tension to develop in the gravity dam the resultant of all the external forces should always lie
(a) at the centre of the base ☐
(b) within the middle third portion of the base ☐
(c) within the d/s third portion ☐
(d) with the u/s third portion. ☐

62. For no tension to develop in the gravity dam, the eccentricity of the resultant force should be
(a) $< \frac{b}{3}$ ☐ (b) $< \frac{b}{4}$ ☐
(c) $< \frac{b}{6}$ ☐ (d) $< \frac{b}{12}$. ☐

63. If H is the height of water to be stored, S is the specific gravity of the dam material and μ is the co-efficient of friction the base width of the elementary profile satisfying the condition of no tension is given by
(a) $\frac{H}{\mu . S}$ ☐ (b) $\frac{H}{\mu (S-1)}$ ☐
(d) $\frac{H}{\sqrt{S}}$ ☐ (d) $\frac{H}{\sqrt{S-1}}$. ☐

64. If the resultant falls outside the middle third for reservoir full condition the gravity dam may fail due to
(a) sliding ☐ (b) crushing ☐
(c) tension ☐ (d) over turning. ☐

65. The contraction joints in a gravity dam are provided
(a) to ensure proper transfer of stresses ☐
(b) to eliminate stress concentrations ☐

(*c*) to prevent cracks in the dam that may develop due to temperature changes ☐
(*d*) to facilitate the construction of dam in stages. ☐

66. The leakage through the joints in a gravity dam is prevented by providing
(*a*) keys ☐ (*b*) drainage galleries ☐
(*c*) water stops ☐ (*d*) all of the above. ☐

67. Which of the following is not a purpose of the drainage gallery
(*a*) intercepts the seepage through the dam and drains it off ☐
(*b*) facilitates the drilling and grouting operations ☐
(*c*) reduces the cost of structure ☐
(*d*) provides access for inspection. ☐

68. The most economical central angle of an arch dam is
(*a*) 33° ☐ (*b*) 93° ☐
(*c*) 183° ☐ (*d*) 133°. ☐

69. The example of multiple arch type Butress dam in India is
(*a*) Mir-Alam dam ☐ (*b*) Koyna dam ☐
(*c*) Idikki dam ☐ (*d*) Tunga Bhadra dam. ☐

70. In a homogeneous embankment type earth dam, the phreatic line is kept well within the body of the dam by
(*a*) providing proper u/s slope protection ☐
(*b*) providing proper d/s slope protection ☐
(*c*) suitably increasing the top width ☐
(*d*) providing horizontal drainage filter at the d/s face. ☐

71. Hydraulic failures of earth dams account for
(*a*) 40% of the total failures ☐ (*b*) 30% of the total failures ☐
(*c*) 50% of the total failures ☐ (*d*) 60% of the total failures. ☐

72. The purpose of the outer shells in a zoned embankment type earth dam is
(*a*) to reduce the seepage through the dam ☐
(*b*) to provide stability to the central core ☐
(*c*) to permit steep slopes for the u/s and d/s faces ☐
(*d*) to avoid cut off trench. ☐

73. The cut of trench in earth dams is provided
(*a*) to reduce the seepage through the dam ☐
(*b*) to reduce the seepage through the foundation ☐
(*c*) to increase the stability of the slopes ☐
(*d*) to reduce the dam section and economise. ☐

74. For reservoir full condition the upstream face of an earth dam is
(*a*) a stream line ☐
(*b*) an equipotential line ☐
(*c*) neither a stream line nor an equipotential line ☐
(*d*) an interface. ☐

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