ESE

Civil Engineering

Preliminary Examination

(Previous Years Solved Papers 1995-1999)

Volume-II

Contents

MADE EASY
PUBLICATIONS

UNIT

I

Fluid Mechanics & Hydraulic Machines

Syllabus

Fluid Mechanics, Open Channel Flow, Pipe Flow: Fluid properties; Dimensional Analysis and Modeling; Fluid dynamics including flow kinematics and measurements; Flow net; Viscosity, Boundary layer and control, Drag, Lift, Principles in open channel flow, Flow controls. Hydraulic jump; Surges; Pipe networks.

Hydraulic Machines and Hydro power: Various pumps, Air vessels, Hydraulic turbines–types, classifications & performance parameters; Power house–classification and layout, storage, pondage, control of supply.

Contents

1 Fluid Mechanics & Hydraulic Machines

1. Fluid Properties

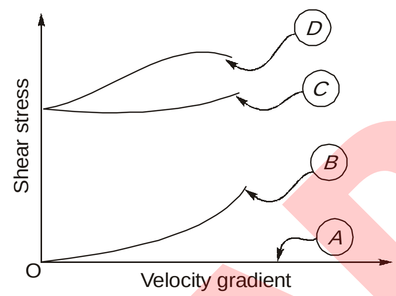
1.1 The surface tension of water at 20°C is 75×10^{-3} N/m. The difference in the water surfaces within and outside an open-ended capillary tube of 1 mm internal bore, inserted at the water surface would nearly be

(a) 5 mm (b) 10 mm
(c) 15 mm (d) 20 mm

[ESE : 1998]

1.2 Match **List-I** (Curves labelled *A*, *B*, *C* and *D* in figure) with **List-II** (Type of fluid) and select the correct answer using the codes given below the lists:

List-I



List-II

1. Ideal plastic
2. Ideal
3. Non-Newtonian
4. Thixotropic
5. Rheopectic

Codes:

	A	B	C	D
(a)	2	3	1	5
(b)	3	2	1	5
(c)	4	2	5	1
(d)	2	3	5	1

[ESE : 1999]

2. Manometry

2.1 If a hole is made in the Torricelli's vacuum portion of a barometer, then the mercury

(a) level will fall in the stem and the mercury will collect in the reservoir
(b) level will oscillate between reservoir level and original level of the mercury in the stem
(c) will spill through the hole made
(d) level in the stem will remain at the same level indicating atmospheric pressure

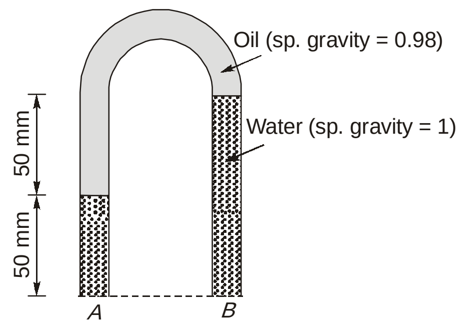
[ESE : 1995]

2.2 Which one of the following pressure units represents the LEAST pressure?

(a) millibar (b) mm of Hg
(c) N/mm^2 (d) kgf/cm^2

[ESE : 1997]

2.3 In the set-up shown in the given figure, assuming the specific weight of water as 10,000 N/m^3, the pressure difference between the points *A* and *B* will be



(a) 10 N/m^2 (b) –10 N/m^2
(c) 20 N/m^2 (d) –20 N/m^2

[ESE : 1999]

3. Hydrostatic Forces

3.1 As depth of immersion of a vertical plane surface increases, the location of centre of pressure

(a) comes closer to the centre of gravity of the area
(b) moves apart from the centre of gravity of the area
(c) ultimately coincides with the centre of gravity of the area

(d) remains unaffected

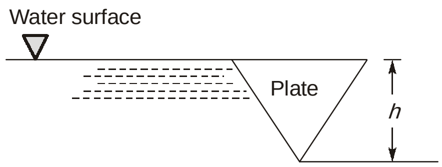
[ESE : 1995]

3.2 A vertical gate 6 m × 6 m holds water on one side with the free surface at its top. The moment about the bottom edge of the gate of the water force will be (γ_w is the specific weight of water)

(a) 18 γ_w (b) 36 γ_w
(c) 72 γ_w (d) 216 γ_w

[ESE : 1997]

3.3 An equilateral triangular plate is immersed in water as shown in the figure below. The centre of pressure below the water surface is at a depth of



(a) $\frac{3h}{4}$ (b) $\frac{h}{3}$
(c) $\frac{2h}{3}$ (d) $\frac{h}{2}$

[ESE : 1999]

4. Buoyancy & Floatation

4.1 A 10 m high rocket containing liquid fuel of specific gravity 1.2 lifts off at an acceleration of 5 g. The pressure on the bottom plate of the rocket during lift-off is

(a) 6.7 kgf/cm^2 (b) 7.2 kgf/cm^2
(c) 8.4 kgf/cm^2 (d) 8.9 kgf/cm^2

[ESE : 1995]

4.2 A symmetrical right-circular cone of wood floats in fresh water with axis vertical and the apex down. The axial height of the cone is 1 unit. The submerged portion has a height h, measured upwards from the apex. What would be the height of the centre of buoyancy from the apex?

(a) $\frac{h}{2}$ (b) $\frac{5}{8}h$
(c) $\frac{2}{3}h$ (d) $\frac{3}{4}h$

[ESE : 1998]

4.3 A homogeneous circular cylinder of length h, radius r and specific gravity S, floats in water. It is noted that $r = 2/3h$ Under which one of the following conditions will the flotation be unstable?

(a) $0.11 \le S < 0.22$ (b) $0.22 \le S < 0.33$
(c) $0.33 \le S < 0.66$ (d) $0.66 \le S \le 0.99$

[ESE : 1998]

5. Fluid Kinematics

5.1 Match **List-I** with **List-II** select the correct answer using the codes given below the lists:

List-I

A. Stream lines
B. Streak line
C. Path lines
D. Equipotential lines

List-II

1. Tracing of motion of any fluid particle
2. Tracing of motion of different fluid particles
3. Identification of location of number of fluid particles
4. Orthogonal to streak lines
5. Location of equal piezometric heads

Codes:

	A	B	C	D
(a)	2	3	4	5
(b)	3	2	1	4
(c)	1	2	4	3
(d)	2	3	1	5

[ESE : 1995]

5.2 The stream function for a two-dimensional flow is given by $\psi = 2xy$. The velocity at (2, 2) is

(a) $4\sqrt{2}$ (b) 4
(c) $2\sqrt{2}$ (d) $\sqrt{2}$

[ESE : 1995]

5.3 Consider the following parameters related to fluid flow:

1. Vorticity
2. Velocity potential
3. Stream function

Among these, those which exist both in rotational flows and irrotational flows should include

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 1995]

5.4 **Assertion (A):** $\psi = 14.14y - 10x$ represents uniform flow at an angle of 45° to the X-axis with a velocity of 24.14 units along the X-axis.

Reason (R): The velocity component is derivable from the appropriate sum of the partial derivatives.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

5.5 Given $\phi = 3xy$ and $\psi = \frac{3}{2}(y^2 - x^2)$, the discharge passing between the streamlines through the points (1, 3) and (3, 3) is

(a) 2 units (b) 4 units
(c) 8 units (d) 12 units

[ESE : 1996]

5.6 In a parallel two-dimensional flow in the positive x-direction, the velocity varies linearly from zero at $y = 0$ to 75 m/sec at $y = 1$ m. The expression for ψ is given by

(a) $22.5y^2$ (b) $30.0y^2$
(c) $37.5y^2$ (d) $45.0y^2$

[ESE : 1996]

5.7 Which of the following conditions will be satisfied by steady irrotational flow?

1. $\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} = 0$
2. $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = 0$
3. $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 1997]

5.8 **Assertion (A):** The following potential function in two-dimensional flow field represents irrotational flow $\phi = 2x^2 - 3y^2$

Reason (R): For the given function $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

5.9 In steady flow of a compressible fluid through a pipe, the density, area and velocity at a particular section are 1.5 kg/m^3, 0.5 m^2 and 3 m/s, respectively. At another section the density and area are 0.75 kg/m^3 and 1.0 m^2 respectively. What is the velocity at this section?

(a) 1.5 m/s (b) 3.0 m/s
(c) 4.5 m/s (d) 6.0 m/s

[ESE : 1998]

5.10 The velocity potential ϕ at any point for a two dimensional steady irrotational flow in polar co-ordinates, is given by (with usual notations) $\phi = \frac{m\cos\theta}{r}$

This equation represents a

(a) vortex (b) sink
(c) source (d) doublet

[ESE : 1998]

5.11 Which one of the following can be a set of velocity components of a two-dimensional flow?

(a) $u = x + y$ and $v = x^2 + y^2$
(b) $u = x + y$ and $v = x - y$
(c) $u = xy$ and $v = \frac{x}{y}$
(d) $u = x^2 + y^2$ and $v = x^2 - y^2$

[ESE : 1999]

5.12 For stream function $\psi = 3x^2 - y^3$, the magnitude of velocity at the point (2, 1) is

(a) 12.37 (b) 12
(c) 13 (d) 13.5

[ESE : 1999]

6. Fluid Dynamics, Flow Measurements

6.1 Which of the following pairs are correctly matched?

1. Piezometric head
...Sum of datum head and pressure head
2. Dynamic head
... Sum of datum head and velocity head
3. Stagnation head
...Sum of pressure head and velocity head

4. Total head
   ... Sum of piezometric head and dynamic head

Select the correct answer using the codes given below:

(a) 1, 2 and 3   (b) 1, 3 and 4
(c) 1, 2 and 4   (d) 2, 3 and 4

[ESE : 1995]

6.2 The flow of water in a wash hand basin when it is being emptied through a central opening, is an example of

(a) free vortex   (b) forced vortex
(c) rotational vortex   (d) Rankine vortex

[ESE : 1995]

6.3 In fluid flow, the line of constant piezometric head passes through two points which have the same

(a) elevation
(b) pressure
(c) velocity
(d) velocity potential

[ESE : 1995]

6.4 **Assertion (A):** Pressure intensity in a liquid flow is a form of energy.

Reason (R): The pressure gradient is a measure of the rate of energy dissipation in steady uniform flow.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

6.5 Two small orifices *A* and *B* of diameters 1 cm and 2 cm, respectively, are placed on the sides of a tank at depths of h_1 and h_2 below the open liquid surface. If the discharges through *A* and *B* are equal, then the ratio of h_1 and h_2 (assuming equal C_d values) will be

(a) 16 : 1   (b) 8 : 1
(c) 4 : 1   (d) 2 : 1

[ESE : 1997]

6.6 A right circular cylinder, open at the top, is full of water. It is rotated about the vertical axis at such a speed that half the liquid spills out. The pressure at the centre of the bottom would be

(a) one half of the original magnitude when the cylinder was full
(b) one-fourth of the original magnitude when the cylinder was full
(c) unchanged
(d) zero

[ESE : 1997]

6.7 A cylindrical vessel of radius 42.31 cm and height 1 m is open at the top. It holds water to half its depth. Which one of the following values approximates the speed at which the cylinder is to be rotated about the vertical axis, so as to make the apex of the paraboloid just reach the centre of the bottom of the vessel?

(a) 100 rpm   (b) 150 rpm
(c) 250 rpm   (d) 300 rpm

[ESE : 1998]

6.8 The coefficient of velocity for an orifice is given by (using usual notations)

(a) $\dfrac{x}{2\sqrt{yH}}$ (b) $\dfrac{2x}{\sqrt{yH}}$

(c) $\dfrac{x}{\sqrt{yH}}$ (d) $\sqrt{\dfrac{x^2}{2yH}}$

[ESE : 1998]

6.9 Match **List-I** (Name of instrument) with **List-II** (Variable measured) and select the correct answer using the codes given below the lists:

List-I

A. Hot-wire anemometer
B. Orifice meter
C. Pitot tube
D. Preston tube

List-II

1. Boundary shear stress
2. Discharge
3. Mean velocity
4. Pressure
5. Turbulence

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	5	2	3	4
(c)	2	5	1	3
(d)	5	2	3	1

[ESE : 1998]

7. Viscous Flow of Incompressible Fluid

7.1 Match **List-I** (Flow type) with **List-II** (Flow characteristics) and select the correct answer using the codes given below the lists:

List-I
A. Transient flow
B. Turbulent flow
C. Steady-state flow
D. Laminar flow

List-II
1. Seepage flow is a function of time
2. Hydraulic gradient varies with square of velocity
3. Flow at low velocity
4. Governing equation in 2-*D* is

$$k_x \frac{\partial^2 h}{\partial x^2} + k_y \frac{\partial^2 h}{\partial y^2} = 0$$

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	3	2	1	4
(c)	1	2	3	4
(d)	2	1	4	3

[ESE : 1996]

7.2 Laminar flow occurs between extensive stationary plates. The kinetic energy correction factor is nearly
(a) 1.0 (b) 1.5
(c) 2.0 (d) 2.3

[ESE : 1996]

7.3 In steady laminar flow of a liquid through a circular pipe of internal diameter *D*, carrying a constant discharge, the hydraulic gradient is inversely proportional to
(a) D (b) D^2
(c) D^4 (d) D^5

[ESE : 1996]

7.4 For laminar flow between parallel plates separated by a distance $2h$, head loss varies
(a) directly as h (b) inversely as h
(c) inversely as h^2 (d) inversely as h^3

[ESE : 1996]

7.5 The highest velocity (in cm/sec) for flow of water of viscosity 0.01 poise to be laminar in a 6 mm pipe is
(a) 100/3 (b) 125/3
(c) 50 (d) 200

[ESE : 1996]

7.6 For laminar flow in a pipe carrying a given discharge, the height of surface roughness is doubled. In such a case, Darcy-Weisbach friction factor will
(a) remain unchanged
(b) be halved
(c) be doubled
(d) increase fourfold

[ESE : 1997]

7.7 In laminar flow, local instability occurs first at a point where (symbols have the usual meaning)
(a) u is maximum
(b) du/dy is maximum
(c) $\rho\frac{uy}{\mu}$ is maximum
(d) $\dfrac{\rho y^2 \frac{du}{dy}}{\mu}$ is maximum

[ESE : 1997]

7.8 Given that, as flow takes place between two parallel static plates, the velocity midway between the plates is 2 m/s, the Reynolds number is 1200 and the distance between the plates is 10 cm, which of the following statements are true?
1. The velocity of the boundary is 1 m/s.
2. The rate of flow is 0.1 m^3/s/metre width.
3. The flow is turbulent.
4. The energy correction factor is 2.0.

Select the correct answer using the codes given below:
(a) 2 and 3 (b) 2 and 4
(c) 1 and 3 (d) 1, 2, 3 and 4

[ESE : 1997]

7.9 **Assertion (A):** If laminar flow of oil between two points of a given pipeline is doubled, then the power consumption is increased to four times the original power
Reason (R): In laminar flow through circular pipes, head loss varies directly as the discharge.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

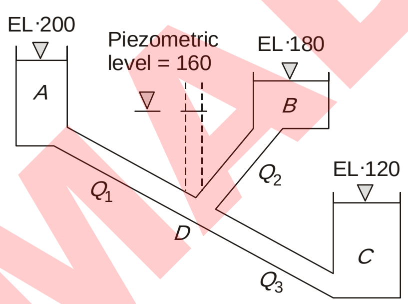
[ESE : 1998]

8. Flow Through Pipes

8.1 **Assertion (A):** A loss of head at a sudden contraction in a pipe is smaller than that at a sudden expansion.
Reason (R): When the flow contracts, it tends to become irrotational.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

8.2 Three reservoirs *A*, *B* and *C* are interconnected by pipes as shown in the given figure. Water surface elevations in the reservoirs and the piezometric level at the junction *D* are also indicated in the figure.



Flow Q_1, Q_2 and Q_3 are related as
(a) $Q_1 + Q_2 = Q_3$
(b) $Q_1 - Q_2 = Q_3$
(c) $Q_2 - Q_1 = Q_3$
(d) $Q_1 + Q_2 + Q_3 = 0$

[ESE : 1995]

8.3 The cavitation and pitting can be prevented by creating which one of the following conditions?
(a) Reducing the pressure head
(b) Reducing the velocity head
(c) Increasing the elevation head
(d) Reducing the piezometric head

[ESE : 1995]

8.4 The following parameters relate to flow in a penstock:
1. Water level in the reservoir
2. Density of water
3. Elasticity of water
4. Roughness of pipe

Pressure rise due to water in a penstock depends upon
(a) 1 and 2 (b) 2 and 3
(c) 2 and 4 (d) 1, 2, 3 and 4

[ESE : 1995]

8.5 Two reservoirs at different levels are connected by two parallel pipes of diameter '2*d*' and '*d*'. The ratio of the flows in the two pipes (larger: smaller) is
(a) $\sqrt{2}:1$ (b) $2:1$
(c) $4:1$ (d) $4\sqrt{2}:1$

[ESE : 1995]

8.6 A pipeline of 5 cm diameter is reduced abruptly to 2.5 cm diameter at a section to enable measurement of the water flowing through it. The loss of head at the contraction is 0.5 m. Given that, in metric units, $\sqrt{2g} = 4.43$ and $\sqrt{g} = 3.132$, the mean velocity in the reduced section will be
(a) 0.5 m/sec (b) 1.1075 m/sec
(c) 1.566 m/sec (d) 4.43 m/sec

[ESE : 1996]

8.7 Consider the following statements:
A horizontal pipe reduces from 10 cm to 5 cm in diameter. If the pressure head at 10 cm section is 10 metres and velocity head is 1 metre, then the
1. total head at any point is 11 metres
2. pressure head at the 5 cm section is negative
3. discharge varies proportionate to the diameter
4. datum head at all sections is constant

Which of these statements is/are correct?
(a) 1, 2 and 4 (b) 1 and 3
(c) 4 alone (d) 1, 2, 3 and 4

[ESE : 1996]

8.8 A penstock is 2000 m long and the velocity of pressure wave in it is 1000 m/s. Water hammer pressure head for instantaneous closure of valve at the downstream end of pipe is 60 m. If the valve is closed in 4 sec, then the peak water hammer pressure head is equal to

(a) 15 m (b) 30 m
(c) 60 m (d) 120 m

[ESE : 1996]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

8.9 **Assertion (A):** Loss of head at a sudden expansion of a pipe is larger than that at a sudden contraction.

Reason (R): Separation of flow occurs at sudden contractions.

[ESE : 1997]

8.10 **Assertion (A):** In the equation $h_f = f\frac{L}{d}\frac{V^2}{2g}$, for laminar flow through the pipe, the term V (mean velocity of flow) is given by $V = \frac{(p_1 - p_2)r^2}{8\mu L}$

Reason (R): The term 'f' (friction factor) in the above equation equals $\frac{64}{\text{Re}}$ where Re is the Reynolds number.

[ESE : 1998]

8.11 The loss of head at various pipe fittings is given by the expression $K\frac{v^2}{2g}$. If values of K were 0.40, 0.90, 1.5 and 2.2, then these would correspond respectively to

(a) foot valve of pump, 45° elbow, 90° elbow and close return bend
(b) 45° elbow, 90° elbow, foot valve of pump and close return bend
(c) 90° elbow, foot valve of pump, close return bend and 45° elbow
(d) foot valve of pump, close return bend, 45° elbow and 90° elbow

[ESE : 1998]

8.12 A pipe network consists of a pipe of 60 cm diameter and branches out at a point T into two branches, one of 30 cm diameter and the other of 45 cm diameter. These branch pipes rejoin at a point B. The velocity in the first branch (of 45 cm diameter) is 1.5 m/sec. Which one of the following statements is true?

(a) The velocity in the second branch is 1.0 m/sec.
(b) The velocity in the second branch is 2.25 m/sec.
(c) The velocity in the second branch is $\frac{2}{3}$ (= 0.667) m/sec.
(d) The potential drop between T and B in both branches is the same.

[ESE : 1998]

8.13 Which of the following statements are true in relation to water hammer phenomenon?

1. It causes surface erosion in pipes.
2. The pressure rise is given by ρCU for sudden closure of valve.
3. It is accompanied by serious cavitation.
4. The volume modulus of fluid is the relevant fluid property.
5. It is governed by the Reynolds number of the flow.

Select the correct answer using the codes given below:

(a) 3 and 5 (b) 2 and 4
(c) 2 and 5 (d) 1, 2, 3 and 4

[ESE : 1998]

8.14 The friction factor (f), in terms of boundary shear stress (τ_0) is given by (ρ = mass density, V = mean velocity)

(a) $\frac{2\rho V^2}{\tau_0}$ (b) $\frac{\tau_0}{2\rho V^2}$

(c) $\frac{2\tau_0}{\rho V^2}$ (d) $\frac{\rho V^2}{2\tau_0}$

[ESE : 1998]

8.15 Assertion (A): Water flows through a pipe connecting two reservoirs. The line joining the water surface levels in the reservoirs is the hydraulic gradient.

Reason (R): There will be no negative gauge pressure anywhere in the pipeline, as long as the pipeline lies below the hydraulic gradient.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

8.16 A compound pipe (new cast iron) system consists of pipes of length 1800 m and diameter 50 cm, length 1200 m and diameter 40 cm and length 600 m and diameter 30 cm connected in series. The equivalent length of 40 cm diameter pipe will be nearly

(a) 4300 m (b) 4400 m
(c) 4500 m (d) 3600 m

[ESE : 1999]

8.17 Consider the following statements:
In order to have cavitation,

1. local velocity is increased so that the local pressure is decreased below vapour pressure
2. elevation is kept so high that the local pressure reduces below vapour pressure
3. general ambient pressure is increased to a very high magnitude
4. water hammer must occur in the system

Which of these statements are correct?

(a) 2 and 3 (b) 3 and 4
(c) 1 and 2 (d) 1 and 4

[ESE : 1999]

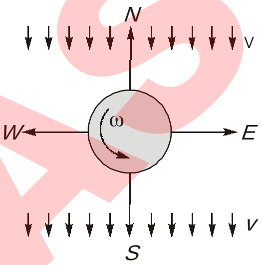
9. Drag and Lift Force

9.1 A sphere of certain diameter, when towed submerged under water, experiences a drag force of 4 N at a velocity of 1.5 m/s. If another sphere of twice the diameter of the sphere referred to above, is towed with the same velocity in water, the drag force experienced by this sphere will be

(a) 8 N (b) 16 N
(c) 24 N (d) 32 N

[ESE : 1995]

9.2 A circular cylinder held in uniform flow from north to south as shown in the figure, is rotated about its own axis in an anticlockwise direction. It will experience a lift force in the direction of



(a) N (b) S
(c) E (d) W

[ESE : 1995]

9.3 The overall drag coefficient of an aircraft of weight W and wing area S is given by

$$C_D = a + bC_L^2$$

where 'a' and 'b' are constants. The maximum drag in horizontal flight will be

(a) $W\sqrt{ab}$ (b) $2W\sqrt{ab}$
(c) $4W\sqrt{ab}$ (d) $6W\sqrt{ab}$

[ESE : 1996]

9.4 If Stokes' law is considered valid below a Reynolds number of unity, then the largest raindrop that will fall in accordance with this law will have a diameter of approximately
(assuming ρ_w = 1000 kg/m^3,
ρ_a = 1.3 kg/m^3, $\nu_w = 10^{-6}$ m^2/s,
$\nu_a = 1.5 \times 10^{-5}$ m^2/s)

(a) 0.75 mm (b) 0.3 mm
(c) 0.15 mm (d) 0.075 mm

[ESE : 1996]

9.5 In the Stoke's experiment of falling sphere, it is found that a sphere of 5 mm diameter falls in a liquid with terminal velocity 20 mm/s giving a drag coefficient of 240. The ratio of specific gravities is 2.85. Which one of the following is the kinematic viscosity of the liquid in stokes?

(a) 3.5 (b) 10.0
(c) 225.0 (d) 1000.0

[ESE : 1998]

9.6 A ping-pong ball, having a diameter of 3.6 cm and weighing 2.4 g is served with a horizontal velocity of 10 m/sec and a spin that gives rise to a coefficient of lift of 0.2. Assuming the density of air to be 0.00129 gf/cc, the lift experienced by the ball is nearly

(a) 13 gf (b) 1.3 gf
(c) 0.13 gf (d) 0.013 gf

[ESE : 1998]

10. Boundary Layer Theory

10.1 Assertion (A): Flow in the boundary layer is always laminar.

Reason (R): In turbulent flow on a smooth boundary, a laminar sublayer still exists within the boundary layer.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

10.2 The relative thickness (δ/x) of turbulent boundary layer on a flat plate

(a) decreases with distance (x)
(b) increases with distance (x)
(c) remains constant
(d) depends on relative roughness

[ESE : 1996]

10.3 The ratio of the coefficient of friction drag in laminar boundary layer compared to that in turbulent boundary layer is proportional to

(a) $R_L^{1/2}$ (b) $R_L^{1/5}$
(c) $R_L^{3/10}$ (d) $R_L^{-3/10}$

[ESE : 1996]

10.4 The displacement thickness of a boundary layer is

(a) the distance to the point where $(v/V) = 0.99$
(b) the distance where the velocity 'v' is equal to the shear velocity V_*, that is, where $v = V_*$
(c) the distance by which the main flow is to be shifted from the boundary to maintain the continuity equation
(d) one half the actual thickness of the boundary layer

[ESE : 1997]

11. Turbulent Flow

11.1 Which of following conditions would entail a greater energy dissipation in turbulent flow?

1. Smaller eddy size
2. Lower viscosity
3. Large intensity of turbulence

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2

[ESE : 1995]

11.2 Shear velocity is

(a) a non-dimensional quantity
(b) the velocity of fluid at the edge of laminar sublayer
(c) a fictitious quantity
(d) the velocity of fluid at the edge of roughness element

[ESE : 1995]

11.3 With increasing ageing of pipes, the proportion between the maximum velocity and mean velocity

(a) initially decreases and then increases
(b) initially increases and then decreases
(c) decreases
(d) increases

[ESE : 1996]

11.4 Match **List-I** (Flow phenomenon) with **List-II** (Associated equation/principle) and select the correct answer using the codes given below the lists:

List-I

A. Turbulent flow
B. Laminar flow

C. Lift on an aerofoil
D. Boundary layer

List-II

1. Circulation
2. Momentum integral equation
3. Mixing length
4. Hagen Poiseuille equation

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	4	1	2	3
(c)	3	4	1	2
(d)	1	2	3	4

[ESE : 1997]

12. Dimensional Analysis & Model Analysis

12.1 Match **List-I** (Non-dimensional numbers) with **List-II** (Application) and select the correct answer using the codes given below the lists:

List-I

A. Mach Number
B. Thoma Number
C. Reynolds Number
D. Weber Number

List-II

1. Waves in an ocean
2. Launching of rockets
3. Cavitation phenomenon
4. Capillary flow in soil
5. Motion of a submarine

Codes:

	A	B	C	D
(a)	1	3	5	2
(b)	3	2	4	1
(c)	2	3	5	4
(d)	2	1	3	4

[ESE : 1995]

12.2 A model of a weir made to a horizontal scale of 1/40 and vertical scale of 1/9 discharges 1 *l*ps. Then the discharge in the prototype is estimated as
(a) 1 *l*ps (b) 108 *l*ps
(c) 1080 *l*ps (d) 10800 *l*ps

[ESE : 1996]

12.3 There are four variables, namely, E (volume modulus of elasticity), p (pressure per unit area), g (acceleration due to gravity) and μ (viscosity of water). They are associated with Mach, Euler, Froude and Reynolds numbers, respectively, in the order
(a) E, p, μ, g (b) p, E, μ, g
(c) p, E, g, μ (d) E, p, g, μ

[ESE : 1997]

12.4 **Assertion (A):** In Rayleigh's method of dimensional analysis, the dependent variable is written as the function of exponential terms of independent variables.

Reason (R): In Rayleigh's method, when the number of independent variables exceeds three, the exponents of non-repeating variables are expressed as the exponents of repeating variables.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

12.5 Water having kinematic viscosity of 0.01 stokes flows at a velocity of 2 m/sec in a pipe of 15 cm diameter. For dynamic similarity, the velocity of oil of kinematic viscosity 0.03 stoke in a pipe of same diameter will be
(a) 0.33 m/sec (b) 0.66 m/sec
(c) 2 m/sec (d) 6 m/sec

[ESE : 1998]

12.6 In the model of a highway bridge constructed to a scale of 1 : 25, the force of water on the pier was measured to be 0.5 kg. The force on the prototype pier will be
(a) 7501.5 kg (b) 7622.5 kg
(c) 7812.5 kg (d) 7916.5 kg

[ESE : 1998]

13. Notches and Weirs

13.1 An error of 0.5% in the measurement of head in a V-notch causes an error of
(a) 0.5% in the discharge
(b) 1.0% in the discharge
(c) 1.25% in the discharge
(d) 1.5% in the discharge

[ESE : 1995]

14. Impact of Jets and Turbines

14.1 A pumped storage plant is a
(a) high head plant (b) run-off river plant
(c) peak load plant (d) base load plant
[ESE : 1995]

14.2 If the discharge is Q in a pipe fitted with an end cap nozzle discharging a jet of water with velocity V and hitting normally a plate which is moving with a velocity $V/2$ towards the nozzle, then the jet would hit the plate with a discharge of
(a) $0.5Q$ (b) Q
(c) $1.5Q$ (d) $2Q$ [ESE : 1995]

14.3 **Assertion (A):** The specific speed of a Pelton wheel is generally much less than that of a reaction turbine.
Reason (R): Pelton wheels generally use more than one nozzle and the specific speed is defined for power developed per nozzle.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1996]

14.4 A turbine works at 20 m head and 500 rpm speed. Its 1 : 2 scale model to be tested at a head of 20 m should have a rotational speed of nearly
(a) 1000 rpm (b) 700 rpm
(c) 500 rpm (d) 250 rpm
[ESE : 1996]

14.5 The correct sequence, in the direction of the flow of water for installation in a hydropower plant is
(a) reservoir, surge tank, turbine, penstock
(b) reservoir, penstock, surge tank, turbine
(c) reservoir, penstock, turbine, surge tank
(d) reservoir, surge tank, penstock, turbine
[ESE : 1997]

14.6 In a 2-jet Pelton wheel working at full load, the jets are issuing from nozzles (so shaped as to avoid any further contraction of jets) of 10 cm diameter. The load is suddenly reduced to 36% of full load. The altered jet diameter shall be
(a) 1.8 cm (b) 3.0 cm
(c) 3.6 cm (d) 6.0 cm
[ESE : 1997]

14.7 Match **List-I** (Types of turbines) with **List-II** (Ranges of specific speed in MKS units) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Francis	**1.** 10 – 35
B. Kaplan	**2.** 35 – 60
C. Pelton with jet	**3.** 60 – 300
D. Pelton with two jet	**4.** 300 – 1000

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	3	1	2

[ESE : 1998]

14.8 **Assertion (A):** The inlet velocity triangle for Pelton turbine is a straight line.
Reason (R): For a Pelton turbine, the vane angle at inlet is 180°.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

14.9 To generate 10,000 HP under a head of 81 m while working at a speed of 500 rpm, the turbine of choice would be
(a) Pelton (b) Kaplan
(c) Bulb (d) Francis
[ESE : 1999]

14.10 Consider the following statements:
1. Run-of-river plants can be located on any river.
2. Runaway speed of a turbine is generally 180% of normal speed.
3. Underground power stations are suited to area susceptible to landslides.
4. Higher the specific speed, higher will be the discharge and head.

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4
[ESE : 1999]

14.11 Match **List-I** (Turbine) with **List-II** (Specific speed) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Pelton	1. 25
B. Propeller	2. 75
C. Kaplan	3. 500
D. Francis	4. 800
	5. 900

Codes:

	A	B	C	D
(a)	1	4	5	2
(b)	3	4	2	5
(c)	4	1	5	3
(d)	1	5	4	2

[ESE : 1999]

15. Pumps

15.1 When two identical centrifugal pumps are operating in series on a common rising main, then
(a) the pressure in the rising main will be nearly doubled, while discharge will remains same
(b) the discharge will be nearly doubled, while the pressure remains the same
(c) discharge as well as the pressure in the rising main will be doubled
(d) discharge as well as the pressure in the rising main will increase but not become double

[ESE : 1995]

15.2 Which one of the following statements regarding reciprocating pump is correct?
(a) Friction head is mainly responsible for causing cavitation in a reciprocating pump at the beginning of the suction stroke.
(b) Effect of acceleration pressure on reciprocating pumps appears parabolic and has the maximum effect at the middle of the delivery stroke.
(c) Air vessels reduces the acceleration head and consequently reduces the effect of friction head also.
(d) The maximum permissible suction lift in a double acting reciprocating pump is independent of vapour pressure.

[ESE : 1996]

15.3 The velocity at the test section of water tunnel is controlled by varying the speed of a propeller pump to increase the speed by 50%, it would be necessary to increase power to approximately
(a) 125% (b) 275%
(c) 350% (d) 400%

[ESE : 1997]

15.4 Match **List-I** (Pump) with **List-II** (Requirement) and select the correct answer using the codes given below the lists:

List-I
A. Multistage centrifugal pump of moderate sized impellers
B. Archimedean screw type pump
C. Simple reciprocating pump
D. Axial flow propeller pump

List-II
1. High head and low discharge
2. Low head and large discharge
3. High head and moderate discharge
4. Low head and low discharge

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	1	2
(c)	4	3	2	1
(d)	3	4	2	1

[ESE : 1998]

15.5 **Assertion (A):** By providing air vessels on the suction and delivery side of the pump, it is possible to increase the delivery head of the pump.
Reason (R): The air vessel eliminates the acceleration head and makes discharge uniform.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

15.6 Two identical centrifugal pumps are operated in parallel so as to deliver into a common delivery pipe. Speed for both is also identical. At what total discharge (Q) and total head (H) will the system operate as compared to discharge and head of each of the pumps operated singly?

(a) Both total Q and total H would increase, each approximately by 50%.
(b) Total Q would be approximately doubled, but H would remain the same.
(c) Total H would be approximately doubled, but Q would remain the same.
(d) Total H would be doubled, but Q would be approximately halved.

[ESE : 1998]

15.7 **Assertion (A):** Inlet side of a pump is less susceptible to cavitation damage.
Reason (R): Cavitation occurs when the velocity is high and pressure is low.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

15.8 The maximum permissible suction lift for centrifugal pump in practice (at sea level and at 30°C) is
(a) 12 m (b) 10 m
(c) 6 m (d) 3 m

[ESE : 1999]

15.9 Consider the following statements:
1. Pumps in series operation allow the head to increase.
2. Pumps in series operation increase the flow rate.
3. Pumps in parallel operation increase the flow rate.
4. Pumps in parallel operation allow the head to increase.

Which of these statements are correct?
(a) 1 and 3 (b) 1 and 4
(c) 2 and 4 (d) 3 and 4

[ESE : 1999]

15.10 A commonly used handpump is the
(a) centrifugal pump
(b) reciprocating pump
(c) rotary pump
(d) axial flow pump

[ESE : 1999]

15.11 Match **List-I** (Pump) with **List-II** (Requirement) and select the correct answer using the codes given below the lists:

List-I
A. Multistage centrifugal pump of moderate sized impellers
B. Archimedean screw type pump
C. Simple reciprocating pump
D. Axial flow propeller pump

List-II
1. High head and low discharge
2. Low head and large discharge
3. High head and moderate discharge
4. Low head and low discharge

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	1	2
(c)	4	3	2	1
(d)	3	4	2	1

[ESE : 1999]

16. Open Channel Flow

16.1 Match **List-I** (Hydraulic structure) with **List-II** (Water surface profile at the structure) and select the correct answer using the codes given below the lists:

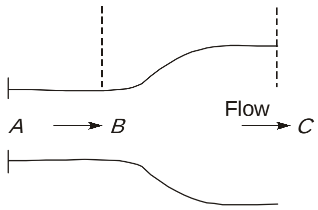
List-I	List-II
A. On a flat topped broad-crested weir	1. M_1
B. Immediately below a sluice gate on a level apron	2. M_2
C. Behind the weir on an alluvial river	3. S_1
D. In a chute spillway	4. S_2
	5. H_2
	6. H_3

Codes:

	A	B	C	D
(a)	5	6	1	4
(b)	4	6	2	1
(c)	2	5	6	4
(d)	5	4	1	3

[ESE : 1995]

16.2 The given figure shows a subcritical open channel flow expansion (*BC* in the figure) of rectangular cross-section. With respect to the water level in the flume (*A* in the figure), water level in the expansion *BC* will



(a) fall
(b) not change
(c) rise
(d) first rise and then fall

[ESE : 1995]

16.3 Which one of the following is analogous to normal shock wave?
(a) An elementary wave in a still liquid
(b) Hydraulic jump
(c) Flow of liquid through an expanding nozzle
(d) Sub-critical flow in an open-channel

[ESE : 1995]

16.4 Though Manning's formula is dimensionally non-homogeneous, it is commonly used in practice because
(a) it is in simple form
(b) it was derived from extensive field data
(c) it can be made dimensionally homogeneous
(d) it can be related to Chezy's coefficient or Darcy-Weisbach's friction factor

[ESE : 1995]

16.5 For flow under a sluice gate where the upstream depth is 1.2 m and the depth at vena-contracta is 0.3 m, the discharge per metre width would be nearly
(a) 0.36 m^3/s (b) 1.5 m^3/s
(c) 1.7 m^3/s (d) 4.0 m^3/s

[ESE : 1996]

16.6 In an open channel of wide rectangular section with constant 'n' value, the bed slope is 1.2×10^{-3}, the local friction slope at a section is 1.05×10^{-3}, the local Froude number of the flow is 0.8. The local rate of variation of depth with longitudinal distance along the flow direction is

(a) $\dfrac{1.2-1.05}{1-0.8}\times10^{-3}$ (b) $\dfrac{-1.2-1.05}{1-0.8}\times10^{-3}$

(c) $\dfrac{1.2+1.05}{1-0.64}\times10^{-3}$ (d) $\dfrac{1.2-1.05}{1-0.64}\times10^{-3}$

[ESE : 1996]

16.7 Before passage of a surge, the depth and velocity of flow at a section are 1.8 m and 3.72 m/s and, after passage, they are 0.6 m and 7.56 m/s respectively. The speed of the surge is
(a) +1.8 m/s (b) –2.7 m/s
(c) +3.6 m/s (d) –4.5 m/s

[ESE : 1996]

16.8 A channel bed slope 0.0009 carries a discharge of 30 m^3/s when the depth of flow is 1.0 m. What is the discharge carried by an exactly similar channel at the same depth of flow if the slope is decreased to 0.0001?
(a) 10 m^3/s (b) 15 m^3/s
(c) 60 m^3/s (d) 90 m^3/s

[ESE : 1997]

16.9 At a hydraulic jump, the depths at the two sides are 0.4 m and 1.4 m. The head loss in the jump is nearly
(a) 1.0 m (b) 0.9 m
(c) 0.7 m (d) 0.45 m

[ESE : 1997]

16.10 Which one of the following pairs relating to flumes carrying open channel flow is correctly matched?
(a) Non-modular flume
... Flow is unaffected by drowning
(b) Venturi flume
... Standing wave forms at the throat
(c) Venturi flume
... Flow at the throat is at less than critical velocity
(d) Standing wave flume
... Hump is not provided at the throat

[ESE : 1997]

16.11 Assertion (A): A hydraulic jump cannot be expected on a long steep slope (fed by a large reservoir) when it is followed by a short reach of adverse slope termination in vertical drop into a deep and wide reservoir.
Reason (R): The terminal depth is such an adverse slope reach will be critical and the flow in the steep slope may be nearly at or at normal depth.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

16.12 Which one of the following pairs is NOT correctly matched (b = bottom width, y = depth of flow, θ = side slope with vertical)?
(a) For least perimeter of rectangular canal section
... $b = 2y$
(b) For least perimeter of trapezoidal canal section
... $b = 2y\,(\sec\theta - \tan\theta)$
(c) For critical flow through rectangular canal
... $v = gy$
(d) For critical flow through trapezoidal canal
... $v = \sqrt{\dfrac{gy(b + y\tan\theta)}{\beta + 2y\tan\theta}}$

[ESE : 1998]

16.13 A rectangular open channel carries a discharge of 15 m^3/s when the depth of flow is 1.5 m and the bed slope is 1 : 1440. What will be the discharge through the channel at the same depth if the slope would have been 1 : 1000?
(a) 21.6 m^3/s (b) 18 m^3/s
(c) 14.4 m^3/s (d) 12.5 m^3/s

[ESE : 1998]

16.14 A trapezoidal section of a channel is 2 m wide at base and the side slopes are 1H to $1\frac{1}{2}$V. It carries a water discharge of 7 m^3/sec at a depth of 1 m. Consider the specific force comprising $(\rho QV + \gamma A\bar{y})$. For an increase of 2 cm of depth, what would be the change in the magnitude of the second term $(\gamma A\bar{y})$?
(a) –35 kgf (b) +35 kgf
(c) +70 kgf (d) +140 kgf

[ESE : 1998]

16.15 Storage of water by impounding is required where
(a) plenty of water is available in the stream in all seasons
(b) excess of suspended and dissolved matter are present in the water
(c) there is a large variation in quantity of the river flow from time to time.
(d) the flow is uniform throughout the year but is insufficient.

[ESE : 1998]

16.16 The height of a hydraulic jump in a stilling pool was found to be 10 cm in a model with L_p/L_m = 36. The prototype jump height would be
(a) 0.6 m
(b) 3.6 m
(c) 21.6 m
(d) Indeterminable for want of adequate data

[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

16.17 Assertion (A): In a venturi flume, the specific energy values at the normal and throat sections are always individually constant, whether the flow in the normal section is subcritical or supercritical.
Reason (R): In a canal transition formed by providing a 'hump' the total energy is constant at both the sections irrespective of the type of flow in the normal section.

[ESE : 1999]

■■■■

Answers Fluid Mechanics & Hydraulic Machines

1.1 (c)	1.2 (a)	2.1 (a)	2.2 (a)	2.3 (b)	3.1 (a)	3.2 (d)	3.3 (d)	4.1 (b)
4.2 (d)	4.3 (c)	5.1 (d)	5.2 (a)	5.3 (c)	5.4 (d)	5.5 (d)	5.6 (c)	5.7 (b)
5.8 (d)	5.9 (b)	5.10 (d)	5.11 (b)	5.12 (a)	6.1 (b)	6.2 (a)	6.3 (c)	6.4 (b)
6.5 (a)	6.6 (d)	6.7 (a)	6.8 (a)	6.9 (d)	7.1 (a)	7.2 (b)	7.3 (c)	7.4 (d)
7.5 (a)	7.6 (a)	7.7 (d)	7.8 (a)	7.9 (a)	8.1 (c)	8.2 (a)	8.3 (b)	8.4 (d)
8.5 (d)	8.6 (d)	8.7 (a)	8.8 (c)	8.9 (b)	8.10 (a)	8.11 (b)	8.12 (d)	8.13 (b)
8.14 (c)	8.15 (d)	8.16 (a)	8.17 (c)	9.1 (b)	9.2 (d)	9.3 (b)	9.4 (d)	9.5 (b)
9.6 (b)	10.1 (d)	10.2 (a)	10.3 (d)	10.4 (c)	11.1 (c)	11.2 (c)	11.3 (d)	11.4 (c)
12.1 (c)	12.2 (c)	12.3 (d)	12.4 (b)	12.5 (d)	12.6 (c)	13.1 (c)	14.1 (c)	14.2 (c)
14.3 (c)	14.4 (a)	14.5 (b)	14.6 (d)	14.7 (c)	14.8 (c)	14.9 (d)	14.10 (b)	14.11 (a)
15.1 (a)	15.2 (c)	15.3 (b)	15.4 (b)	15.5 (b)	15.6 (b)	15.7 (d)	15.8 (c)	15.9 (a)
15.10 (b)	15.11 (b)	16.1 (a)	16.2 (c)	16.3 (b)	16.4 (b)	16.5 (b)	16.6 (d)	16.7 (a)
16.8 (a)	16.9 (d)	16.10 (c)	16.11 (a)	16.12 (c)	16.13 (b)	16.14 (a)	16.15 (c)	16.16 (b)
16.17 (c)								

Explanations Fluid Mechanics & Hydraulic Machines

1. Fluid Properties

1.1 (c)

In this problem, the bore is not defined properly

$$h = \frac{2\sigma\cos\theta}{\rho g R}$$

Cosider $\theta = 0°$ for water with glass surface

$d = 1 \times 2 = 2$ mm

$$= \frac{4 \times 75 \times 10^{-3}}{2 \times 10^{-3} \times 9.81 \times 1000} = 0.015 \text{ m} = 15 \text{ mm}$$

1.2 (a)

The curve (A), horizontal line representing zero shear stress for any velocity gradient is the condition for ideal fluid.

The curve B represents dilatant fluid.

$$\tau = \mu\left(\frac{du}{dy}\right)^n \qquad n > 1$$

For pseudoplastic fluid,

$$\tau = \mu\left(\frac{du}{dy}\right)^n \qquad n < 1$$

For thixotropic fluid,

$$\tau = \tau_0 + \mu\left(\frac{du}{dy}\right)^n \qquad n < 1$$

For rheopectic fluid,

$$\tau = \tau_0 + \mu\left(\frac{du}{dy}\right)^n \qquad n > 1$$

For ideal plastic fluid,

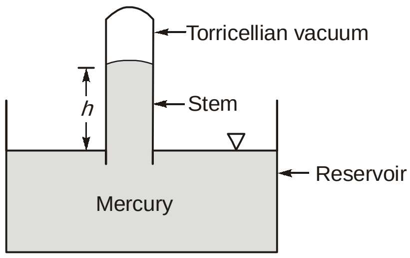
$$\tau = \tau_0 + \mu\left(\frac{du}{dy}\right) \qquad n = 1$$

2. Manometry

2.1 (a)

Barometer measures the atmospheric pressure.

$$p_{atm} = \rho_{Hg}\, gh$$



If there is a hole in the vacuum portion, then there will be zero pressure difference at top and bottom of the stem. The mercury in the stem will show zero reading i.e. it will fall and get collected in the reservoir.

2.2 (a)

$$\begin{aligned} 1 \text{ atm} &= 10.1 \text{ m of water} \\ &= 760 \text{ mm of Hg} \\ &= 1013 \text{ millibar} \\ &= 101.3 \text{ kPa} \\ &= 1.013 \text{ kgf/cm}^2 \\ &= 0.1013 \text{ N/mm}^2 \text{ (MPa)} \end{aligned}$$

$$1 \text{ millibar} = \frac{1}{1013} \text{atm}$$

$$1 \text{ mm Hg} = \frac{1}{760} \text{atm}$$

$$1 \text{ N/mm}^2 = \frac{1}{0.1013} \text{atm}$$

$$1 \text{ kgf/cm}^2 = \frac{1}{1.013} \text{atm}$$

From the above relation, it is clear that

1 millibar < 1 mm Hg < 1 kgf/cm^2 < 1 N/mm^2

2.3 (b)

The equation for pressure at B is

$$p_A - \rho_w gh - \rho_{oil} gh + 2\rho_w gh = p_B$$

$$\therefore \quad p_A - p_B = \rho_{oil} gh - \rho_w gh$$

$$= (0.98 - 1) \times 10000 \times 0.05$$

$$= -10 \text{ N/m}^2$$

3. Hydrostatic Forces

3.1 (a)

$$\bar{h}_{cp} = \bar{h} + \frac{I_{Gxx} \sin^2\theta}{\bar{h} A}$$

or $$\bar{h}_{cp} - \bar{h} = \frac{I_{Gxx} \sin^2\theta}{\bar{h} A}$$

$$\left(\frac{I_{Gxx} \sin^2\theta}{A} = \text{Constant}\right)$$

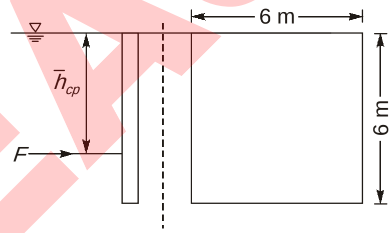
$$\bar{h}_{cp} - \bar{h} = \frac{\text{Constant}}{\bar{h}}$$

At the depth of surface increases $\bar{h}$ increases

so $\left(\bar{h}_{cp} - \bar{h}\right)$ decreases.

It means centre of pressure comes closer to centroid.

3.2 (d)



Moment of hydrostatic force about bottom edge

$$= F \times \left[6 - \bar{h}_{cp}\right]$$

$$= \rho g \bar{h} A (6 - 4) \quad \left\{\bar{h}_{cp} = \frac{2}{3} \times 6 = 4\,\text{m}\right\}$$

$$= \gamma_w \left(\frac{6}{2}\right)(6 \times 6)(2)$$

$$= 216\,\gamma_w$$

3.3 (d)

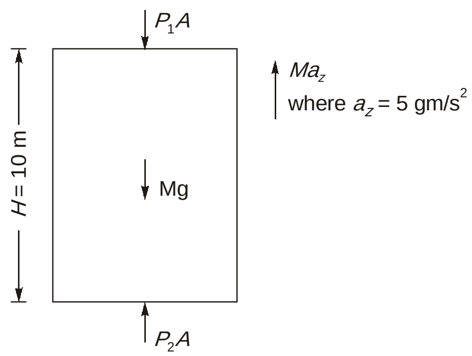
$$\bar{h}_{cp} = \bar{h} + \frac{I_{Gxx} \sin^2\theta}{\bar{h} A}$$

$$= \frac{h}{3} + \frac{\frac{h.h^3}{36} \sin^2 90}{\frac{h}{3} \times \left[\frac{1}{2} \times h \times h\right]}$$

$$= \frac{h}{3} + \frac{\frac{h^4}{36}}{\frac{h^3}{6}} = \frac{h}{3} + \frac{h}{6} = \frac{h}{2}$$

4. Buoyancy & Floatation

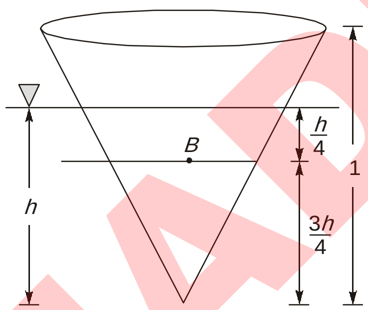
4.1 (b)



Force analysis

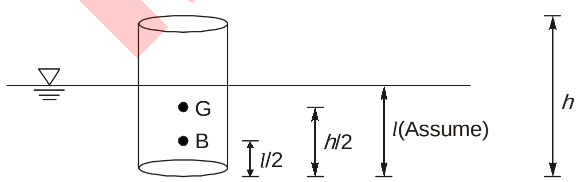
$$(P_2 - P_1)\,A - Mg = Ma_z \qquad (P_1 = 0)$$
$$P_2A = M(a_z + g)$$
$$P_2A = \rho(AH)\,(a_z + g)$$
$$P_2 = 1.2\,(10)\,(5g + g)\text{ N/m}^2$$
$$= 1.2 \times 10 \times 6g\text{ N/m}^2$$
$$= 72g\text{ N/m}^2$$
$$= 7.2\text{ kgf/cm}^2$$

4.2 (d)



The centre of buoyancy from the water surface is $h/4$. So centre of buoyancy from apex is $3h/4$.

4.3 (c)



Given: $r = \frac{2}{3}h$

For unstable condition

$$GM < 0$$

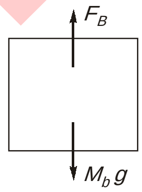
$$\frac{I}{\forall_{Displaced}} - BG < 0$$

$$\frac{\frac{\pi r^4}{4}}{(\pi r^2)\,l} - \frac{1}{2}(h - l) < 0$$

$$\frac{r^2}{4l} - \frac{1}{2}(h - l) < 0$$

$$\frac{r^2}{2l} - h + l < 0 \qquad \text{...(i)}$$

Force analysis



$$\rho_b \forall_b \cancel{g} = \rho_b \forall_{Dis} \cancel{g}$$
$$\rho_b(\pi r^2 h) = \rho(\pi r^2 l)$$
$$\frac{\rho_b}{\rho}h = l$$
$$Sh = l$$

By eq. (i)

$$\frac{r^2}{2Sh} - h + Sh < 0 \qquad \left(r = \frac{2}{3}h\right)$$

$$\frac{\frac{4}{9}h^2}{2Sh} - h + Sh < 0$$

$$\frac{2h}{9S} - h + Sh < 0$$

$$2h - 9Sh + 9S^2h < 0$$
$$9S^2 - 9S + 2 < 0$$
$$(S - 0.33)\,(S - 0.66) < 0$$
$$0.33 < S < 0.66$$

5. Fluid Kinematics

5.1 (d)

- **Streamlines:** It indicates the direction of motion of number of fluid particles at the same instant.
- **Streak line:** It is the locus of different particles passes through a fixed point at an instant. Hence it gives identification of location of number of fluid particles at an instant.
- **Path line:** It is the actual path traced by a fluid particle over a period of time.
- **Equipotential line:** These are the lines along which piezometric heads are constant.

5.2 (a)

$$u = -\frac{\partial \psi}{\partial y} = -2x$$

and $$v = \frac{\partial \psi}{\partial x} = 2y$$

At point (2, 2)

$u = -4$ units and $v = 4$ units

$$\therefore \quad V = \sqrt{u^2 + v^2}$$

$$= \sqrt{(-4)^2 + (4)^2}$$

$$= 4\sqrt{2}\text{ units}$$

5.3 (c)

Velocity potential function can not be defined for rotational flow.

5.4 (d)

$$\psi = 14.14y - 10x$$

$$u = -\frac{\partial \psi}{\partial y} = -14.14 \text{ units}$$

Hence assertion (A) is wrong.

5.5 (d)

$$\phi = 3xy$$

$$\psi = \frac{3}{2}\left(y^2 - x^2\right)$$

At (1, 3) $\psi_1 = \frac{3}{2}(3^2 - 1^2) = 12$ units

At (3, 3) $\psi_2 = \frac{3}{2}\left(3^2 - 3^2\right) = 0$ units

$$Q_{\text{per unit with}} = |\psi_2 - \psi_1|$$

$$\therefore \quad Q = 12 - 0 = 12 \text{ units}$$

5.6 (c)

The velocity $u = 75\,y$

Using $$\frac{\partial \psi}{\partial y} = 75y$$

int.it $$\psi = 37.5y^2$$

5.7 (b)

For steady irrotational flow vorticity will be zero and continuity equation will be satisfied.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad \text{[continuity equation]}$$

$$\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = 0 \quad \text{[zero vorticity]}$$

5.8 (d)

$$\phi = 2x^2 - 3y^2$$

ϕ must satisfy Laplace eq. Here

$$\nabla^2\phi = 4 - 6 \neq 0$$

So ϕ function is not valid here.

So assertion (A) is wrong.

5.9 (b)

Continuity equation for fluid flow is

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$(1.5)\,(0.5)\,(3) = (0.75)\,(1)\,V_2$$

$$V_2 = \frac{1.5 \times 0.5 \times 3}{0.75 \times 1} = 3\text{m/s}$$

5.10 (d)

Flow type	Stream function (ψ)	Velocity potential (ϕ)
A. Vortex (free)	$-\frac{\Gamma}{2\pi} \ln r$	$\frac{\Gamma}{2\pi}\theta$
B. Sink	$-\frac{q}{2\pi}\theta$	$-\frac{q}{2\pi} \ln r$
C. Source	$\frac{q}{2\pi}\theta$	$\frac{q}{2\pi} \ln r$
D. Doublet	$-\frac{m\sin\theta}{r}$	$\frac{m\cos\theta}{r}$

5.11 (b)

Option (b) statisfy the continuity equation of 2D flow.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$\frac{\partial}{\partial x}(x + y) + \frac{\partial}{\partial y}(x - y) = 0$$

$$1 - 1 = 0$$

$$0 = 0$$

5.12 (a)

$$u = -\frac{\partial \psi}{\partial y} = 3y^2 = 3\text{units}$$

$$v = \frac{\partial \psi}{\partial x} = 6x = 12\text{units}$$

$$V = \sqrt{u^2 + v^2} = 12.37 \text{ units}$$

6. Fluid Dynamics, Flow Measurements

6.1 (b)

Statement 1 is correct.

Piezometric head : $\dfrac{P}{\rho g} + z$

Statement 2 is wrong.

Dynamic head : $\dfrac{V^2}{2g}$

Statement 3 is correct.
Stagnation head also includes velocity head
Statement 4 is wrong.

$$\text{Total head} = \underbrace{\frac{P}{\rho g} + z}_{\text{Piezometric head}} + \underbrace{\frac{V^2}{2g}}_{\substack{\text{Kinetic head}\\ \text{or}\\ \text{Dynamic head}}}$$

6.2 (a)

Free vortex flow is irrotational flow and total head (energy) remains constant throughout flow field.

6.3 (c)

According to Bernoulli's equation the sum of piezometric head and velocity head remains constant. So for constant piezometric head line passing through two points, the velocity will remain same.

6.5 (a)

C_d, Q is same

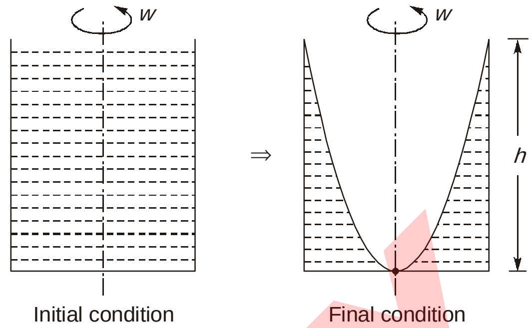
$$C_d a_1 \sqrt{2gh_1} = C_d a_2 \sqrt{2gh_2}$$

$$\frac{h_1}{h_2} = \left(\frac{a_2}{a_1}\right)^2$$

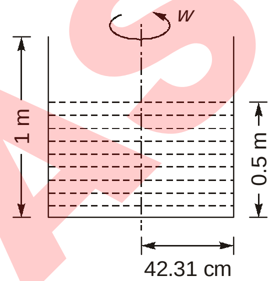
$$= \left[\frac{\frac{\pi}{4}(2)^2}{\frac{\pi}{4}(1)^2}\right]^2 = \frac{16}{1}$$

6.6 (d)

If a right circular cylinder, open at the top, is full ofwater is rotated a such a speed that half of the liquid spillout then the free surface will touch the bottom at the centre. So at that point Gauge pressure is zero.



6.7 (a)



$$z = \frac{\omega^2 r^2}{2g}$$

$$0.5 + 0.5 = \frac{\omega^2 (0.4231)^2}{2g}$$

$$\omega = 10.47 \text{ rad/s}$$

$$\frac{2\pi N}{60} = 10.47$$

$$N = 99.98 \text{ rpm}$$

6.8 (a)

Coefficient of velocity can be determined by Jet distance measurement method

$$C_v = \frac{x}{\sqrt{4Hy}} = \frac{x}{2\sqrt{Hy}}$$

6.9 (d)

Hot water Anemometer: It is a device used to measure instantaneous velocity at any point in the flow. It can be used to study the fluctuation in turbulent flows.

Orifice meter: It is a cheap device used for the measurement of discharge.

Pitot tube: It is a device used for the measurement of velocity.

Preston tube: It is used for measurement of boundary shear stress.

7. Viscous Flow of Incompressible Fluid

7.1 (a)

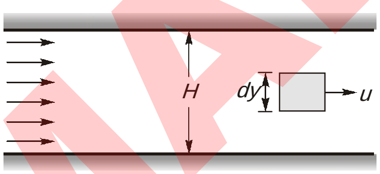
Transient flow, is flow where the flow velocity and pressure are changing with time. When changes occur to a fluid systems such as the starting or stopping of a pump, closing or opening a valve, or changes in tank levels, then transient flow conditions exist: otherwise the system is steady state.

Turbulent flow, type of fluid flow in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow, in which the fluid moves in smooth paths or layers. In turbulent flow the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction.

Steady-state flow refers to the condition where the fluid properties at any single point in the system do not change over time. These fluid properties include temperature, pressure, and velocity.

Laminar flow (or streamline flow) occurs when a fluid flows in parallel layers, with no disruption between the layers. At low velocities, the fluid tends to flow without lateral mixing, and adjacent layers slide past one another.

7.2 (b)



$d\dot{m} = \rho\,(dy1)\,u$

Assume width = 1

$$u = -\frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)(Hy - y^2)$$

Kinetic energy correction factor (α)

$$\alpha = \frac{\int_0^H \frac{1}{2} d\dot{m} u^2}{\frac{1}{2}\dot{m}\bar{u}^2} = \frac{\int_0^H \rho(dy1)u.u^2}{\rho(H.1)\bar{u}.\bar{u}^2}$$

$$= \frac{\int_0^H u^3 dy}{H\bar{u}^3}$$

where $\bar{u} = -\frac{1}{12\mu}\left(\frac{\partial P}{\partial x}\right)H^2$

$$= \frac{\int_0^H \left[-\frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)(Hy - y^2)\right]^3 dy}{H\left[-\frac{1}{12\mu}\left(\frac{\partial P}{\partial x}\right)H^2\right]^3}$$

$$= \frac{\left(\frac{1}{2}\right)^3 H}{\left(\frac{1}{12}\right)^3 H^7}\int_0^H (Hy - y^3)^3\, dy$$

$$= 1.543$$

7.3 (c)

For Laminar flow through pipe.

Hagen-Poiseuille's eq.

$$h_f = \frac{32\mu\bar{u}L}{\rho g D^2}, \quad Q = \left[\frac{\pi}{4}D^2\right].\bar{u}$$

or $$h_f = \frac{128}{\pi}\frac{\mu Q L}{\rho g D^4}$$

Hydraulic gradient

$$\frac{h_f}{L} = \frac{128}{\pi}\frac{\mu Q}{\rho g D^4}$$

$$\frac{h_f}{L} \propto \frac{1}{D^4} \qquad (Q = \text{constant})$$

$$h_f = \frac{12\mu\bar{u}L}{\rho g(2h)^2} \qquad \left(\bar{u} = \frac{Q}{2h1}\right)$$

7.4 (d)

For parallel plates

Head loss,

$$h_f = \frac{12\mu\bar{U}L}{\rho g(2h \times 1)^2}$$

$$h_f = \frac{12\mu QL}{\rho g(2h)^3} \qquad (Q = \text{constant})$$

$$h_f \propto \frac{1}{h^3}$$

7.5 (a)

For Laminar pipe flow critical Reynolds number,

$$Re_{cr} = 2000$$

$$= \frac{\rho VD}{\mu} = 2000$$

$$\therefore \quad \frac{(10^3)V(0.006)}{0.01 \times 10^{-1}} = 2000$$

$$V = \frac{100}{3} \text{ cm/sec}$$

7.6 (a)

For laminar pipe flow Darcy-Weisbach, friction factor only depends on Reynolds Number.

$$f = \frac{64}{\text{Re}}$$

So friction factor remains same if k_s is doubled.

7.7 (d)

The stability of the flow at a given location would by influenced by the velocity gradient $\frac{du}{dy}$, mass density ρ, viscosity μ and the wall distance y at the location.

Rouse combined these qualities to form a dimensionless parameter, known as stability parameter $\chi = \dfrac{y^2 \rho \frac{du}{dy}}{\mu}$

Obviously, smaller the viscosity μ or greater the numerator or this parameter, greater will be the local instability.

7.8 (a)

- For stationary plates, the velocity at boundary is zero. So statement 1 is incorrect.
- For Laminar flow between parallel plates, the kinetic enegy convection factor (α) is 1.54 and for Turbulent flow, kinetic energy factor is lesser than the Laminar flow. So α should be less than 1.54. Hence statement 4 is incorrect.

7.9 (a)

For Lamina pipe flow Hagen-Poiseuille equation

$$h_f = \frac{32\mu VL}{\rho g D^2} = \frac{128}{\pi}\frac{\mu QL}{\rho g D^4}$$

$$h_f \propto Q$$

So, statement 2 is correct.

Power consumption

$$= \dot{m} g h_f$$

$$= \rho Q g (C h_f) \qquad (C = \text{constant})$$

$$= C \rho g Q^2$$

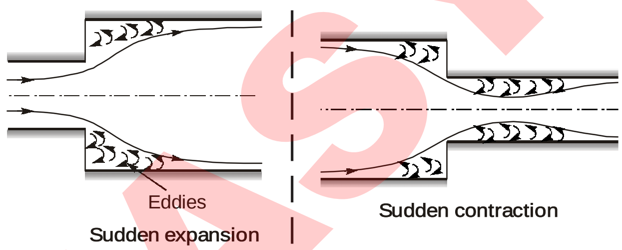
Power consumption $\propto Q^2$

If the discharge is doubled then power consumption is increased to four times the original power.

So, statement 1 is correct.

8. Flow Through Pipes

8.1 (c)



- The head loss in both the above cases is due to eddies formation but the intensity is more in case of sudden expansion.
  So statement 1 is correct.
- In sudden contraction, eddies are formed so flow becomes rotational.
  So statement 2 is incorrect.

8.2 (a)

The direction of flow can be determined from head difference as the flow occurs from high head to low head.

Piezometric head at A > Piezometric level at D so flow Q_1 is from A toward D.

Piezometric head at B > Piezometric level at D so flow Q_2 is from B towards D.

Piezometric head at C < Piezometric level at D so flow Q_3 is from D towards C.

$$\therefore Q_1 + Q_2 = Q_3$$

8.3 (b)

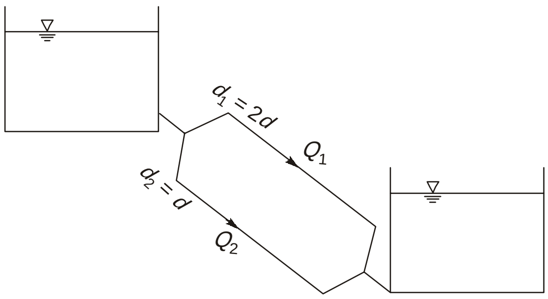
Cavitation occurs due to pressure falling below vapour pressure. Reducing the velocity head will increase pressure head and cavitation can be prevented.

8.4 (d)

Pressure rise due to water in penstock is given by $P = \rho VC$.

As the flow velocity depends on roughness of pipe, reservoir's water level, density of water and modulus of elasticity of water. Pressure rise due to water in penstock is affected by all these parameters.

8.5 (d)



For parallel pipes, head loss is same

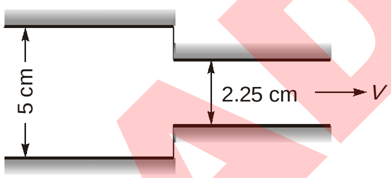
$$\frac{8Q_1^2}{\pi^2 g}\frac{fL}{d_1^5} = \frac{8Q_2^2}{\pi^2 g}\frac{fL}{d_2^5}$$

$$\frac{Q_1^2}{d_1^5} = \frac{Q_2^2}{d_2^5}$$

$$\frac{Q_1}{Q_2} = \left(\frac{d_1}{d_2}\right)^{5/2}$$

$$\frac{Q_1}{Q_2} = \left(\frac{2d}{d}\right)^{5/2} = 4\sqrt{2}$$

8.6 (d)



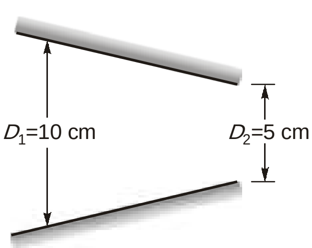
Given: $h_L = 0.5$ m

$$0.5\frac{V^2}{2g} = 0.5$$

$$0.5\frac{V^2}{(4.43)^2} = 0.5$$

$$V = 4.43 \text{ m/s}$$

8.7 (a)



Given: $\frac{P_1}{\rho g} = 10$ m, $\frac{V_1^2}{2g} = 1$ m

- Since the pipe is horizontal so datum is same for all the points.
  Assume centre line as datum.
  So, $z = 0$
- Total head at section 1

$$= \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1$$

$$= 10 + 1 + 0$$

$$= 11 \text{ m}$$

So statement 1 is correct.

- Apply energy equation between (i) and (ii)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

Apply continuity

$$A_1V_1 = A_2V_2$$

$$(4A_2)\, V_2 = A_2V_2$$

$$V_2 = 4V_1$$

So, $$\frac{V_2^2}{2g} = \frac{16V_1^2}{2g}$$

$$= 16 \times 1$$

$$= 16$$

$$10 + 1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$11 = \frac{P_2}{\rho g} + 16$$

$$\frac{P_2}{\rho g} = -5$$

Statement 2 is correct.

- Q is constant.
  So statement 3 is wrong.

8.8 (c)

We know that critical time is given by

$$T_0 = \frac{2L}{C}$$

$$\Rightarrow \quad T_0 = \frac{2 \times 2000}{1000}$$

$$\Rightarrow \quad T_0 = 4 \text{ s.}$$

Actual time for valve closure, $T = 4$s.

We know that if $T \le T_0$, then the closure is known as rapid closure or instantaneous closure. Therefore the peak water hammer pressure will be equal to the water hammer pressure head for instantaneous closure of the valve at the downstream end i.e. 60 m.

8.9 (b)

Both the statements are correct but not right explanations.

8.10 (a)

According to Darcy-Weisbach, for Laminar flow through pipe head loss is

$$h_f = \frac{fLV^2}{2gD} \qquad \left(\text{where } f = \frac{64}{\text{Re}}\right)$$

Then, $$h_f = \frac{32\mu VL}{\rho g D^2}$$

For horizontal pipe flow

$$\frac{P_1 - P_2}{\rho g} = \frac{32\mu VL}{\rho g D^2}$$

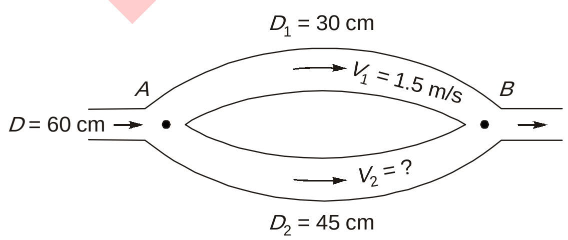
$$V = \frac{(P_1 - P_2)D^2}{32\mu L} \qquad (D = 2R)$$

$$V = \frac{(P_1 - P_2)R^2}{8\mu L}$$

8.11 (b)

Fitting type	K-value
45° elbow	0.4
90° elbow	0.9
Pump foot valve	1.5
Close return bend	2.2
Gate valve wide open	0.2
Globe valve wide open	10

8.12 (d)



For parallel connection

$$h_{f_1} = h_{f_2}$$

- So statement 4 is correct.

Now, $$\frac{fLV_1^2}{2gD_1} = \frac{fLV_2^2}{2gD_2}$$

Assume length (L) and friction factor (f) is same for both the pipes.

$$\frac{V_1^2}{D_1} = \frac{V_2^2}{D_2}$$

$$\frac{(1.5)^2}{30} = \frac{V_2^2}{45}$$

$$V_2 = 1.23 \text{ m/s}$$

- So statement (a), (b) and (c) is wrong.

8.13 (b)

Water hammer is a transient flow condition and it is governed by Euler's model. The velocity of pressure wave.

$$C = \sqrt{\frac{k/\rho}{1 + \dfrac{Dk}{Et}}}$$

Where E is the volume modulus of fluid

E_p is modulus of elasticity of pipe

d, t are diameter and thickness of pipe respectively

8.14 (c)

$$\sqrt{\frac{\tau_0}{\rho}} = V^* = V\sqrt{\frac{f}{8}}$$

where

V = Mean velocity of pipe flow

τ_0 = Wall shear stress

f = Friction factor

V^* = Shear velocity

$$\sqrt{\frac{\tau_0}{\rho}} = V\sqrt{\frac{f}{8}}$$

$$\frac{\tau_0}{\rho} = V^2 \times \frac{4f'}{8} \qquad (f = 4f')$$

f' = Friction coefficient

$$f' = \frac{2\tau_0}{\rho V^2}$$

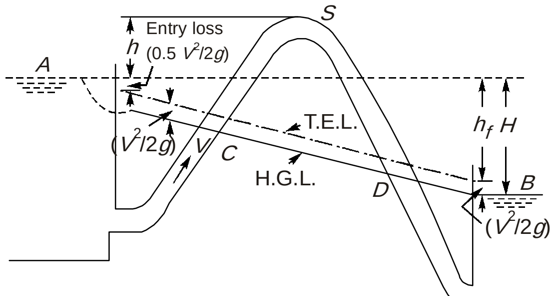
Note: In this problem friction factor is asked but actually options are given for coefficient of friction.

8.15 (d)

- Assertion is wrong.
  HGL is not properly defined at the entrance loss at the upstream of reservoir.

- Reason is correct.

  Because pressure is negative where the pipe line is above to HGL. (Example pressure at point in the diagram)



Siphon

8.16 (a)

The equivalence of head loss in compound pipe and equivalent pipe is the basis for finding the equivalent length.

$$\frac{L_1}{D_1^5}+\frac{L_2}{D_2^5}+\frac{L_3}{D_3^5}=\frac{L_e}{D_e^5}$$

$$\therefore L_e=\left[\frac{1800}{(50)^5}+\frac{1200}{(40)^5}+\frac{600}{(30)^5}\right]\times(40)^5$$

$$= 4318.2 \text{ m}$$

8.17 (c)

Cavitation is the formation of liquid free zones such as vapour bubbles or voids in a flowing liquid where pressure falls below vapour pressure. When subjected to high pressure, the bubbles collapse. Increase in local velocity or high elevation can cause local pressure to reduce below vapour pressure and cause cavitation.

9. Drag and Lift Force

9.1 (b)

$$F_D = C_D \times A \times \frac{1}{2}\times \rho \times V^2$$

(Since sufficient data is not given, Assume C_D = Constant.)

Then $F_D \propto A$

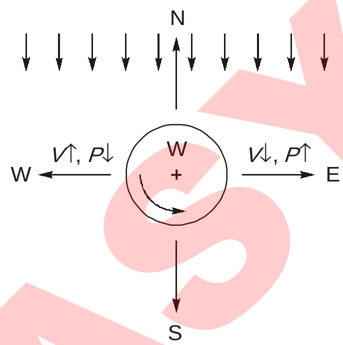
$F_D \propto D^2$

$$\frac{F_{D_1}}{F_{D_2}} = \left(\frac{D_1}{D_2}\right)^2$$

$$\frac{F_{D_1}}{F_{D_2}} = \left(\frac{D}{2D}\right)^2$$

$$F_{D_2} = 4F_{D_1} = 4\times 4 = 16 \text{ N}$$

9.2 (d)



So lift force from *E* to *W* side due to magnus effect.

9.3 (b)

The lift force, $F_L = C_L S\left(\frac{\rho V^2}{2}\right)$ ...(i)

The drag force, $F_D = C_D S\left(\frac{\rho V^2}{2}\right)$ ...(ii)

The weight of aircraft shall be equal to the lift force

$$C_L S\left(\frac{\rho V^2}{2}\right) = W$$

Now eq. (i) and (ii) becomes

$$F_L = W$$

$$F_D = C_D \frac{W}{C_L}$$

or $$F_D = \left(\frac{C_D}{C_L}\right)W$$

Drag force will be maximum when $\frac{C_D}{C_L}$ is maximum

Given $$C_D = a + bC_L^2$$

$$\therefore \quad \frac{C_D}{C_L} = \frac{a}{C_L} + bC_L$$

$$\frac{d(C_D/C_L)}{dC_L} = -\frac{a}{C_L^2}+b=0$$

$$C_L = \sqrt{(a/b)}$$

$$\therefore \text{ Maximum drag } = \left[\frac{a}{\sqrt{a/b}} + b\sqrt{a/b}\right]W$$

$$= 2W\sqrt{ab}$$

9.4 (d)

The weight of rain drop,

$$W = \rho_w\left(\frac{\pi D^3}{6}\right)g$$

The drag force,

$$F_D = 3\pi\,\mu_{air}\,DV = 3\pi(\rho_a\nu_a)\,DV$$

where V is the termimal velocity.

$$F_D = W$$

$$3\pi(\rho_a\nu_a)DV = \rho_w\left(\frac{\pi D^3}{6}\right)g$$

$$\therefore \quad V = \frac{\rho_w D^2 g}{18\rho_a\nu_a} \quad \text{...(i)}$$

By eq. (i) for largest raindrop, Re = 1

$$\text{Re} = \frac{VD}{\nu_a} = \left(\frac{\rho_w D^2 g}{18\rho_a(\nu_a)}\right)\frac{D}{\nu_a}$$

$$\therefore \frac{\rho_w D^3 g}{18\rho_a(\nu_a)^2} = 1.0$$

$$\Rightarrow \quad D = \left[\frac{18\rho_a(\nu_a)^2}{\rho_w g}\right]^{1/3}$$

$$= \left[\frac{18\times 1.3\times(1.5\times 10^{-5})^2}{1000\times 10}\right]^{1/3}$$

$$= 0.081 \text{ mm}$$

9.5 (b)

$$\text{Drag coefficient, } C_D = \frac{24}{\text{Re}}$$

$$\text{Given, } \quad C_D = 240$$

$$240 = \frac{24}{\text{Re}}$$

$$\text{Re} = \frac{1}{10}$$

$$\frac{VD}{\nu} = \frac{1}{10}$$

$$\frac{(0.02)(0.005)}{\nu} = \frac{1}{10}$$

$$\nu = 10^{-3} \text{ m/s} = 10 \text{ stokes}$$

9.6 (b)

$$\text{Lift force, } F_L = C_L A_p \frac{\rho V^2}{2}$$

$$= 0.2\times\frac{\pi\times(3.6)^2}{4}\times\frac{0.00129\times(1000)^2}{2}$$

$$= 1.3 \text{ gf}$$

10. Boundary Layer Theory

10.1 (d)

Statement 1 is wrong.

Since the flow in the boundary layer over a flat plate remain Laminar upto Reynold's number 5×10^5. After wards the flow becomes transition and then turbulent.

10.2 (a)

$$\frac{\delta}{x} = \frac{0.376}{\text{Re}_x^{1/5}}$$

As x increases, Re_x increases.

So $\frac{\delta}{x}$ decreases with x.

10.3 (d)

$$\text{Laminar boundary layer, } \bar{C}_{f_L} = \frac{1.328}{\text{Re}_L}$$

$$\text{Turbulent boundary layer, } \bar{C}_{f_T} = \frac{0.074}{\text{Re}_L^{1/5}}$$

$$\therefore \quad \frac{\bar{C}_{f_L}}{\bar{C}_{f_T}} = 17.95\,\text{Re}_L^{-3/10}$$

10.4 (c)

The displacement thickness of a boundary layer is the distance by which main flow should be shifted in order to compensate for decrease in velocity in the *boundary layer* and to maintain the continuity equation.

11. Turbulent Flow

11.1 (c)

In turbulent flow:

- Smaller eddy size – This means the wave size will be shorter which leads to smaller energy loss.
- Lower Viscosity – This implies smaller laminar sublayer. Boundary will behave as hydrodynamically rough boundary.

The eddies will thus come in contact with the surface irregularities and large amount of energy loss will take place.

- Larger intensity of turbulence – Larger losses.

11.2 (c)

Shear velocity, $V^* = \sqrt{\frac{\tau_o}{\rho}}$

where ρ_0 = wall shear stress

The dimensions of shear velocity is LT^{-1}

The shear velocity is used for scaling velocity in laminar sublayer. It is a fictitious quantity.

11.3 (d)

$$\frac{u_{max}}{\bar{u}} = 1.43\sqrt{f} + 1$$

For both smooth and rough pipes, the friction factor (f) increases with ageing. So ratio $\frac{u_{max}}{\bar{u}}$ also increases.

12. Dimensional Analysis & Model Analysis

12.1 (c)

Waves in an ocean are governed by Froude number.

12.2 (c)

When vertical and horizontal scales are different, the model is called distorted model.

$$Q_r = (L_{rH})(L_{rV})^{3/2}$$

$$= \left(\frac{1}{40}\right)\left(\frac{1}{9}\right)^{3/2}$$

$$\frac{Q_m}{Q_p} = \frac{1}{1080}$$

$$\frac{1}{Q_p} = \frac{1}{1080}$$

$$Q_p = 1080 \text{ Lps}$$

12.3 (d)

$$\text{Mach number} = \frac{V}{\sqrt{E/\rho}}$$

$$\text{Euler number} = \frac{V}{\sqrt{\frac{P}{\rho}}}$$

$$\text{Froude number} = \frac{V}{\sqrt{gy}}$$

$$\text{Reynolds number} = \frac{\rho VL}{\mu}$$

12.5 (d)

For dynamic similarity. Reynolds model law will be used.

$$Re = \frac{V_1 D}{\nu_1} = \frac{V_2 D}{\nu_2}$$

$$V_2 = 2 \times \frac{0.03}{0.01} = 6 \text{ m/s}$$

12.6 (c)

In this case Froude model law is applicable.

Force ratio, $F_r = \rho_r L_r^3 g_r$

$\rho_r = 1$

$g_r = 1$

$F_r = L_r^3$

$$\frac{F_m}{F_p} = \left(\frac{1}{25}\right)^3$$

$$\frac{0.5}{F_p} = \left(\frac{1}{25}\right)^3$$

$$F_p = 7812.5 \text{ kg}$$

13. Notches and Weirs

13.1 (c)

Error in discharge measurement,

(i) for a V-notch $\frac{dQ}{Q} = 2.5\frac{dH}{H}$

$= 2.5 \times 0.5 = 1.25\%$

(ii) for rectangular notch $\frac{dQ}{Q} = 1.5\frac{dH}{H}$

14. Impact of Jets and Turbines

14.1 (c)

A pumped storage plant generates power during peak hours, but during the off-peak hours water is pumped back. They are peak load plants and use reversible turbines which can be medium head or high head.

14.2 (c)

Relative velocity of plate with respect to jet

$$V_r = \frac{V}{2} + V = 1.5V$$

$$\text{Force, } F = \rho A V_r . V_r = 2.25\rho V^2$$

Therefore, the discharge with which water is striking plate is $1.5Q$.

14.3 (c)

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

where P = Total power developed

14.4 (a)

We know that

$$\left(\frac{DN}{\sqrt{H}}\right)_m = \left(\frac{DN}{\sqrt{H}}\right)_P$$

$$\frac{1}{2} = \frac{500}{N_m}$$

$$N_m = 1000 \text{ rpm}$$

14.5 (b)

Reservoir - Penstock - Surge tank - Turbine

The surge tank is open to atmosphere and connected to penstock. It should be as close as possible to the power house (turbine).

14.6 (d)

Power developed $P \propto Q \propto d^2$ where d is the diameter of the jet.

$$\frac{P_1}{P_2} = \frac{d_1^2}{d_2^2}$$

$$\frac{100}{36} = \frac{10^2}{d_2^2}$$

$$d_2 = 6 \text{ cm}$$

14.7 (c)

Specific speed of Kaplan > Francis > Pelton with two jets > Pelton with single jet.

14.8 (c)

For Pelton turbine, $\alpha = 0°$ and $\theta = 0°$.

14.9 (d)

$$\text{Specific speed} = \frac{N\sqrt{P}}{H^{5/4}} = \frac{500 \times \sqrt{10000}}{(81)^{5/4}}$$

$$= 205.76 \quad \text{(in MKS)}$$

14.10 (b)

Run of the river plants are those which utilize the flow as it comes without any storage being provided. These plants would be feasible only on such river which have minimum dry weather flow. Higher specific speed means higher discharge but lower head and smaller size of runner.

14.11 (a)

Turbine type	Specific Speed
Pelton	10-60
Francis	60-300
Kaplan	300-1000
Propeller	300-1000

15. Pumps

15.1 (a)

When two pumps operate in series, discharge remains same and head produced is doubled and if they operate in parallel, discharge is doubled and head remains the same.

15.2 (c)

In a reciprocating pump, at the beginning of suction stroke the pressure head will be $(H_s + H_{as}) + h_{fs}$ below the atmospheric pressure. However the head loss due to friction (h_{fs}) is very small compared to sum of suction head and head due to acceleration ($H_a + H_{as}$).

Effect of acceleration pressure on reciprocating pump is linear with maximum effect at the start of suction or delivery stoke.

15.3 (b)

As $\qquad P \propto N^3$

Then if speed is increased by 50% then new speed will be 1.5 N.

$$\%\text{change in power} = \frac{(1.5N)^3 - N^3}{N^3} \times 100$$

$$= 237.5\% \simeq 275\%$$

15.5 (b)

Air vessels are used to obtain uniform rate of flow in both suction and delivery pipes of a reciprocating pump. It increases the delivery head but reduction of suction head increases danger of cavitation.

15.6 (b)

When two identical pumps are connected in parallel, volume flow rate(discharge) is doubled, head remains constant.

15.7 (d)

As the liquid flows through the rotating impeller it receives energy from the vanes which results in an increase in both pressure and velocity energy. The cavitation is likely to occur at the inlet to the pump i.e. suction side.

15.9 (a)

Pumps in parallel: individual volume flow rates are added, head remains constant.

Pumps in series: total head is sum of individual pump heads.

15.11 (b)

Multistage centrifugal pump of moderate sized impeller can be used to produce high head if connected in series (i.e., on the same shaft) for discharging large quantity of water they can be connected in parallel.

16. Open Channel Flow

16.2 (c)

By expanding the width, discharge per unit width (q) in a rectangular channel will decrease. For subcritical flow depth of flow in expansion BC will rise continuously.

16.3 (b)

The flow on upstream of the shock is supersonic having a relatively lower pressure while on the downstream of the shock it is subsonic having a high pressure. The process of formation of shock wave in a compressible fluid is analogous to the formation of hydraulic jump in open channel. In case of hydraulic jump the flow changes from supercritical to subcritical flow and is accompanied by an increase in depth and decrease in the velocity of flow.

16.4 (b)

Manning's equation $V = \frac{1}{n} R^{2/3} S_0^{1/2}$ has the dimensions of roughness coefficient n as $[L^{-1/3}T]$. Owing to its simplicity and **acceptable degree of accuracy in a variety of practical applications**, the formula is the most widely used uniform-flow formula in the world. It represents rough turbulent flow.

16.5 (b)

$$q = \frac{\sqrt{2g}\, y_1 y_2}{\sqrt{y_1 + y_2}} = \frac{4.43 \times 1.2 \times 0.3}{\sqrt{(1.2 + 0.3)}} = 1.30$$

This is nearly equal to 1.5 m^3/s/m

16.6 (d)

The equation for GVF is

$$\frac{dy}{dx} = \frac{S_0 - S_f}{\left(1 - F^2\right)}$$

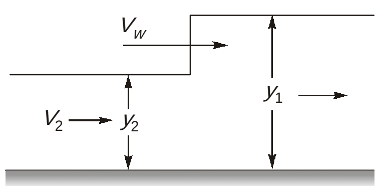
Given $S_0 = 1.2 \times 10^{-3}$

$S_f = 1.05 \times 10^{-3}$

$$\frac{dy}{dx} = \left[\frac{1.2 - 1.05}{1 - (0.8)^2}\right] \times 10^{-3}$$

16.7 (a)

A surge is a moving wavefront which brings about an abrupt change in the depth of the channel.



As there is decrease in the depth and increase in depth and increase in velocity of flow after passage of surge so it means the surge is negative and travels downstream.

$$V_w = \frac{V_1 y_1 - V_2 y_2}{y_1 - y_2}$$

$$= \frac{3.72 \times 1.8 - 7.56 \times 0.6}{1.8 - 0.6}$$

$$= 1.8 \text{ m/s}$$

16.8 (a)

Exactly similar channel means that area and wetted perimeter are same i.e.

$$\frac{Q_2}{Q_1} = \sqrt{\frac{S_2}{S_1}}$$

$$\Rightarrow Q_2 = \sqrt{\frac{0.0001}{0.0009}} \times 30 = 10 \text{ m}^3/\text{s}$$

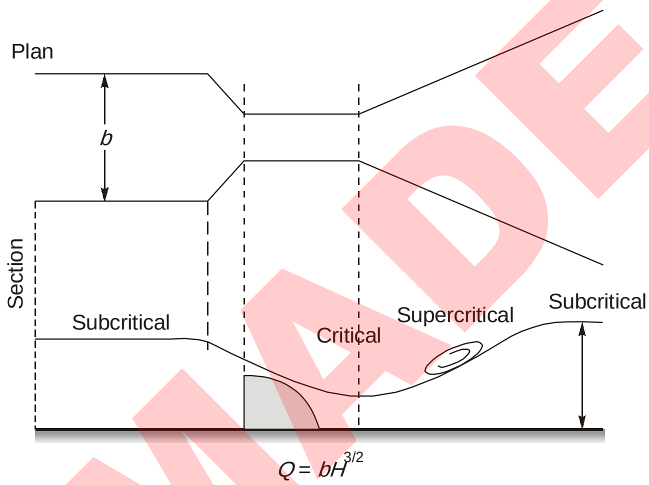
16.9 (d)

Head loss or energy loss,

$$E_L = \frac{(y_2 - y_1)^3}{4y_1y_2} = \frac{(1.4 - 0.4)^3}{4 \times 1.4 \times 0.4} = 0.45 \text{ m}$$

16.10 (c)

Critical depth flume is known as a standing wave flume or throated flume. In the throat section there is a hump to assist the formation of hydraulic jump. Constriction flume operating in the subcritical range are called venturi flumes.



16.11 (a)

Since the steep slope is long so flow in steep channel will be nearly at or at normal depth. When it is followed by short reach of adverse slope it will fall in deep and wide reservoir before reaching critical depth so hydraulic jump cannot be expected.

16.12 (c)

For critical flow in rectangular channel $V = \sqrt{gy}$

16.13 (b)

Area, perimeter and hydraulic radius will not change.

$$\therefore \quad \frac{Q_2}{Q_1} = \sqrt{\frac{S_2}{S_1}}$$

$$\Rightarrow \quad Q_2 = 15 \times \sqrt{\frac{1}{1000} \times \frac{1440}{1}} = 18 \text{m}^3/\text{s}$$

16.14 (a)

When the depth increases by 2 cm, the area of flow and centre of gravity also increases. Hence the change in magnitude of the second term will be negative.

16.15 (c)

When there is large variation in quantity of river flow from time to time, then excess water during monsoon is stored by impounding and utilized when flow is lean.

16.16 (b)

$$\frac{L_p}{L_m} = 36$$

$\therefore$ Height of jump in prototype

$= 36 \times 10 = 360 \text{ cm} = 3.6 \text{ m}$

16.17 (c)

Venturi flume consists of a gradually contracting channel leading to 'throat' and a gradually expanding channel away from it. For the same discharge Q, the discharge per unit width (q) is more at throat section so the specific energy at throat is more than that at normal section for super critical flow while the reverse happens in subcritical flow. However, the specific energy at normal and throat section is individually constant.

By providing hump, some loss of energy occurs and total energy at throat will be less.

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UNIT

II

Engineering Hydrology

Syllabus

Hydrological cycle, Ground water hydrology, Well hydrology and related data analysis; Streams and their gauging; River morphology; Flood, drought and their management.

Contents

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1 Engineering Hydrology

1. Precipitation and General Aspects of Hydrology

1.1 An accurate estimate of average rainfall in a particular catchment area can be obtained by
(a) arithmetic mean method
(b) isohyetal method
(c) normal ratio method
(d) Thiessen method

[ESE : 1995]

1.2 The percentage standard error of precipitation averages is often expressed functionally or graphically in terms of (i) precipitating gauge network density expressed as area per gauge, and (ii) total area of catchment. The percentage standard error
(a) increases with area per gauge as well as with total area
(b) decreases with area per gauge as well as with total area
(c) increases with area per gauge but decreases with total area
(d) decreases with area per gauge but increases with total area

[ESE : 1996]

1.3 If '*p*' is the precipitation, '*a*' is the area represented by a rain gauge, and '*n*' is the number of rain gauges in a catchment area, then the weighted mean rainfall is

(a) $\dfrac{\Sigma ap^3}{\Sigma a^2}$ (b) $\dfrac{\Sigma ap}{n}$

(c) $\dfrac{\Sigma ap}{\Sigma a}$ (d) $\dfrac{\Sigma ap^5}{\Sigma a^3}$

[ESE : 1996]

1.4 Depth-Area-Duration curves of precipitation are drawn as
(a) minimizing envelopes through the appropriate data points
(b) maximizing envelopes through the appropriate data points
(c) best fit mean curves through the appropriate data points
(d) best fit mean straight lines through the appropriate data points

[ESE : 1996]

1.5 Mean precipitation over an area is best obtained from gauged amounts by
(a) arithmetic mean method
(b) Thiessen method
(c) linearly interpolated isohyetal method
(d) orographically weighted isohyetal method

[ESE : 1997]

1.6 Depth-Area-Duration curves would seem to resemble
(a) arcs of circle concave upwards with duration increasing outward
(b) first quadrant limbs of hyperbolae with duration increasing outward
(c) third quadrant limbs of hyperbolae with duration decreasing outward
(d) first quadrant limbs of hyperbolae with duration decreasing outward

[ESE : 1997]

1.7 The following rainfall data refers to station *A* and *B* which are equidistant from station *X*:

	Station *A*	**Station *X***	**Station *B***
Long-term normal annual rainfall in mm	200	250	300
Annual rainfall in mm for the year 1940	140	P	270

The value of P will be
(a) 250 (b) 220
(c) 205 (d) 200

[ESE : 1998]

2. Infiltration, Runoff and Hydrograph

2.1 Which one of the following constitute the basic assumption of Unit Hydrograph theory?
(a) Non-linear response and time invariance
(b) Non-linear time variance and linear response
(c) Linear response and linear time variance
(d) Time invariance and linear response

[ESE : 1995]

2.2 The following four hydrological features have to be estimated or taken as inputs before one can compute the flood hydrograph at any catchment outlet:
1. Unit hydrograph
2. Rainfall hydrograph
3. Infiltration index
4. Base flow

The correct order in which they have to be employed in the computations is
(a) 1, 2, 3, 4 (b) 2, 1, 4, 3
(c) 2, 3, 1, 4 (d) 4, 1, 3, 2

[ESE : 1996]

2.3 The following steps are involved in arriving at a unit hydrograph:
1. Estimating the surface runoff in depth.
2. Estimating the surface runoff in volume.
3. Separation of base flow.
4. Dividing surface runoff ordinates by depth of runoff.

The correct sequence of these steps is
(a) 3, 2, 1, 4 (b) 2, 3, 4, 1
(c) 3, 1, 2, 4 (d) 4, 3, 2, 1

[ESE : 1997]

2.4 If a 4-hour unit hydrograph of a certain basin has a peak ordinate of 80 m^3/s, the peak ordinate of a 2-hour unit hydrograph for the same basin will be
(a) equal to 80 m^3/s
(b) greater than 80 m^3/s
(c) less than 80 m^3/s
(d) between 40 m^3/s to 80 m^3/s

[ESE : 1998]

2.5 Match **List-I** (Name of scientists) with **List-II** (Contribution to field of hydrology) and select the correct answer using the codes given below the lists:

List-I
A. Dalton
B. Snyder
C. Blaney-Criddle
D. Sherman

List-II
1. Unit Hydrograph
2. Evaporation
3. Empirical flood formula
4. Synthetic Unit Hydrograph
5. Consumptive use equation

Codes:

	A	B	C	D
(a)	2	3	5	1
(b)	1	4	3	2
(c)	2	4	5	1
(d)	1	3	4	5

[ESE : 1998]

3. Floods, Flood Routing & Flood Control

3.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Conservation reservoirs
B. Retarding basins
C. Flood plains
D. Flood walls

List-II
1. Uncontrolled outlets
2. Flood-fighting
3. Temporary storage of flood water
4. Controlled outlets

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	1	4	2	3
(c)	4	1	3	2
(d)	4	1	2	3

[ESE : 1996]

3.2 Probability of a 10 year flood to occur at least once in the next 4 years is
(a) 25% (b) 35%
(c) 50% (d) 65%

[ESE : 1997]

3.3 The Standard Project Flood is
(a) derived from the probable maximum precipitation in the region
(b) derived from the severemost meteoro-logical conditions anywhere in the country
(c) the flood with return period of 1000 years
(d) the same as the probable maximum flood
[ESE : 1997]

3.4 Consider the following statements:
1. A 100 year flood discharge is greater than a 50 year flood discharge.
2. 90% dependable flow is greater than 50% dependable flow.
3. Evaporation from salt-water surface is less than that from fresh-water surface.

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3
[ESE : 1998]

3.5 In a linear reservoir, the
(a) volume varies linearly with elevation
(b) outflow rate varies linearly with storage
(c) storage varies linearly with time
(d) storage varies linearly with inflow rate
[ESE : 1998]

3.6 A culvert is designed for a peak flow Q_p on the basis of rational formula. If a storm of the same intensity as used in the design and twice the duration occurs, then the resulting peak discharge will be
(a) Q_p (b) $Q_p/2$
(c) $\sqrt{2}Q_p$ (d) $2Q_p$
[ESE : 1998]

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Answers Engineering Hydrology

1.1	(b)	1.2	(a)	1.3	(c)	1.4	(b)	1.5	(d)	1.6	(b)	1.7	(d)	2.1	(d)	2.2	(c)
2.3	(a)	2.4	(b)	2.5	(c)	3.1	(c)	3.2	(b)	3.3	(b)	3.4	(c)	3.5	(b)	3.6	(a)

Explanations Engineering Hydrology

1. Precipitation and General Aspects of Hydrology

1.1 (b)

Normal ratio method is used for estimating missing annual precipitation value at a station when the annual precipitation and normal annual precipitation at neighbouring stations are known. In calculating average rainfall in a catchment area arithmetic mean method is very crude method and it is rarely used. Thiessen-polygon method of calculating the average precipitation is superior to the arithmetic average method as some weightage is given to the various stations on a rational basis. The isohyetal method is superior to other methods (arithmetic mean and thiessen) when stations are large in number.

1.2 (a)

As the gauge network density increases (area per gauge decreases) the error of precipitation averages decreases. In other words with increase in area per gauge the standard error increases. With increase in total area of catchment, the standard error will increase.

1.3 (c)

Weighted mean rainfall can be calculated according to Theissen Polygon method also called as Weighted Area Method.

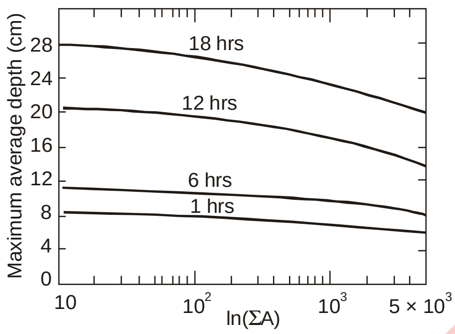
1.4 (b)

The maximum depth area curve for a given duration D is prepared by assuming the area distribution of rainfall for smaller duration to be similar to the total storm. The procedure is then repeated for different storms and the envelope curve of maximum depth area for duration *D* is obtained. A similar procedure for various values of *D* results in a family of envelope curves of maximum depth vs area, with duration as the third parameter. These curves are called DAD curves.

1.5 (d)

Isohyets are contours of equal rainfall. The orographically weighted isohyets are prepared by tracing paper for mountainous areas and therefore they are more accurate than linearly interpolated isohyets.

1.6 (b)



Typical DAD curves

1.7 (d)

Since the normal annual rainfall at stations *A* and *B* does not lie within 10% of the normal annual rainfall at station *X*.

So, using normal ratio method, we get

$$P = \frac{250}{2}\left[\frac{140}{200} + \frac{270}{300}\right] = 200 \text{ mm}$$

If the normal annual rainfall at non-missing station lie within 10% of that at missing station then arithmetic average method can be used.

2. Infiltration, Runoff and Hydrograph

2.1 (d)

Time invariance and linear response are the two basic assumptions of UH-theory. Other assumptions are:

(i) Rainfall excess occurs uniformly over the basin

(ii) The distribution of storm over the basin is uniform.

2.2 (c)

First determine the rainfall hydrograph and then infiltration index. The effective rainfall can be determined from the rainfall hydrograph and infiltration index. Now multiply the ordinates of unit hydrograph by effective rainfall. This will give direct runoff hydrograph (DRH). Finally add base flow to the DRH and flood hydrograph can be obtained.

2.3 (a)

The separation of base flow gives direct runoff hydrograph (DRH). The area under the DRH gives volume of surface runoff. The effective depth of precipitation can be obtained by using ϕ-index or volume of surface runoff can be divided by the catchment area. Finally the ordinates of UH can be obtained by dividing the ordinates of DRH by effective depth of precipitation.

2.4 (b)

With the reduction of unit hydrograph duration, 1 cm excess rainfall will occur in reduced period. So peak ordinate of UH will increase and time base will decrease. Thus the peak ordinate of 2 hr UH will be greater than 80 m^3/s.

2.5 (c)

$$E_L = C\,(e_w - e_a)$$

This equation is known as Dalton's law of evaporation after John Dalton who first recognized this law. Evaporation continuous till $e_w = e_a$. If $e_w > e_a$ Condensation takes place.

Snyder was the one to develop a synthetic UH based on a study of watersheds in the Appalachian Highlands. In basins ranging from 10 – 10,000 mi^2

Snyder relations are $t_p = C_t\,(L\,L_C)^{0.3}$

The Blaney–Criddle equation is a relatively simplistic method for calculating evapo-transpiration. The equation is ideal when only air-temperature datasets are available for a site. Given the coarse accuracy of the equation, it is recommended that it should be used to calculate evapotranspiration for periods of one month or greater.

3. Floods, Flood Routing & Flood Control

3.1 (c)

Storage or conservation reservoirs has gates and valves installed at its spillway and can retain excess flow during periods of peak flow and can release them gradually during low flows as and when need arises. Thus they have controlled outlets.

Retarding basins or retarding reservoirs has uncontrolled and ungated outlets.

Masonry structures used to confine the river in a manner similar to levees are known as flood walls. These are used to protect important structures against floods especially where the land is at a premium.

3.2 (b)

Probability corresponding to 10 year return period is

$$P = \frac{1}{10} = 0.1$$

The probability of flood occurring at least once in 4 years is

$= 1 - (1 - P)^4 = 1 - 0.9^4 = 0.3439 \approx 35\%$

3.3 (b)

The flood that would result from a severe combination of meteorological and hydrological factors that are reasonably applicable to the region. Extremely rare combinations of factors are excluded.

3.4 (c)

For a return period T, the magnitude of flood is given by equation of hydrologic frequency analysis as

$$x_T = \bar{x} + k\sigma$$

The value of k increases with higher return period. So flood magnitude for 100 year return period is more than that of 50 year return period.

% dependable flow means number of times the given discharge is equalled or exceeded.

$$\%\ \text{Dependability} = \frac{100}{\text{Returnperiod}}$$

90% dependable flow has lesser return period while, 50% dependable flow has higher return period. So, 90% dependable flow is less than 50% dependable flow.

When a solute is dissolved in water, the vapour pressure is less than that of pure water and hence causes a reduction in the rate of evaporation.

3.5 (b)

For linear reservoir $S = kQ$

The storage varies linearly with outflow discharge, or outflow rate varies linearly with storage.

3.6 (a)

Rational formula $Q_p = kiA$.

There is no term for duration of rainfall in the rational formula so peak discharge will not change.

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UNIT

III

Water Resources Engineering

Syllabus

Multipurpose uses of Water, River basins and their potential; Irrigation systems, water demand assessment; Resources - storages and their yields; Water logging, canal and drainage design, Gravity dams, falls, weirs, Energy dissipators, barrage Distribution works, Cross drainage works and head-works and their design; Concepts in canal design, construction & maintenance; River training, measurement and analysis of rainfall.

Contents

3 Water Resources Engineering

1. Introduction to Irrigation and Methods of Irrigation

1.1 The most economical method of soil conservation is to
 (a) construct check dams
 (b) construct contour bunds
 (c) drain the soil
 (d) afforest the area

[ESE : 1995]

2. Water Logging and Quality of Irrigation Water

2.1 **Assertion (A) :** Leaching requirement is defined as the fraction of irrigation water that must be leached through the root zone of the plant in order to prevent soil salinity exceeding a specified level.
Reason (R) : The concept of leaching requirement can be used to compute the quantity of drainage water that must be removed from an identified land spread.

[ESE : 1997]

2.2 The spacing of tile drains to relieve water-logged land is directly proportional to the
 (a) depth of drain below the ground surface
 (b) depth of impervious strata from the drain
 (c) depth of drain below the water level
 (d) coefficient of permeability of the soil to be drained

[ESE : 1999]

3. Water Requirement of Crops

3.1 Given that the base period is 100 days and the duty of the canal is 1000 hectares per cumecs, the depth of water will be
 (a) 0.864 cm (b) 8.64 cm
 (c) 86.4 cm (d) 864 cm

[ESE : 1995]

3.2 The following data were recorded from an irrigated field:
 1. Field capacity : 20%
 2. Permanent wilting point : 10%
 3. Permissible depletion of available soil moisture: 50%
 4. Dry unit weight of soil : 1500 kgf/m^3
 5. Effective rainfall : 25 mm

Based on these data, the net irrigation requirement per metre depth of soil will be
 (a) 75 mm (b) 125 mm
 (c) 50 mm (d) 25 mm

[ESE : 1997]

3.3 **Assertion (A):** Duty is an expression of the irrigating capacity of a unit volume of water.
Reason (R): Duty at the head of a distributary will be less than that at the head of a watercourse and more than that at the head of a canal.
 (a) both A and R are true and R is the correct explanation of A
 (b) both A and R are true but R is not a correct explanation of A
 (c) A is true but R is false
 (d) A is false but R is true

[ESE : 1999]

4. Design of Unlined and Lined Canals

4.1 In the alignment of an irrigation channel wherefrom offtakes have to be provided at regular intervals, changes in the given channel parameters are made use of. The correct sequence of the decreasing order of preference of these parameters is
 (a) width, slope, depth
 (b) width, depth, slope
 (c) depth, slope, width
 (d) depth, width, slope

[ESE : 1996]

4.2 **Assertion (A) :** Irrigation canals are constructed at a maximum grade.
Reason (R) : It is advantageous to command as much arid land as possible.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

4.3 For medium silt whose average grain size is 0.16 mm, Lacey's silt factor is likely to be
(a) 0.30 (b) 0.45
(c) 0.70 (d) 1.32

[ESE : 1997]

5. Design and Construction of Gravity Dam

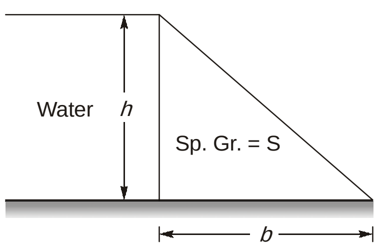
5.1 If ρ is the specific gravity of the material used in the design of a masonry dam of triangular section, then the ratio between the height and base width of the dam for structural safety and stability is equal to
(a) $\sqrt{2\rho}$ (b) $\sqrt{\rho}$
(c) $\frac{1}{\rho}$ (d) $\frac{1}{\sqrt{\rho}}$

[ESE : 1997]

5.2 If the eccentricity of total self-weight W of a masonry dam at its base is equal to one-fourth of base width B, then the maximum pressure at the base is given by
(a) 2W/3B (b) 4W/3B
(c) 5W/2B (d) 8W/3B

[ESE : 1998]

5.3 **Assertion (A):** In the retaining wall shown in the given figure when the ratio $\frac{h}{b} = \sqrt{S}$, the eccentricity is $\frac{b}{6}$ whether the storage is nil or full.



Reason (R): The resultant force will pass through the centroid of the pressure distribution diagram on the base, for the nil or full storage if the ratio $\frac{h}{b} = \sqrt{S}$.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

6. Conveyance Structures for Canals & Outlets/Modules

6.1 Match **List-I** (Control structures) with **List-II** (Functions of the control structures) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Canal drop	**1.** Control of flow depth
B. Canal escape	**2.** Control of bed grade
C. Canal cross regulator	**3.** Control of full supply level
D. Canal outlets	**4.** Control of discharge

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	2	3	1	4
(c)	3	2	1	4
(d)	3	2	4	1

[ESE : 1997]

6.2 A submerged pipe outlet from a minor feeds into a well chamber across the bank. Water from the well chamber overflows a weir-like face into the field channel. The flow into the field channel
(a) will increase with any drop in the water level in the minor
(b) will not be much affected by any change in the water level in the minor
(c) will decrease with any drop in the water level in the minor
(d) will be proportional to the flow in the minor when the minor flows between set ranges

[ESE : 1998]

7. Theories of Seepage

7.1 The following parameters relate to the design of weirs on permeable foundations:

1. Scour depth 2. Exit gradient
3. Uplift pressure 4. Unbalanced head

Design of the downstream end pile of the weir depends upon

(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) 3 and 4

[ESE : 1995]

7.2 While considering weir designs on permeable soils, the correction for mutual interference of sheet piles is NOT applicable on an intermediate pile if the outer pile

(a) goes deeper than the intermediate pile and is farther from the intermediate pile by more than twice its own length.
(b) goes only just as deep as the intermediate pile and is within a distance of one and a half times its own length.
(c) does not go as deep as the intermediate pile, no matter what the horizontal distance between them is.
(d) is safe against deleterious exit gradient.

[ESE : 1997]

7.3 A road is passing in cut with impervious strata at a depth of 0.5 m from the subgrade level. To intercept seepage flow, a longitudinal pipe drain in trench filled with filter material and clay seal is constructed. What shall be the depth of the trench?

(a) 1.75 m (b) 1.5 m
(c) 1.0 m (d) 0.5 m [ESE : 1998]

8. River Training Works & Diversion Headworks

8.1 When a river starts meandering, the sediment carrying capacity

(a) first decreases and ultimately increases
(b) first increases and ultimately decreases
(c) remains unaffected as the plan shape changes continuously
(d) changes erratically all the time leaving permanent braids

[ESE : 1998]

9. Dams (general), Spillways & Energy Dissipators

9.1 **Assertion (A):** When friction blocks are provided in a stilling basin to localize and stabilize the jump formation, the downstream depth in the jump is less than that without the friction blocks.

Reason (R): The discharge per unit width at the section where the blocks are located is increased.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

9.2 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Tailwater curve much above jump height curve
B. Tailwater curve slightly above jump height curve
C. Tailwater curve coinciding with jump height curve
D. Tailwater curve below the jump height curve

List-II

1. Basin at bed level
2. Sunk basin
3. Roller bucket
4. Sloping apron

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	3	4	1	2
(c)	4	3	1	2
(d)	3	4	2	1

[ESE : 1996]

9.3 The construction of impounding reservoir is required when

(a) average annual flow in the stream is lower than average demand
(b) the rate flow in the stream, in dry season is more than the demand
(c) the rate of flow in the stream, in dry season is less than the demand
(d) the rate of flow in the stream is equal to the demand

[ESE : 1996]

9.4 Match **List-I** (Main provision) with **List-II** (Surplussing arrangement) and select the correct answer using the codes below the lists:

List-I
A. Minor irrigation work
B. Medium irrigation project in interior area
C. Earth dam across main river
D. Masonry dam on good rock

List-II
1. Saddle spillway
2. Syphon spillway
3. Ogee spillway
4. Surplus weir

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	4	2	3	1
(c)	2	4	3	1
(d)	2	4	1	3

[ESE : 1997]

9.5 The trap efficiency of a reservoir is a function of
(a) inflow into the reservoir
(b) ratio of inflow to storage capacity
(c) ratio of reservoir capacity to inflow
(d) reservoir capacity

[ESE : 1998]

9.6 The best design of an arch dam is when
(a) all horizontal water loads are transferred horizontally to the abutments
(b) the dam is safe against sliding at various levels
(c) the load is divided between the arches and cantilevers and the deflections at the conjugal points being equal
(d) the deflections of the cantilevers are equal at different points

[ESE : 1999]

■■■■

Answers Water Resources Engineering

1.1	(d)	2.1	(b)	2.2	(d)	3.1	(c)	3.2	(c)	3.3	(d)	4.1	(c)	4.2	(d)	4.3	(c)
5.1	(b)	5.2	(d)	5.3	(b)	6.1	(b)	6.2	(c)	7.1	(a)	7.2	(a)	7.3	(d)	8.1	(a)
9.1	(c)	9.2	(b)	9.3	(c)	9.4	(a)	9.5	(c)	9.6	(c)						

Explanations Water Resources Engineering

1. Introduction to Irrigation and Methods of Irrigation

1.1 (d)

Check dam and contour bunding are mainly water harvesting techniques. Contour bunding can check erosion in hilly areas but it is not very economical as every year the bunds are to be maintained before rainy season. The afforestation of catchment area is the long lasting and economic solution for soil conservation.

2. Water Logging and Quality of Irrigation Water

2.1 (b)

Leaching water percolates down to join the water table or is drained away by sub-surface drains. It is needed to compute the leaching requirement so that quantity of drainage water to be removed from identified land can be estimated. The leaching water percolates vertically and joins the sub-surface drains and a part of it is removed by runoff.

2.2 (d)

Spacing of the drains $S = \frac{4K}{q}\left(b^2 - a^2\right)$

where

K is coefficient of permeability

q is discharge per unit length in the drain

a is depth of impervious strata below the drain

b is maximum height of the drained water table above the impervious layer.

3. Water Requirement of Crops

3.1 (c)

$$\Delta \times D = 864 \times B$$
$$D = 1000 \text{ ha/cumec}$$
$$B = 100 \text{ days}$$
$$\Delta = \frac{864 \times 100}{1000} = 86.4 \text{ cm}$$

3.2 (c)

The readily available moisture

$= 0.5 \times (20 - 10) = 5\%$

Deficiency due to the fall of moisture is

$$= \frac{\gamma_d}{\gamma_\omega} \times d \times \text{readily available moisture}$$
$$= \frac{1500}{1000} \times 1000 \times 0.05 = 75 \text{ mm}$$

25 mm depth of water is available from precipitation so net irrigation needed is 75 – 25 = 50 mm

Note: 1 kg-f = 9.81 N

3.3 (d)

Duty is an expression of irrigating capacity of a unit discharge of water. Due to loss of water by evaporation and per-colation, the duty is less at the head of distributary than at the head of the water course and more than that at the head of the canal.

4. Design of Unlined and Lined Canals

4.1 (c)

The best alignment of off-taking channel is that in which the off-taking channel makes zero angle with the parent channel initially and then separates out in transition. The depth of water should always be such that off take channel runs full. The transitions should be properly designed, so as to avoid accumulation of silt. The transition can also be used as metering flume. Thus depth, slope and width will be the correct order of preference of parameters.

4.2 (d)

The slope of the channel is fixed on available country slope consistent with economy. A steeper slope governed by the maximum permissible velocity, will be most economical, but it will lower the FSL, causing less irrigation. Hence, the maximum possible irrigation would indicate flatter slope governed by minimum permissible velocity for no silting to occur. A via media between these two limits must be adopted for selecting a suitable bed slope for the channel.

4.3 (c)

Lacey's silt factor, $f = 1.76\sqrt{d_m}$

$= 1.76 \times \sqrt{0.16} = 0.704$

5. Design and Construction of Gravity Dam

5.1 (b)

$H/b = \sqrt{\rho}$ from stress criterion

$H/b = \mu\rho$ from stability or sliding criterion

(Not considering uplift in this case)

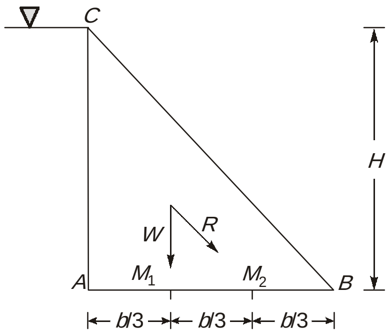
5.2 (d)

Masonry cannot take tension. So maximum pressure for $e > \frac{b}{6}$ is

$$p_{max} = \frac{2W}{3\left[\frac{B}{2} - e\right]} = \frac{8W}{3B} \qquad \text{Given } e = \frac{B}{4}$$

5.3 (b)

When the reservoir is empty, the resultant force should pass through the inner third point (M_1) so that no tension is developed. For the reservoir full condition, the resultant must pass through the outer third point (M_2) so that no tension is developed. Taking the moment of the forces about M_2 and equating it to zero.



$$b = \frac{H}{\sqrt{\rho - c}}$$

If uplift is not considered

$$b = \frac{H}{\sqrt{\rho}}$$

6. Conveyance Structures for Canals & Outlets/Modules

6.1 (b)

Canal drop or fall is provided whenever the available natural ground slope is steeper than the designed bed slope of the channel. Thus it controls the grade of bed.

Canal escape is constructed as a side channel to remove surplus water from an irrigation channel into a natural drain. The water in the irrigation channel may become surplus due to some mistake, or difficulty in regulation at the head, or due to excessive rainfall in upper reaches. Thus it controls the full supply level to avoid breaching of canal and work as safety valve. The minimum capacity of the escape is generally kept half of the channel capacity at the point of escape.

Canal cross-regulator controls the flow depth by heading up water on the U/S when the water level in main channel is low.

Canal outlets or modules are built at the head of the water course so as to connect it with a minor or distributary channel. They control discharge to watercourse on the principle of equitable distribution of water.

6.2 (c)

Submerged pipe outlet is non-modular type so the discharge depends upon the water level in both the minor and well chamber.

$$Q = C_d A\sqrt{2gH_L}$$

Thus discharge through outlet can be increased by increasing H_L or by increasing the depth of water in minor. If there is any drop in the water level in the minor, the H_L and discharge will decrease.

7. Theories of Seepage

7.1 (a)

The downstream vertical cut-off at the end of the pucca floor is used to prevent undermining of foundation and sufficient depth of downstream pile is provided to ensure no scouring below the foundation.

7.2 (a)

In the Khosla's theory for calculating seepage pressure under the weir, following corrections are used:

(i) Correction for mutual interference of piles

(ii) Correction for thickness of floor

(iii) Correction for the slope of the floor

The correction for mutual interference of piles is given by

$$C = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

where

b' is distance between two pile lines.

D is the depth of the pile line, the influence of which is to be determined on the neighbouring pile of depth d. It is to be measured below the level at which interference is desired

d is the depth of pile on which the effect is considered

b is total floor length

This equation does not apply to the effect of an outer pile on intermediate pile, if the intermediate pile is equal to or smaller than the outer piles and is at a distance greater than twice the length of the outer pile.

7.3 (d)

The depth of trench should be equal to depth of impervious strata below the subgrade level of pavement i.e 0.5 m

8. River Training Works & Diversion Headworks

8.1 (a)

During floods river carries silt charge in excess of the quantity required for stability, the river starts building up its slope by depositing the silt on its bed. This accretion is the primary process, which consequently leads to meandering. The increase in slope tends to increase the width of the channel and the sediment carrying capacity decreases.

Finally due to shifting of the convex bar, the width between the banks reduces, which increases the velocity and sediment carrying capacity also.

9. Dams (general), Spillways & Energy Dissipators

9.1 (c)

Baffle piers (friction blocks) help in breaking the flow and dissipate energy mostly by impact. Therefore the length of jump is less. Although there is a increase in discharge per unit width also.

9.2 (b)

When TWC is much above JHC, the jump forming at the toe will be drowned and little energy will be dissipated. In such a case roller bucket will be the most suitable choice.

If TWC is slightly above JHC, then sloping apron will be the suitable choice.

Tail water curve (TWC) coincides with jump height curve (JHC) then stilling basin at bed level with horizontal apron is provided.

A subsidiary dam below the main dam can also be provided.

When TWL is slightly below JWC, then sloping apron with depressed floor may be provided. When TWL is considerably below JHC, ski-jump bucket should be provided.

9.3 (c)

Impounding reservoirs can store water during high flow and utilize the same during lean flow period (i.e. when flow in stream is less than demands).

9.4 (a)

Straight drop spillway or overfall spillway may be constructed on small bunds or on thin arch dams etc.

Ogee or overflow spillway is widely used with concrete, masonry, arch and buttress dams.

For earthen and rockfill dams a separate spillway is generally constructed in a flank or a saddle away from the main valley. It is also called chute or trough spillway.

Schemes involving-cultivable command area (CCA) upto 2000 ha are minor irrigation schemes; those involving CCA between 2000 to 10,000 ha are medium irrigation schemes; and those involving CCA greater than 10,000 ha are major irrigation schemes.

A surplus weir is a masonry weir with its crest level equal to full tank level. It is used in tank irrigation (minor irrigation schemes).

Syphon spillway is provided within the body of the gravity dam in medium or major irrigation projects.

9.5 (c)

Trap efficiency increases with increase in ratio of reservoir capacity to inflow. Therefore to minimize sediment accumulation in a reservoir, the capacity to inflow ratio should be kept minimum possible. It implies that reservoir should be constructed in stages.

9.6 (c)

Arch dams are solid walls curved in plan. They behave as a cantilever retaining wall standing up from its base, and partly the load will be transferred to the two ends of the arch span by horizontal action. In the trial load method of design, the load is assumed to be distributed between the arch elements and the cantilever elements. The deflection calculated at conjugal points should be the same.

UNIT

IV

Environmental Engineering

Syllabus

Water Supply Engineering: Sources, Estimation, quality standards and testing of water and their treatment; Rural, Institutional and industrial water supply; Physical, chemical and biological characteristics and sources of water, Pollutants in water and its effects, Estimation of water demand; Drinking water Standards, Water Treatment Plants, Water distribution networks.

Waste Water Engineering: Planning & design of domestic waste water, sewage collection and disposal; Plumbing Systems. Components and layout of sewerage system; Planning & design of Domestic Waste-water disposal system; Sludge management including treatment, disposal and re-use of treated effluents; Industrial waste waters and Effluent Treatment Plants including institutional and industrial sewage management.

Solid Waste Management: Sources & classification of solid wastes along with planning & design of its management system; Disposal system, Beneficial aspects of wastes and Utilization by Civil Engineers.

Air, Noise pollution and Ecology: Concepts & general methodology.

Contents

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4 Environmental Engineering

1. Water Demand

1.1 When was the water (Prevention and Control of Pollution) Act enacted by the Indian Parliament?

(a) 1970 (b) 1974
(c) 1980 (d) 1985

[ESE : 1996]

1.2 Which of the following statements about design period are true?

1. It is concerned with economy of investments.
2. It takes into account aspects like life and durability and ease or difficulty in capacity increase of installations.
3. It considers the frequency of occurrence of extremes of river flow.
4. It is concerned with estimating future requirements.

Select the correct answer using the codes given below:

(a) 1, 2, 3 and 4 (b) 2 and 3
(c) 1, 2, and 4 (d) 1, 3 and 4

[ESE : 1997]

1.3 Consider the following statements:
The daily per capita consumption of water apparently increases with

1. higher standard of living of people
2. availability of sewerage in the city
3. metered water supply
4. wholesome and potable quality of water

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1,2 and 4

[ESE : 1999]

1.4 Match **List-I** (Industry and unit of production) With **List-II** (Water need in kL/unit/day) and select the correct answer using the codes given below the lists:

	List I		List-II
A.	Automobile (per vehicle)	1.	1 to 2
B.	Leather (per 100 kg)	2.	4
C.	Paper (per tonne)	3.	40
D.	Crude petroleum refinery (per tonne)	4.	50-100
		5.	200-400

Codes:

	A	B	C	D
(a)	3	2	5	1
(b)	1	3	5	4
(c)	3	2	4	5
(d)	5	4	2	1

[ESE : 1999]

2. Sources of Water and Well

2.1 The yield of a well depends upon

(a) permeability of soil
(b) area of aquifer opening into the wells
(c) actual flow velocity
(d) all of the above

[ESE : 1996]

2.2 Match **List-I** (Soil classification of an aquifer) with **List-II** (Values of the range of hydraulic conductivities in metre per day) and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Fine gravel	1.	1 to 10
B.	Very fine sand	2.	0.1 to 0.01
C.	Silt	3.	100 to 1000
D.	Pure clay	4.	10^{-5} to 10^{-6}

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	1	3	2	4
(c)	3	1	4	2
(d)	3	1	2	4

[ESE : 1997]

2.3 A commonly used handpump is the
(a) centrifugal pump
(b) reciprocating pump
(c) rotary pump
(d) axial flow pump

[ESE : 1998]

2.4 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Specific yield
B. Specific capacity
C. Specific retention
D. Specific storage

List-II
1. Volume of water retained per unit volume of aquifer
2. Volume of water drained by gravity per unit volume of aquifer
3. Difference of porosity and specific storage
4. Well yield per unit drawdown
5. Volume of water released from unit volume of aquifer for unit decline in piezometric head

Codes:

	A	B	C	D
(a)	2	4	1	5
(b)	4	2	3	5
(c)	2	5	1	4
(d)	4	2	3	1

[ESE : 1998]

2.5 Water present in an artesian aquifer is usually
(a) at sub atmospheric pressure
(b) at atmospheric pressure
(c) at 0.5 times of the atmospheric pressure
(d) above atmospheric pressure

[ESE : 1998]

2.6 An aquifer confined at top and bottom by impermeable layers is stratified into three layers as follows:

Layer	Thickness (m)	Permeability (m/day)
Top layer	4	30
Middle layer	2	10
Bottom layer	6	20

The transmissivity (m^2/day) of the aquifer is
(a) 260 (b) 227
(c) 80 (d) 23 [ESE : 1998]

3. Water Quality Parameters

3.1 If the total hardness and alkalinity of a sample of water are 300 mg/L and 100 mg/L ($CaCO_3$ scale) respectively, then its carbonate and non-carbonate hardness (in units of mg/L) will be respectively
(a) 100 and 200 (b) 400 and 300
(c) 100 and 400 (d) 400 and zero

[ESE : 1995]

3.2 Electrical conductivity (EC) of water and total dissolved solids (TDS) are interrelated. The value of EC will
(a) decrease with increase in TDS
(b) increase with increase in TDS
(c) decrease initially and then increase with increase in TDS
(d) increase initially and then decrease with increase in TDS

[ESE : 1995]

3.3 Which one of the following would contain water with the maximum amount of turbidity?
(a) Lakes (b) Oceans
(c) Rivers (d) Wells

[ESE : 1996]

3.4 **Assertion (A):** Presence of E.Coli bacteria in water indicates that the water is polluted with fecal discharge.
Reason (R): E.Coli is a pathogenic bacteria.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

3.5 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Absence of fluorides
B. Excess of lead
C. Presence of excess nitrates
D. Absence of iodide

List-II
1. Methaemo globinemia
2. Goitre
3. Dental caries

4. Anaemia

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	2	3	4	1
(c)	3	4	1	2
(d)	1	2	4	3

[ESE : 1997]

3.6 Which of the following determinations are NOT necessary for raw water from a lake for use as source of supply of water for boiler-feed?

1. Turbidity
2. Bacterial count
3. Iron
4. Hardness

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 1, 3 and 4 (d) 2, 3 and 4

[ESE : 1997]

3.7 Which of the following is/are the characteristic(s) of coliform organism?

1. Bacillus
2. Gram-negative
3. Ferments lactose
4. Spore-forming

Select the correct answer using the codes given below:

(a) 1 alone (b) 1, 2 and 4
(c) 1, 2 and 3 (d) 2, 3 and 4

[ESE : 1998]

3.8 **Assertion (A):** Chlorides should be absent in drinking water.

Reason (R): Chlorides give salty taste to water.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

3.9 If the methyl orange alkalinity of water equals or exceeds total hardness, all of the hardness is

(a) non-carbonate hardness
(b) carbonate hardness
(c) pseudo hardness
(d) negative non-carbonate hardness

[ESE : 1999]

3.10 Consider the following statements:

Some amount of chlorides is allowed in drinking water because

1. it helps in killing bacteria
2. small quantity of chlorides adds to the taste
3. it is not injurious to human health
4. it is not economical to remove it completely

Which of these statements are correct?

(a) 1, 2 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 1, 3 and 4

[ESE : 1999]

4. Water Treatment

4.1 The following residual chlorine compounds are formed during chlorination of water:

1. NH_2Cl
2. $NHCl_2$
3. $HOCl$
4. OCl^-

The correct sequence of formation of these residual chlorine compounds is

(a) 2, 1, 3, 4 (b) 1, 2, 4, 3
(c) 1, 2, 3, 4 (d) 2, 1, 4, 3

[ESE : 1995]

4.2 Match **List-I** (Type of water source) with **List-II** (Treatment to be given) and select the correct answer using the codes given below the lists:

List-I

A. Surface water (river or canal)
B. Water from infiltration gallery
C. Lake/pond water
D. Tube well water

List-II

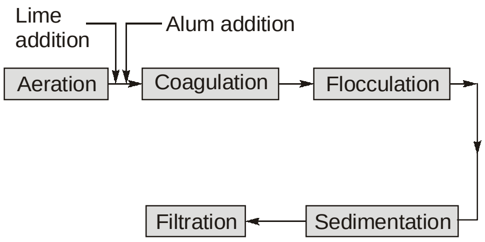
1. Aeration, coagulation, sedimentation and disinfection
2. Disinfection
3. $CuSO_4$ treatment, coagulation, sedimentation, filtration and disinfection
4. Coagulation, flocculation, sedimentation, filtration and disinfection

Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	1	4	3	2
(c)	1	4	2	3
(d)	4	1	2	3

[ESE : 1995]

4.3 The flow chart of water treatment plant is shown in the following figure. If it is proposed to defluoridate the water using 'Nalgonda treatment' then it should be done



(a) after adjusting the dose of lime and alum
(b) after sedimentation
(c) after filtration
(d) before aeration

[ESE : 1995]

4.4 **Assertion (A):** Tapered flocculation is more efficient when compared to the conventional process of flocculation.
Reason (R): In tapered flocculation, velocity gradient at the inlet is less than that at the outlet of the flocculation unit.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995, 1996]

4.5 Which of the following treatment reduce salinity of water?
1. Flash mixing and sedimentation
2. Electrodialysis
3. Reverse osmosis
4. Freezing
5. Filtration

Select the correct answer using the codes given below:
(a) 1, 2, 3, 4 and 5 (b) 2, 3 and 4
(c) 1, 3 and 5 (d) 1, 2 and 4

[ESE : 1996]

4.6 The cleaning of slow sand filter is done by
(a) reversing the direction of flow of water
(b) passing air through the filter
(c) passing a solution of alum and lime through the filter
(d) scraping off top layers of sand and admitting water

[ESE : 1996]

4.7 What is the correct sequence of formation of the following compounds during chlorination of water in which ammonia is present?
1. NCl_3 2. NH_2Cl
3. $NHCl_2$

Select the correct answer using the codes given below:
(a) 1, 2, 3 (b) 2, 3, 1
(c) 3, 1, 2 (d) 2, 1, 3

[ESE : 1996]

4.8 Match **List-I** (Name of impurity in water) with **List-II** (Removed by) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Fluorides	**1.** Activated carbon
B. Manganese	**2.** Activated alumina
C. Taste and odour	**3.** Manganese zeolite

Codes:

	A	B	C
(a)	1	2	3
(b)	2	3	1
(c)	2	1	3
(d)	3	2	1

[ESE : 1996]

4.9 A river is the source of water for water supply to a town. Its water is very turbid and polluted. The correct sequence of steps for treating the river water would be
(a) pre-sedimentation → pre-chlorination → coagulation → sedimentation → filtration → post chlorination
(b) coagulation → sedimentation → post-chlorination
(c) coagulation → filtration → sedimenta-tion → post-chlorination
(d) sedimentation → post-chlorination

[ESE : 1997]

4.10 Uniformity coefficient of filter sand is given by
(a) $\frac{D_{50}}{D_5}$ (b) $\frac{D_{50}}{D_{10}}$
(c) $\frac{D_{60}}{D_5}$ (d) $\frac{D_{60}}{D_{10}}$

[ESE : 1997]

4.11 Which of the following statement is/are true in relation to the term 'detention period' in a settling tank?

1. It may be determined by introducing a dye in the inlet and timing its appearance at the outlet.
2. Greater the detention period, greater the efficiency of removal of settleable matter.
3. It is the time taken for any unit of water to pass through the settling basin.
4. It is usually more than the flowthrough period.

Select the correct answer using the codes given below:

(a) 1, 2, 3 and 4 (b) 2, 3 and 4
(c) 1 and 3 (d) 4 alone

[ESE : 1997]

4.12 Which of the following treatment(s) will be indicated for a rural water supply from a deep ground water source?

1. Sedimentation
2. Alum dosage
3. Potassium permanganate dosing
4. Bleaching powder application

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 3 and 4 (d) 4 alone

[ESE : 1997]

4.13 Zero hardness of water is achieved by

(a) using lime soda process
(b) excess lime treatment
(c) ion exchange method
(d) using excess alum dosage

[ESE : 1997]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.14 Assertion (A): Ozone is not widely used in community water supplies.

Reason (R): It is not possible to maintain residual concentrations of ozone in water after the disinfection process.

[ESE : 1998]

4.15 Assertion (A): In the case of dual media filter, the rate of filtration is more than that of rapid sand filter.

Reason (R): The direction of flow is from fine medium to coarse medium.

[ESE : 1998]

4.16 Air-binding in rapid sand filters is encountered when

(a) there is excessive negative head
(b) the water is subjected to prolonged aeration
(c) the raw water contains dissolved gases
(d) the filter bed comprises largely of coarse sand

[ESE : 1998]

4.17 In a water treatment plant, dissolved iron and manganese can be removed from the water by

(a) aeration
(b) aeration and coagulation
(c) aeration and flocculation
(d) aeration and sedimentation

[ESE : 1998]

4.18 The various treatment processes in a water treatment plant are listed below:

1. Filtration 2. Chlorination
3. Sedimentation 4. Coagulation
5. Flocculation

The correct sequence of processes in water treatment is

(a) 1, 2, 3, 4, 5 (b) 4, 5, 3, 1, 2
(c) 2, 3, 1, 5, 4 (d) 1, 2, 5, 3, 4

[ESE : 1998]

4.19 The effective size (ES) of sand and its uniformity coefficient (UC) are the usually specified parameters for sand filters. In slow sand filters, as compared to rapid sand filters,

(a) ES is less but UC is more
(b) ES is more but UC is less
(c) both ES and UC are more
(d) both ES and UC are less

[ESE : 1998]

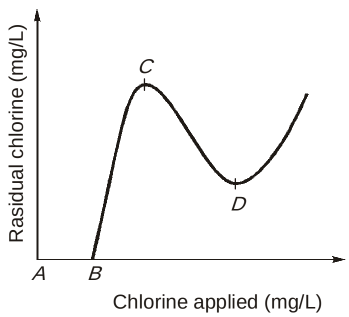
4.20 For proper slow mixing in the flocculator of a water treatment plant, the temporal mean velocity gradient G needs to be of the order of

(a) 5 to 10 s^{-1} (b) 20 to 80 s^{-1}

(c) 100 to 200 s^{-1} (d) 250 to 350 s^{-1}

[ESE : 1998]

4.21 If only ammonia was present in water, the only change in the diagram below would have been that the curve would



(a) be a straight line

(b) become parallel to Y-axis

(c) become parallel to X-axis after D

(d) be passing through the origin

[ESE : 1998]

4.22 Match **List-I** (Water treatment units) with **List-II** (Detention time) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Rapid mixing unit	1. 1.5 hours
B. Flocculator	2. 10 seconds
C. Propeller mixing unit	3. 30 seconds
D. Sedimentation tank	4. 30 minutes

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	4	3	2	1
(d)	3	4	1	2

[ESE : 1998]

4.23 Match **List-I** (Operational problems in rapid gravity filter) with **List-II** (Methods to overcome the problems) and select the correct answer using the codes given below the lists:

List I

A. Incrustation of filter sand media

B. Air binding and development of negative head

C. Mud ball formation

D. Slime growth on filter

List II

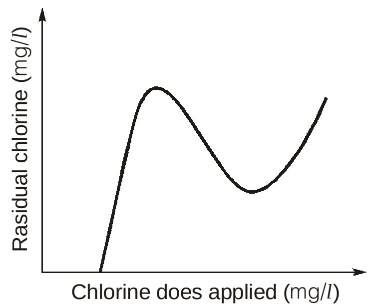
1. Compressed air scouring for about 4 minutes at the time of backwashing and manual surface raking
2. Washing the filter with sodium hydroxide or bleaching powder occasionally
3. Thorough backwashing with salt solution after soaking the filter in it
4. Increasing the depth of water during filter operation by about 15-20 cm as compared to the normal depth maintained during daily operation and more frequent backwashing

Codes:

	A	B	C	D
(a)	2	4.	3	1
(b)	4	2	1	3
(c)	2	4	1	3
(d)	4	2	3	1

[ESE : 1999]

4.24 In the plot of residual chlorine dose applied shown in the figure below, the curve will not have any (0, 0) point because



(a) of experimental error

(b) chlorine escapes into the atmosphere

(c) chlorine requires some contact time

(d) chlorine is consumed for disinfection

[ESE : 1999]

4.25 The correct sequence of processes in a water treatment plant for rural water supply is

(a) chlorination, aeration, sedimentation, rapid sand filter

(b) coagulation, sedimentation, slow sand filter, chlorination

(c) coagulation, flocculation, clarification, pressure filter

(d) aeration, plain sedimentation, slow sand filter, chlorination

[ESE : 1999]

5. Conveyance and Distribution of Water

5.1 Which one of the following pairs is not correctly matched?
(a) Check valve : To check water flow in all directions
(b) Sluice valve : To control flow of water through pipelines
(c) Air valve : To release the accumul-ated air
(d) Scour valve : To remove silt in a pipeline
[ESE : 1996]

5.2 The following steps are involved in making a spigot and socket joint of cast iron pipes used in water supply systems:
1. Tarred gasket or hemp yarn is wrapped around the spigot.
2. The spigot end is centred into the socket end of the preceding pipe.
3. A jointing ring is placed around the barrel and against the face of the socket.
4. The gasket or hemp yarn is caulked slightly.
5. Molten pig lead is poured and then caulked.

The correct sequence of these steps is
(a) 2, 1, 4, 3, 5 (b) 2, 1, 3, 4, 5
(c) 1, 2, 4, 5, 3 (d) 1, 2, 3, 5, 4
[ESE : 1997]

5.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Dead-end system
B. Grid-iron system
C. Ring system
D. Radial system

List-II
1. Equal pressures and multiple flow paths
2. Both economy and reasonably equal pressures
3. Economy and simplicity
4. Zonal distribution

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	2	4	1	3
(c)	3	1	2	4
(d)	2	1	4	3

[ESE : 1997]

5.4 In a flow-mass curve study, the demand line drawn from a ridge does not intersect the mass curve again. This implies that
(a) the reservoir is not full at the beginning
(b) the storage is not adequate
(c) the demand cannot be met by the inflow as the reservoir will not refill
(d) the reservoir is wasting water by spill
[ESE : 1998]

5.5 Which one of the following is the purpose of providing a surge tank in a pipeline carrying water?
(a) To store water
(b) To increase the pressure throughout the pipeline
(c) To store overflowing water
(d) To protect the pipeline against water hammer
[ESE : 1998]

5.6 Service connection consists of
(a) ferrule, stopcock and gooseneck
(b) ferrule, check valve and gooseneck
(c) stopcock, meter and sluice valve
(d) sluice valve, check valve and meter
[ESE : 1999]

5.7 **Assertion (A):** At the ferrule point of a water supply distribution pipe network for Indian towns having a majority of two-storey buildings, the ideal minimum pressure head of water is 12 m.
Reason (R): This magnitude of pressure head at ferrule is necessary to reach the highest floor of the two storey buildings.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

6. Waste Water Quality Characteristics

6.1 Which of the following pairs is not correctly matched?
(a) BOD : Strength of sewage
(b) Methane : Product of anaerobic decomposition
(c) COD : Biodegradability of waste-water
(d) Nitrate : Methaemoglobinemia
[ESE : 1996]

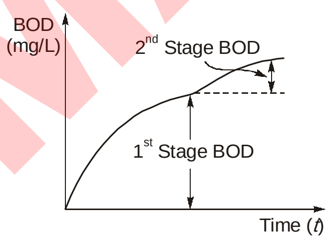
6.2 The formation for BOD assimilation in a stream should include
(a) BOD rate constant
(b) sedimentation of organic matter
(c) BOD rate constant and sedimentation of organic matter
(d) pathogenic bacterial decay coefficient
[ESE : 1996]

6.3 The following data pertain to a sewage sample:
Initial DO = 10 mg/L
Final DO = 2 mg/L
Dilution to 1%
The BOD of the given sewage sample is
(a) 8 mg/L (b) 10 mg/L
(c) 100 mg/L (d) 800 mg/L
[ESE : 1997]

6.4 Consider the following statements associated with water pollution parameters:
1. One of the primary indicators of the degree of water pollution is the concentration of organic matter.
2. Total organic carbon (TOC), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) are important parameters of water pollution.
3. Generally TOC > COD > BOD.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3
[ESE : 1999]

6.5 The second stage BOD as shown in the figure is due to



(a) experimental error
(b) increased activity of bacteria
(c) nitrification demand
(d) interference by certain chemical reactions
[ESE : 1999]

7. Disposal of Sewage Effluent

7.1 A polluted stream undergoes self-purification in four distinct zones:
1. Zone of clear water
2. Zone of active decomposition
3. Zone of degradation
4. Zone of recovery

The correct sequence of these zones is
(a) 3, 4, 2, 1 (b) 2, 3, 4, 1
(c) 2, 4, 3, 1 (d) 3, 2, 4, 1
[ESE : 1995]

7.2 An industrial waste water enters a stream having a BOD concentration of 10 mg/L and a flow of 20 m^3/s. If the flow of wastewater is 1.5 m^3/s and its BOD concentration is 250 mg/L, then the BOD concentration in the stream at a point downstream of the point of confluence of wastewater with the stream will be
(a) 2.67 mg/L (b) 12.09 mg/L
(c) 13.00 mg/L (d) 26.74 mg/L
[ESE : 1995]

7.3 Eutrophication of water bodies is caused by the
(a) discharge of toxic substances
(b) excessive discharge of nutrients
(c) excessive discharge of suspended solids
(d) excessive discharge of chlorides
[ESE : 1996]

7.4 Which of the following pairs is/are correctly matched?
1. Eutrophication... Nutrient accumulation leading to ecosystem change occurring in impounded water
2. Autotrophism... Utilization, rearrange-ment and decom-position of complex materials predominate
3. Heterotrophism... Predominance of fixation of light energy, use of simple inorganic substances and built-up of complex substances

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 alone
(c) 2 and 3 (d) 1 and 3

[ESE : 1997]

7.5 Self purification of running streams may be due to
(a) sedimentation, oxidation and coagulation
(b) dilution, sedimentation and oxidation
(c) dilution, sedimentation and coagulation
(d) dilution, oxidation and coagulation

[ESE : 1997]

7.6 Sewage sickness occurs when
(a) sewage contains pathogenic organisms
(b) sewage enters the water supply system
(c) sewers get clogged due to accumulation of solids
(d) voids of soil clogged due to continuous application of sewage on a piece of land

[ESE : 1997]

7.7 The following zones are formed in a polluted river
1. Zone of clear water
2. Zone of active decomposition
3. Zone of recovery
4. Zone of pollution

The correct sequence in which these zones occur progressively downstream in a polluted river is
(a) 4, 2, 1, 3 (b) 4, 2, 3, 1
(c) 2, 4, 3, 1 (d) 2, 4, 1, 3

[ESE : 1998]

7.8 For fish habitat in a river, the minimum dissolved oxygen required is
(a) 2 mg/L (b) 4 mg/L
(c) 8 mg/L (d) 10 mg/L

[ESE : 1999]

7.9 Sewage sickness is a term used for
(a) persons who become sick after drinking polluted water
(b) a treatment plant which does not function properly
(c) a stream where the flora and fauna die due to sewage inflow
(d) the condition of land where sewage is applied continuously for a long period

[ESE : 1999]

8. Treatment of Waste Water

8.1 Match **List-I** (Process) with **List-II** (Biological agent) and select the correct answer using the codes given below the lists:

List-I
A. Oxidation ditch
B. Waste stabilization pond
C. Imhoff tank
D. Rotating Biological Contractor (RBC)

List-II
1. Facultative bacteria
2. Anaerobic bacteria
3. Aerobic bacteria (suspended culture)
4. Aerobic bacteria (attached culture)

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	3	1	2	4
(c)	1	2	3	4
(d)	3	4	1	2

[ESE : 1995]

8.2 One litre of sewage, when allowed to settle for 30 minutes gives a sludge volume of 27 cm^3. If the dry weight of this sludge is 3.0 grams, then its sludge volume index will be
(a) 9 (b) 24
(c) 30 (d) 81

[ESE : 1995]

8.3 **Assertion (A):** In waste-water treatment, waste stabilisation ponds are more successful in sunny tropical regions.
Reason (R): The bacterial action of purification is achieved through photo-synthetic bacteria.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

8.4 The waste stabilization ponds can be
(a) aerobic (b) anaerobic
(c) facultative (d) any of the above

[ESE : 1996]

8.5 The following are the sewage treatment processes:
1. Primary sedimentation
2. Screening
3. Grit removal
4. Secondary sedimentation

When only preliminary treatment is to be given for sewage, select the required treatment processes including their correct sequence from the codes below:

(a) 2, 3 (b) 2, 3, 1
(c) 1, 2, 3, 4 (d) 3, 1, 2, 4

[ESE : 1996]

8.6 Match **List-I** (Impurities to be removed from sewage) with **List-II** (Treatment unit used) and select the correct answer using the codes given below the lists:

List-I
A. Large floating matter
B. Suspended inorganic matter
C. Suspended organic matter
D. Dissolved organic matter

List-II
1. Trickling filter
2. Primary clarifier
3. Grit chamber
4. Screens

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	3	4	1	2
(c)	4	3	2	1
(d)	4	3	1	2

[ESE : 1997]

8.7 A grit chamber of dimensions 12.0 m × 1.50 m × 0.80 m liquid depth has a flow of 720 m^3/hr. Its surface loading rate and detention time are, respectively

(a) 4000 $m^3/hr/m^2$ and 1.2 minute
(b) 40000 Lph/m^2 and 40 minutes
(c) 40 $m^3/hr/m^2$ and 12 minutes
(d) 40000 Lph/m^2 and 1.2 minutes

[ESE : 1997]

8.8 Which of the following are claimed advantageous in respect of anaerobic sludge digestion as compared to aerobic sludge digestion?
1. Lower BOD concentration in super-natant liquor.
2. Production of a sludge with excellent dewatering propensity.
3. Greater production of methane.
4. Lesser operating cost.
5. Lesser capital cost.

Select the correct answer using the codes given below:

(a) 1, 2 and 4 (b) 2, 3, 4 and 5
(c) 3, 4 and 5 (d) 1, 2 and 5

[ESE : 1997]

8.9 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Sludge disposal	**1.** Seeding
B. Sludge digestion	**2.** Biofilters
C. Aerobic action	**3.** Lagooning
D. Recirculation	**4.** Contact bed

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	3	1	2	4
(c)	1	3	2	4
(d)	1	3	4	2

[ESE : 1997]

8.10 Which of the following waste disposal tasks are achieved by a septic tank with its dispersion trench?
1. Aerobic sludge digestion
2. Settling and anaerobic sludge digestion
3. Anaerobic sewage stabilization
4. Bio-oxidation of effluent

Select the correct answer using the codes given below:

(a) 1 and 3 (b) 3 and 4
(c) 2 and 4 (d) 1 and 4

[ESE : 1997]

8.11 **Assertion (A):** Horizontal velocity of flow through grit chambers is maintained between 24 to 30 cm/sec.

Reason (R): Removal of organic and inorganic particles larger than 0.1 mm diameter is very essential.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

8.12 The following three stages are known to occur in the biological action involved in the process of sludge digestion:
1. Acid fermentation
2. Alkaline fermentation
3. Acid regression

The correct sequence of these stages is
(a) 1, 2, 3 (b) 2, 3, 1
(c) 3, 1, 2 (d) 1, 3, 2

[ESE : 1998]

8.13 Fresh sludge has moisture content of 99% and, after thickening, its moisture content is reduced to 96%. The reduction in volume of sludge is
(a) 3% (b) 5%
(c) 75% (d) 97%

[ESE : 1998]

8.14 In the oxidation ditch, the excess sludge is taken to
(a) anaerobic digestor
(b) aerobic digester
(c) drying beds
(d) incinerator

[ESE : 1998]

8.15 The flow sheet of the liquid stream of a sewage treatment scheme consists of
1. Trickling filter
2. Primary settling tank
3. Grit chamber
4. Screen chamber
5. Secondary settling tank

The correct sequence of these units in the sewage treatment scheme of a liquid stream is
(a) 3, 4, 1, 2, 5 (b) 3, 4, 2, 1, 5
(c) 4, 3, 1, 2, 5 (d) 4, 3, 2, 1, 5

[ESE : 1998]

8.16 Which one of the following pairs is NOT correctly matched?
(a) Activated sludge...aeration
(b) Trickling filters...attached growth system
(c) Oxidation ditch...algae
(d) Channel grit chamber...proportional weir

[ESE : 1998]

8.17 The two main gases liberated from an anaerobic sludge digestion tank would include
(a) ammonia and carbon dioxide
(b) carbon dioxide and methane
(c) methane and hydrogen sulphide
(d) ammonia and methane

[ESE : 1998]

8.18 Which one of the following sewage treatment units has a Parshall flume?
(a) Trickling filter (b) Oxidation ditch
(c) Grit chamber (d) Aerated lagoon

[ESE : 1998]

8.19 Which one of the following principal types of reactors is related to trickling filter?
(a) Plug flow (b) Complete-mix
(c) Packed-bed (d) Fluidized-bed

[ESE : 1998]

8.20 Which one of the following is LEAST important in the activated sludge process?
(a) Proper proportion of the return sludge from the secondary settling tank
(b) Adequate aeration in the biological reactor, so as to maintain certain minimum dissolved oxygen
(c) Proper food to micro-organisms (F : M) ratio
(d) The sludge volume index of the return sludge to be less than 200

[ESE : 1998]

8.21 Match **List-I** (Nature of the solids) with **List-II** (Unit operation or process connected with its removal) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Dissolved solids	**1.** Sedimentation
B. Colloidal solids	**2.** Reverse osmosis
C. Volatile solids	**3.** Coagulation
D. Settleable solids	**4.** Digestion

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	3	2	4	1

(c) 2 3 1 4
(d) 3 2 1 4

[ESE : 1998]

8.22 Sludge bulking can be controlled by
(a) chlorination (b) coagulation
(c) aeration (d) denitrification

[ESE : 1998]

8.23 The purpose of a propo rtional weir at the effluent end of a channel type grit removal unit is to
(a) provide easy passage of solid particles
(b) measure the rate of flow in the channel
(c) keep the depth of flow in the channel above a certain value
(d) maintain constant mean velocity in the channel

[ESE : 1999]

8.24 The correct sequence of the sludge digestion steps is
(a) acid formation, hydrolysis, methane formation
(b) methane formation, acid formation, hydrolysis
(c) hydrolysis, methane formation, acid formation
(d) hydrolysis, acid formation, methane formation

[ESE : 1999]

8.25 Consider the following statements about waste stabilization ponds:
1. The pond has a symbiotic behaviour of waste stabilization through algae on one hand and bacteria on the other.
2. The oxygen in ponds is provided by algae through photosynthesis.
3. The detention period for waste stabilization pond is of the order of two to three days.
4. The bacteria, which develop in the pond, are aerobic bacteria.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2 and 4 (d) 1 and 2

[ESE : 1999]

8.26 For a colony of 10,000 persons having sewage flow rate of 200 L/capita/day, BOD of applied sewage of 300 mg/L and organic loading of 300 kg/day/hectare, the area of an oxidation pond required for treating the sewage of the colony is
(a) 0.2 hectares (b) 1 hectare
(c) 2 hectares (d) 6 hectares

[ESE : 1999]

8.27 **Assertion (A):** Vent should be provided over both the septic tank and the seepage pit.
Reason (R): The vent pipes remove the gases that are generated due to bacterial action and avoid building up of pressure.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

9. Design of Sewers & Sewerage System

9.1 In transition of sewers from smaller diameter sewers to larger diameter sewers, the continuity of sewers is maintained at the
(a) bottom of the concrete bed of sewers
(b) inverts of the sewers
(c) crowns of the sewers
(d) hydraulic gradients of the sewers

[ESE : 1995]

9.2 The slope of a 1.0 m diameter concrete sewer laid at a slope of 1 in 1000, develops a velocity of 1 m/s, when flowing full. When it is flowing half-full, the velocity of flow through the sewer will be
(a) 0.5 m/s (b) 1.0 m/s
(c) 2 m/s (d) 2.0 m/s

[ESE : 1995]

9.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Soil pipe	**1.**	Ventilating pipe
B.	Intercepting trap	**2.**	Wash basin
C.	P-trap	**3.**	Water closet waste
D.	Cowl	**4.**	House drainage

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	3	4	2	1
(c)	4	3	2	1
(d)	4	3	1	2

[ESE : 1995]

9.4 The entry of foul smelling gases into the house coming from the sewers can be prevented by
(a) providing water seals for all the fixtures

(b) providing water seals for all the fixtures and a vent pipe in the plumbing system
(c) providing sufficient vent pipes in the plumbing system
(d) exhaust fans

[ESE : 1996]

9.5 **Assertion (A):** While laying a sewer line, the socket end of a sewer is kept facing the downward slope in the trench.

Reason (R): The socket end being heavy will slide down the slope if it faces the downward slope.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

9.6 Self-cleansing velocity is
(a) the minimum velocity of flow required to maintain a certain amount of solids in the flow
(b) the maximum velocity of flow required to maintain a certain amount of solids in the flow
(c) such flow velocity as would be sufficient to flush out any deposited solids in the sewer
(d) such flow velocity as would be sufficient to ensure that sewage does not remain in the sewer

[ESE : 1997]

9.7 The following steps are involved in laying a sewer in a trench:
1. Transferring the centre line of the sewer to the bottom of a trench.
2. Setting sight rails over the trench.
3. Driving pegs to the level of the invert line of the sewer.
4. Placing the sewer in the trench.

The correct sequence of these steps is
(a) 1, 2, 3, 4 (b) 2, 3, 4, 1
(c) 4, 2, 3, 1 (d) 2, 3, 1, 4

[ESE : 1997]

9.8 In the design of storm sewers, "time of concentration" is relevant to determine the
(a) rainfall intensity
(b) velocity in the sewer
(c) time of travel
(d) area served by the sewer

[ESE : 1997]

9.9 Which one of the following would help prevent the escape of foul sewer gases from a water closet?
(a) Air gap (b) Vent pipe
(c) Gully trap (d) none of these

[ESE : 1997]

9.10 The maximum flow occurs in an egg shaped sewer when the ratio of flow to vertical diameter is
(a) 0.33 (b) 0.50
(c) 0.95 (d) 1.00

[ESE : 1998]

9.11 In a design of storm sewers, if the time taken by rain-water to flow from the farthest point of the watershed to the sewer inlet is 't_i' and the time of flow of water from the sewer inlet to the point in the sewer that is under consideration is 't_f' then the time of concentration will be
(a) t_i
(b) t_f
(c) $t_i + t_f$
(d) t_i or t_f whichever is greater

[ESE : 1999]

9.12 A circular sewer of diameter 1 m carries storm water to a depth of 0.75 m. The hydraulic radius is approximately
(a) 0.3 m (b) 0.4 m
(c) 0.5 m (d) 0.6 m

[ESE : 1999]

9.13 The trap used for a water closet is called
(a) gully trap (b) P-trap
(c) intercepting trap (d) anti-siphon trap

[ESE : 1999]

9.14 Consider the following statements:
Ventilation of sewer lines is necessary to
1. avoid building up of sewer gases
2. ensure atmospheric pressure in the waste water surface
3. ensure the safety of sewer maintenance people
4. provide oxidation facility to sewage

Which of these statements are correct?

(a) 1, 2 and 4 (b) 1, 3 and 4

(c) 2, 3 and 4 (d) 1, 2 and 3

[ESE : 1999]

10. Municipal Solid Waste Management

10.1 Which one of the following solid waste disposal methods is ecologically most acceptable?

(a) Sanitary landfill (b) Incineration

(c) Composting (d) Pyrolysis

[ESE : 1995]

10.2 Non-disposal of solid waste may cause the spread of

(a) malaria

(b) rodents related plague

(c) typhoid

(d) dysentery

[ESE : 1996]

10.3 Which of the following materials are used as landfill sealants for the control of gas and leachate movements?

1. Lime 2. Sand
3. Bentonite 4. Fly ash
5. Butyl rubber

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 4 and 5

(c) 3 and 5 (d) 1, 2 and 4

[ESE : 1997]

10.4 The typical density in kg/m^3 (in situ) of well-compacted municipal solid waste in landfill is in the range of

(a) 100 to 300 (b) 310 to 500

(c) 550 to 850 (d) 900 to 1100

[ESE : 1997]

10.5 Which one of the following methods can be employed for plastic and rubber waste disposal?

(a) Composting (b) Incineration

(c) Sanitary landfill (d) Pyrolysis

[ESE : 1998]

10.6 **Assertion (A):** Sanitary landfills can no longer be used for the disposal of solid wastes in India.

Reason (R): The leachates from sanitary landfills may pollute the ground water.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true [ESE : 1999]

10.7 Match **List-I** (Methods of solid wastes disposal) with **List-II** (Terms pertaining to the methods) and select the correct answer using the codes given below the lists:

List I

A. Incineration

B. Sanitary landfill

C. Composting

D. Salvage by sorting

List-II

1. Requires presorting, grinding and turning

2. Limited to special wastes and selected materials

3. High operational and maintenance cost

4. Tractor

5. Rat and fly breeding

Codes:

	A	B	C	D
(a)	2	5	4	3
(b)	1	4	2	3
(c)	3	4	1	2
(d)	3	5	4	2

[ESE : 1999]

11. Air Pollution

11.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. CO	**1.** Greenhouse effect
B. CO_2	**2.** Acid rains
C. SO_2	**3.** Acute toxicity
D. NO_x	**4.** Ozone liberation at ground level

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	4	1
(c)	3	1	2	4
(d)	4	1	2	3

[ESE : 1995]

11.2 The atmosphere extends upto a height of 10,000 km. It is divided into the following four thermal layers:

1. Mesosphere
2. Stratosphere
3. Thermosphere
4. Troposphere

The correct sequence of these starting from the surface of the earth upwards is

(a) 2, 4, 1, 3
(b) 4, 2, 1, 3
(c) 4, 2, 3, 1
(d) 2, 4, 3, 1

[ESE : 1995]

11.3 Which of the following air pollutants is/are responsible for photochemical smog?

1. Oxides of nitrogen
2. Ozone
3. Unburnt hydrocarbons
4. Carbon monoxide

Select the correct answer using the codes given below:

(a) 1 alone
(b) 2, 3, and 4
(c) 1, 3 and 4
(d) 1 and 3

[ESE : 1997]

11.4 Match **List-I** (Equipment) with **List-II** (Pollutants removed) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Electrostatic precipitators	1. Coarse particles
B. Cyclones	2. Fine dust
C. Wet scrubbers	3. Gas
D. Adsorbers	4. Sulphur dioxide

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	4	3

[ESE : 1997]

11.5 Match **List-I** (Pollutants) with **List-II** (Sources) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Acid water	1. Volcanoes
B. SO_2	2. Automobiles
C. CO	3. Thermal power station
D. Fly ash	4. Mining

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	4	1	3	2
(c)	1	4	3	2
(d)	1	4	2	3

[ESE : 1998]

11.6 Aerosol is

(a) carbon particles of microscopic size
(b) dispersion of small solid or liquid particles in gaseous media
(c) finely divided particles of ash
(d) diffused liquid particles

[ESE : 1998]

11.7 Match **List-I** (Air pollutant) with **List-II** (Environmental effect) and select the-correct answer using the codes given below the lists:

List I

A. Carbon monoxide
B. Particulate matter
C. Nitrogen oxides
D. Sulphur dioxide

List-II

1. Respiratory distress for living beings
2. Chemical reaction with haemoglobin in blood
3. Reduction in visibility and aeroallergens carrier
4. Photochemical smog in atmosphere

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	3	2	4	1
(c)	2	3	4	1
(d)	3	2	1	4

[ESE : 1999]

11.8 If carbon monoxide is released at the rate of 0.03 m^3/min from a gasoline engine and 50 ppm is the threshold limit for an 8 hour exposure, the quantity of air which dilutes the contaminant to a safe level will be

(a) 60 m^3/min
(b) 600 m^3/min
(c) 60 m^3/s
(d) 600 m^3/s

[ESE : 1999]

12. Noise Pollution

12.1 Two sources generate noise levels of 90 dB and 94 dB respectively. The cumulative effect of these two noise levels on the human ear is
(a) 184 dB (b) 95.5 dB
(c) 94 dB (d) 92 dB
[ESE : 1997]

12.2 The sound pressure level for a jet plane on the ground with sound pressure of 2000μ bar should be
(a) 60 decibel (b) 100 decibel
(c) 140 decibel (d) 180 decibel
[ESE : 1999]

■■■■

Answers Environmental Engineering

1.1	(b)	1.2	(c)	1.3	(d)	1.4	(a)	2.1	(d)	2.2	(d)	2.3	(b)	2.4	(a)	2.5	(d)
2.6	(a)	3.1	(a)	3.2	(b)	3.3	(c)	3.4	(c)	3.5	(c)	3.6	(a)	3.7	(c)	3.8	(d)
3.9	(b)	3.10	(b)	4.1	(c)	4.2	(a)	4.3	(a)	4.4	(c)	4.5	(b)	4.6	(d)	4.7	(b)
4.8	(b)	4.9	(a)	4.10	(d)	4.11	(a)	4.12	(d)	4.13	(c)	4.14	(a)	4.15	(c)	4.16	(a)
4.17	(d)	4.18	(b)	4.19	(a)	4.20	(b)	4.21	(d)	4.22	(a)	4.23	(c)	4.24	(d)	4.25	(d)
5.1	(a)	5.2	(c)	5.3	(c)	5.4	(c)	5.5	(d)	5.6	(a)	5.7	(a)	6.1	(c)	6.2	(a)
6.3	(d)	6.4	(b)	6.5	(c)	7.1	(d)	7.2	(d)	7.3	(b)	7.4	(b)	7.5	(b)	7.6	(d)
7.7	(b)	7.8	(b)	7.9	(d)	8.1	(b)	8.2	(a)	8.3	(c)	8.4	(d)	8.5	(a)	8.6	(c)
8.7	(d)	8.8	(b)	8.9	(a)	8.10	(c)	8.11	(c)	8.12	(d)	8.13	(c)	8.14	(c)	8.15	(d)
8.16	(c)	8.17	(b)	8.18	(c)	8.19	(c)	8.20	(d)	8.21	(a)	8.22	(a)	8.23	(d)	8.24	(d)
8.25	(d)	8.26	(c)	8.27	(d)	9.1	(c)	9.2	(b)	9.3	(b)	9.4	(b)	9.5	(d)	9.6	(c)
9.7	(d)	9.8	(a)	9.9	(d)	9.10	(c)	9.11	(c)	9.12	(a)	9.13	(b)	9.14	(d)	10.1	(c)
10.2	(c)	10.3	(c)	10.4	(c)	10.5	(d)	10.6	(d)	10.7	(c)	11.1	(c)	11.2	(b)	11.3	(d)
11.4	(b)	11.5	(a)	11.6	(b)	11.7	(c)	11.8	(b)	12.1	(b)	12.2	(c)				

Explanations Environmental Engineering

1. Water Demand

1.1 (b)

The various regulations are:
(i) The Forest Act, 1927
(ii) The Wild Life (Protection) Act, 1927
(iii) The Water (Prevention and Control of Pollution) Act, 1974
(iv) The Water (Prevention and Control of Pollution) Cess Act, 1977
(v) The Forest conservation Act, 1980
(vi) The Air (Prevention and Control of Pollution) Act, 1981
(vii) The Environment (Protection) Act, 1986
(viii) The Public Liability Insurance Act, 1991

1.2 (c)

Design period considers the useful life of any structure. Further hydrological analysis for design of the hydraulic structure considers the frequency of occurrence of extremes of river flow. It is not relevant for designing of structures in general.

1.3 (d)

The daily per capita consumption of water depends on the following factors.

Factors Affecting	Remarks
Size of the city	Demand increases with the size of the city. Big cities are generally sewered, also commercial and industrial activities are generally more, thus requireing more water.
Calimatic conditions	At hotter and dry places, the consumption of water is generally more.
Types of gentry and habits of people	The amount of water consumption is directly dependent upon the economic status of the consumers. Ex. Rich and upper class communities generally consume more water due to their affluent living standards.
Industrial and commercial activities	Industrial and commercial activities at a particular place increases the water consumption by large amounts.
Quality of water supplies	If the quality and taste of the supplied water is good, it will be consumed more.
Pressure in the distribution system	If the pressure in the distribution pipe is high and sufficient to make the water reach at 3rd or even 4th storey water consumption shell definitely be more.
System of supply	The water may be supplied to either continuously or intermittently. The intermittent supplies, may lead to some savings in water consumption due to losses occurring for lesser time.
Cost of water	If the water rates are high lesser quantity may be consumed by people.
Policy of metering and method of charges	To avoid wastage of water, the government sometimes used metered water supply. In metered water supply government can keep track amount of water used, it reduces the tendency of people to waste water.

1.4 (a)

Water demand for certain important industries:

S.No.	Name of Industry	Unit of production or raw material used	Approximate quantity of water required per unit of production/ raw material in kilolitres (kl/unit/day)
1.	Automobiles	Vehicle	40
2.	Fertilizers	Tonne	80-200
3.	Leather	Tonne (per 100 kg)	40 4
4.	Paper	Tonne	4200-400
5.	Crude petroleum refinery	Tonne	1-2
6.	Textile	Tonne (goods)	80-140
7.	Sugar	Tonne (crusted cane)	1-2

(Based on old GOI manual data as it is an old question)

2. Sources of Water and Well

2.1 (d)

Yield of a well means the discharge from the well excavated through given aquifer

$$Q = nv_a A = KiA$$

where

n is porosity

v_a is actual flow velocity of ground water

A is area of the aquifer opening into the wells

K is permeability of soil

2.2 (d)

Soil Classification of an Aquifer	Hydraulic Conductivity (m/day)	Drainage characteristics
Gravel	100-1000	Pervious
Sand	1-10	Pervious
Silt	0.1-0.01	Slightly pervious
Clay	10^{-5} to 10^{-6}	Impervious

2.3 (b)

Hand pumps are manually operated pumps; they use human power and mechanical advantage to move fluids or air from one place to another. There are many different types of hand pump available, mainly operating on a piston, diaphragm or rotary vane principle with a check valve on the entry and exit ports to the chamber operating in opposing directions. Most hand pumps have plungers or reciprocating pistons, and are positive displacement. All other pumps operate at very high rpm and hence cannot be used as hand pump.

2.4 (a)

Specific Yield + Specific Retention = Porosity

- Specific Yield is the ratio of volume of water in an aquifer that can be extracted by the force of gravity to the total volume of the saturated aquifer.
- Specific Capacity of a well is its yield per unit drawdown.
- Specific Retention is the ratio of volume of water retained in an aquifer to the total volume of the saturated aquifer.
- Specific Storage is the volume of water released from unit volume of aquifer for unit decline in piezometric head.

2.5 (d)

In Artesian aquifer or Confined aquifer the water present is usually above atmospheric pressure as it is confined between two impermeable stratas thus preventing it from any exposure to atmospheric pressure.

2.6 (a)

Transmissibility, $T = \Sigma kd$

$= (4 \times 30) + (2 \times 10) + (6 \times 20)$

$= 120 + 20 + 120 = 260\ m^2/day$

3. Water Quality Parameters

3.1 (a)

Carbonate hardness is equal to total hardness or alkalinity, whichever is less i.e. 100 mg/L

Non-carbonate hardness

= Total hardness – Alkalinity

= 300 – 100

= 200 mg/L

3.2 (b)

An approximate analysis for TDS is often made by determining the electrical conductivity of the water. The ability of water to conduct electricity is called specific conductance and it is a function of its ionic strength. Unfortunately, specific conductance and concentration of TDS are not related on a one to one basis. Only ionized substances contribute to specific conductance. Organic molecules and compounds that dissolve without ionizing are not measured. Additionally, the magnitude of specific conductance is influenced by the valence of the ions in the solution, their mobility and their relative numbers. The temperature also has an important effect with specific conductance increasing as the water temperature increases. The ions usually accounting for majority of TDS in natural waters are Na, Ca, Mg, HCO_3^-, SO_4^{2-}, Cl^-, etc. Hence their presence increases the electrical conductivity of water.

3.3 (c)

Rivers during monsoon season have high suspended solids concentration in suspension. This causes high turbidity.

3.4 (c)

E-coli is a nonpathogenic bacteria of Fecal coliform group of organisms. These are believed to have long survival time outside the animal body than most pathogens have because the die-off rate of fecal coliform (E-coli) is logarithmic. The number of surviving organisms may be an indication of the time lapse since contamination.

3.5 (c)

- Fluoride or fluorine deficiency is a disorder which may cause increased dental caries (or tooth decay) is the breakdown of dental tissues by the acidic products released by the "bacterial fermentation of dietary carbohydrates.") and possibly osteoporosis (a bone disorder which leads to a decrease in bone mass, and an increase in bone fragility).
- Lead in excess is toxic to many organs and tissues including heart, kidney, bones, intestines, reproductive system and nervous system. Hence it should not be greater than 0.05 mg/*l*. Excess lead causes anaemia.
- Too much of nitrates is harmful for infants and causes Methemoglobinemia or Blue Baby Disease.
- Iodine deficiency causes Goitre.

3.6 (a)

Turbidity, bacterial count and iron has no significant effect on efficiency of boiler. However, hardness causes scaling.

3.7 (c)

Coliform group organisms have following characteristics.

(i) It is bacillus (straight rod like shape with square or rounded ends)

(ii) Gram negative rods will be present

(iii) Glucose (Lactose bile) fermentation and gas production within 24 ± 2 to 48 ± 3 hours of incubation.

(iv) No spores should be present.

3.8 (d)

Some amount of chlorides is needed for maintaining salt balance of body. The permissible limit for chlorides is 250 mg/L.

3.9 (b)

The alkalinity is measured by titrating the water with an acid and determining the hydrogen equivalent. Alkalinity is expressed as mg/L of $CaCO_3$. Methyl orange is an indicator with pH range 2.8 to 4.4. It changes colour from red to yellow and thus indicates end of titration.

The hardness due to monovalent cations like Na^+ is called pseudo hardness.

Total alkalinity = carbonate + bicarbonate + hydroxide alkalinity

If total alkalinity is more than or equal to total hardness.

Carbonate hardness = total hardness

Non carbonate hardness = 0

3.10 (b)

Small amout of chlorine (practically 0.2 gm/*l*) of residual is ensure of the break point to safeguard the water against future recontamination, not for it is uneconomical to remove.

4. Water Treatment

4.1 (c)

First chloramines (combined residuals) will form by reaction of ammonia with chlorine. The chloramines are formed first by following reactions of ammonia and chlorine (hypochlorous acid HOCl)

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$
$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$$
$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$$

At pH > 6.5 monochloramine will be the predominant species.

Then free residual chlorine compounds (HOCl and OCl^-) will form as follows:

$$Cl_2 + H_2O \rightarrow HOCl + H^+$$
$$HOCl \rightleftharpoons H^+ + OCl^-$$

Thus correct sequence is $NH_2Cl - NHCl_2 - HOCl - OCl$

4.2 (a)

Surface water contains inorganic suspended matter, organic suspended matter and pathogens mainly. They are generally soft and less corrosive than ground water. So coagulation, flocculation, sedimentation, filtration and disinfection shall be the treatment.

Ground water has no suspended matter and it can be used after disinfection.

Lake water will have odour, taste and colour due to heavy algal growth. Some turbidity will also be there due to mixing of layers. So $CuSO_4$ treatment for colour, odour and taste followed by coagulation, sedimentation, filtration and disinfection is needed.

4.3 (a)

Defluoridation using Nalgonda technique uses alum with prior mixing of lime (CaO) or sodium carbonate (Na_2CO_3). The added lime helps to ensure adequate alkalinity required for effective hydrolysis of alum, so that residual alum does not remain in the treated water.

4.4 (c)

Large *G* value with short times tend to produce small, dense flocs, while low *G* values and long time produce larger, lighter flocs. Since large, dense flocs are more easily removed in the settling basin, it will be advantageous to have high *G* values at inlet compared to the outlet end.

4.5 (b)

Chlorides are generally present in water in the form of sodium chloride and may be due to leaching of marine sedimentary deposits, pollution from sea water, brine, or industrial and domestic wastes, etc. Their concentrations above 250 mg/L produce brackish taste which is objectionable. It is measured by potentio-metric method using titration with silver nitrate solution. In Argentometric method, of chloride measurement, silver nitrate titration in the presence of potassium chromate indicator is used. The red precipitate of silver chromate indicates end of titration.

Brackish taste of chlorides can be removed by:

(i) Evaporation and distillation
(ii) Electrodialysis method
(iii) Reverse osmosis method
(iv) Freezing process
(v) Solar distillation method.

Lime soda process and cation exchange process are used for hardness removal. Chemical coagulation is used for colloidal particle removal.

4.6 (d)

The cleaning of slow sand filters is not done by backwashing as is done for rapid gravity filters, but is done by scrapping and removing the 1.5 to 3 cm of top sand layer. The top surface is finally racked, roughened, cleaned and washed with good water.

4.7 (b)

Chlorine immediately reacts with NH_3 present in the water, resulting in the formation of Chloramines which are termed as combined form of chlorine. The various reactions involved in chlorination are as follows:

$$NH_3 + HOCl \xrightarrow{pH > 7.5} \underbrace{NH_2Cl + H_2O}_{\text{Monochloromine}}$$

$$NH_2Cl + HOCl \xrightarrow{pH(5-6.5)} \underbrace{NHCl_2 + H_2O}_{\text{Dishloromine}}$$

$$NHCl_2 + HOCl \xrightarrow{pH < 4.4} \underbrace{NHCl_3 + H_2O}_{\text{Trichloremine}}$$

4.8 (b)

Fluoride can be removed by:

(i) Nalgonda technique
(ii) Activated alumina
(iii) Bone charcoal

Nalgonda technique uses aluminium salt (alum) for removing fluoride.

Manganese and iron can be removed by aeration or manganese zeolite (a natural green sand coated with manganese dioxide).

Taste and odour can be removed by:

(i) Aeration
(ii) Activated carbon
(iii) Copper sulphate

Copper sulphate is an algicide also.

4.9 (a)

For highly turbid and polluted water pre-chlorination before coagulation–sedimentation reduces load on filter and also reduces the taste, odour, algae and other organisms.

4.10 (d)

Uniformity coefficient $C_u = D_{60}/D_{10}$ should be 1.65 for rapid sand filter.

4.11 (a)

- The detention period of a settling tank may be defined as the average theoretical time required for water to flow through the tank length.
- Thus, if we introduce a dye at inlet and measure the time upto which it remain in the basin, we can calculate the detention period.
- Detention time (D_t) for a rectangular tank

$$= \frac{\text{Volume of the tank}}{\text{Rate of flow}} = \frac{BLH}{Q}$$

Similarly, detention time for circular tank

$$= \frac{d^2(0.011d + 0.785H)}{Q}$$

Where, d = dia. of the tank

H = vertical depth at well or side water depth

- D_t = 2 to 4 hrs (for coagulation aided sedimentation) = 4 to 8 hrs (for plain sedimentation).
- Detention period is computed such that within that time frame, most of the suspended solid can settle down and thereby get removed, hence longer detention period increases the efficiency of removal of settleable matter.

4.12 (d)

Ground water sources do not have turbidity so sedimentation, alum doses is not needed.

Both bleaching powder and $KMnO_4$ can be used for disinfection process. $KMnO_4$ is used in rural areas where water is contaminated with lesser amount of bacteria.

4.13 (c)

Ion exchange process is used for zero hardness water.

A variety of dissolved solids can be removed by ion exchange. For hardness removal zeolite (a naturally occurring sodium alumino-silicate material sometime called green sand) and synthetic resins are used. The removal process is based on high adsorption capacity of calcium and magnesium ions compared to sodium ions. In this process exchange sites are utilized to remove hardness. When all the exchange sites are utilized, hardness begins to appear in the effluent. This is called break through and it necessitates the regeneration of the medium by contacting it with a strong sodium-chloride solution.

4.14 (a)

Ozone is the allotropic form of oxygen.

Ozone is a powerful oxidant which reacts with reduced inorganic compounds and with organic material. It reacts vigorously with bacteria and viruses. It is more effective than chlorine in activating resistant strains of bacteria and viruses. It does not form carcinogenic compounds like chlorine by reacting with organic acids etc.

However it is chemically unstable and so it must be produced on site and used immediately. The cost of ozonation is two to three times higher than the cost of chlorination. Since no residual remains, it will be necessary to use small amounts of chlorine after ozonation to provide continued protection against regrowth of pathogens in the distribution system.

4.15 (c)

The dual media filter have filtration rate between 10 to 20 $m^3/h/m^2$. It is approxi-mately 4 times higher than that in rapid sand filter.

The dual media filter has anthracite coal and silica sand as medium. The density of coal is less than sand so coal is on top and the flow occurs from coarse medium to fine medium (silica sand).

	Coal	Sand
Depth (m)	0.3	0.3
Specific gravity	1.4-1.6	2.65
Effective size (mm)	0.9-1.0	0.5- 0.55
Uniformity coefficient	< 1.8	< 1.65

4.16 (a)

The negative pressure in filter media tends to release the dissolved air and other gases present in water. The gas bubbles gets attached to the sand grains and seriously affects the working of the filter. This is called air binding. Algae may also produce oxygen and cause air binding. So algae growth should be controlled by using algicides.

Increase in water temperature reduces solubility of dissolved air and it gets released to cause air binding. So this should be avoided.

The filter should be cleaned as soon as loss of head exceed the optimum allowable values. Herein compressed air and water can be used.

4.17 (d)

Aeration will oxidize the iron and manganese and then they can be separated by sedimentation.

4.18 (b)

The sequence of treatment in a water treatment plant:

Coagulation → Flocculation → Sedimentation → Filtration → Chlorination

4.19 (a)

	Slow sand filter	Rapid sand filter
Effective Size	0.2 mm to 0.4 mm	0.35 to 0.55 mm
Uniformity Coefficient	1.8 to 2.5	1.2 to 1.8

Thus in slow sand filters effective size is less but uniformity coefficient is more than that in rapid sand filter.

4.20 (b)

For mixing basins Gt should be 30,000 to 60,000 where t is the detention period or mixing periods (usually 60 to 120 sec). For flocculator the G value ranges between 20 to 80 s^{-1} and detention period 20 to 60 minutes.

4.21 (d)

If only ammonia is present then first chloramines will be formed. Thus there will be no destruction of chlorine residual by reducing compounds, which is represented by AB. So curve will pass through origin.

4.22 (a)

Rapid Mixing Unit – 30 Seconds
Flocculator – 30 minutes
Propeller Mixing Unit – 10 seconds
Sedimentation Tank – 1.5 hours

4.23 (c)

Common Operational Troubles in Rapid Gravity Filters

Air Binding :

- When the filter is newly commissioned, the loss of head of water percolating through the filter is generally very small. However, the loss of head goes on increasing as more and more impurities get trapped into it.
- A stage is finally reached when the frictional resistance offered by the filter media exceeds the static head of water above the and bed. Most of this resistance is offered by the top 10 to 15 cm sand layer. The bottom sand acts like a vacuum, and water is sucked through the filter media rather than getting filtered through it.
- The negative pressure so developed, tends to release the dissolved air and other gases present in water. The formation of bubbles takes place which stick to the sand grains. This phenomenon is known as Air Binding as the air binds the filter and stops its functioning.
- To avoid such troubles, the filters are cleaned as soon as the head loss exceeds the optimum allowable value, or depth of water during filtration must be increase by 15-20 cm to compensate the lost head and thereby reducing the negative head.
- The problem of incrustation of filter sand media can be avoided with backwashing the filter with solidum hydroxide or bleaching powder occasionally.

Formation of Mud Balls: The mud from the atmosphere usually accumulates on the sand surface to form a dense mat. During inadequate washing this mud may sink down into the sand bed and stick to the sand grains and other arrested impurities, thereby forming mud balls.

Cracking of Filters: The fine sand contained in the top layers of the filter bed shrinks and causes the development of shrinkage cracks in the sand bed. With the use of filter, the loss of head and, therefore, pressure on the sand bed goes on increasing, which further goes on widening these cracks.

Remedial Measures to Prevent Cracking of Filters and Formation of Mud Balls

- Breaking the top fine mud layer with rakes and washing off the particles.
- Washing the filter with a solution of caustic soda.
- Removing, cleaning and replacing the damaged filter sand.

4.24 (d)

In the initial dose of chlorine there is no residual because chlorine, being a strong oxidant, reacts with almost any matter in a reduced state such as Fe^{2+}, Mn^{2+}, H_2S and organics.
Thus there is no exact answer but closest answer will be (d).

4.25 (d)

Disinfection using chlorine is necessary part of water treatment for rural water supply. Therefore (a) and (c) can not be the answer. Before slow sand filter, coagulation is not suitable. Therefore (b) is not possible.

5. Conveyance and Distribution of Water

5.1 (a)

Types of valves	Remarks
Check valve/Reflux valve/ Non-returning valve	It allows the water to flow in one direction only.
Sluice valve/Gate valve/ Shut off valves	These valves are provided to regulate the flow of water through the pipe and are essential to divide the main line into several sections. These valves are usually placed at the summits of the pressure conduits where the pressure is low.
Air valves/Air relief valves	It is provided at the summits to release the air pressure. At every summit of a pipeline and U/S of sluice vale, an air valve should be provided. They ensure gravity flow under atmospheric pressure.
Scour valve/Blow off and Valve/ Drain valve	Similar to sluice valves, but their function is different. It is provided at the dead end of the pipeline. It's function is to remove the sand, silt etc. from the pipeline.
Butterfly valve	Butterfly valve are used to regulate and stop the flow especially in large sized conduits. Butterfly valves involve slightly higher head loss than sluice valves and also are not suitable for continuous throttling.
Relief valve/Safety valve/Pressure relief valves/Cutoff valves	These valves protect the pipeline from bursting. When the pressure of the water suddenly exceeds the permissible pressure due to water hammer phenomenon, then the valve is opened automatically and the excess pressure is released instantaneously.
Ball valves/Bell float valves	It is used to maintain a constant level in a service reservoir or elevated tank.
Needle & Cone valve	It is similar to sluice valve but are more expensive then sluice and butterfly valves. It is suitable for throttling flow.

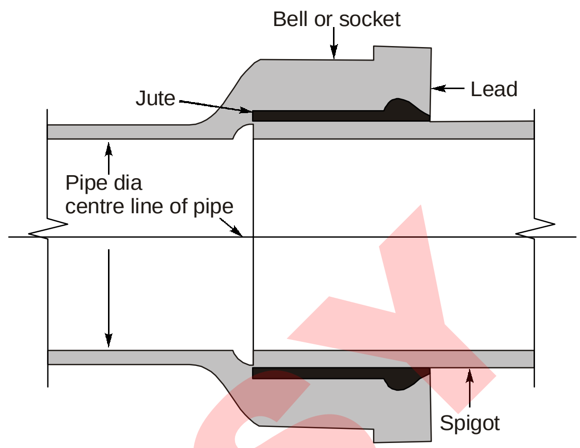
Keypoints: The valve which works automatically are as follows:

1. Check valve/Reflux valve
2. Pressure relief valve
3. Air relief valve

5.2 (c)

Spigot and Socket joint:

- The joint is also called Bell and Spigot joint.



- The plain end of teh pipe is known as spigot end and the expended end is known as bell end.
- The yerm of jute is wound round teh spigot end and a rubber gasket is placed tightly over teh yern.
- The gasket or hemp yern is caulked (filled the space) slightly between the socket and the spigot and is finally filled with molten lead, which gets solidfied and tightly caulked into the joint after cooling, and thus making a water tight joint.

5.3 (c)

- Dead end system is economic and simple, and can be extended or expanded easily.
- In grid-iron system, the water reaches at different places through more than one route. The discharge to be carried by each pipe, the friction loss, and the size of the pipe therefore, get reduced.
- However, more length of pipe lines, a large number of sluice valves and loops make the design difficult and costlier.
- The ring system has lesser number of valves and smaller pipe lengths. The peripheral main pipe maintains reasonably equal pressures at all points.
- In radial system water flow occurs from distribution reservoirs (centre) to branches (periphery and radial) in a radial manner. This ensures high pressure and efficient water distribution to various zones. The calculations for design of sizes are also simple.

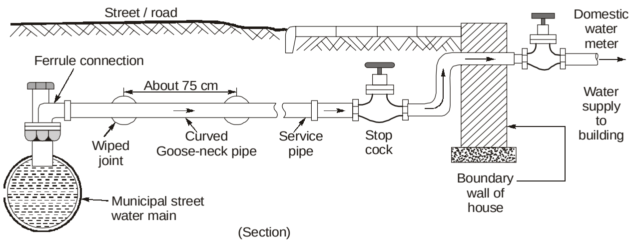
5.4 (c)

In case the demand line drawn from a ridge does not intersect the mass curve again, it means the rate of inflow is less than or equal to rate of demand. So, the reservoir will not be refilled and the demand cannot be met by the inflow.

5.5 (d)

Surge tanks are provided at the end of the line where water hammer is created by rapid closing of a valve.

5.6 (a)



(Section)

Service connection includes ferrules, stop cock, goose pipe, service pipe, water meters, water taps, bib cocks, spouts, pipe fittings such as bends, crosses, tees, elbows, union, plugs, flanges etc.

5.7 (a)

Ferrule point is the connecting point from the main supply line to the domestic connection. The pressure at this point should be such that water can reach the highest floor of the two storey building. Also as per government manuals, for towns where two-storeyed buildings are common, the minimum residual pressure at ferrule point should be 12m.

6. Waste Water Quality Characteristics

6.1 (c)

BOD (Biochemical oxygen demand)

- The amount of oxygen required to carry out the decomposition of biodegradable organic matter only.
- As the organic matter present in sewage is mostly biodegradable, it is the most commonly used method to determine the strength of sewage.

Anaerobic decomposition:

- It takes place under the absence of free oxygen

  Organic matter $\xrightarrow{\text{Anaerobic}}$

  Gases + Unstable product (acids/alcohols) + CO_2 + H_2O + Energy↑ + New cells

  End product — CO_2, CH_4, H_2S and NH_3

  The main product obtained is methane.

COD (Chemical oxygen demand)

- It is the amount of oxygen required to oxidize both the biodegradable and non-biodegradable organic matter.
- **Nitrate:** Methemoglobinemia or blue baby diseases is caused in infants due to high concentration of nitrate in water.

6.2 (a)

In a stream the natural purification processes are:

(i) Dilution
(ii) Sedimentation and resuspension
(iii) Filtration
(iv) Gas transfer i.e., aeration
(v) Heat transfer
(vi) Chemical conversions i.e., oxidation, reduction and precipitation
(vii) Metabolic processes

The BOD (dissolved and suspended) gets diluted when a point/line source discharges waste water into a water body. The suspended organic matter gets settled and resuspended due to eddies. The microorganism consume BOD by metabolic processes and it depends upon BOD rate.

6.3 (d)

BOD = [Initial DO – Final DO] × Dilution Factor

Where Dilution Factor

$$= \frac{\text{Volume of diluted sample}}{\text{Volume of undiluted sample}}$$

$$= (10-2) \times \frac{100}{1} = 800 \text{ mg/L}$$

6.4 (b)

$\left(\frac{COD}{TOC}\right)$ ratio may vary from zero for an organic material resistant to dichromate oxidation to 5.33

for methane. However generally wastewater from houses and industries contain non-biodegradable (refractory) organics so COD > BOD > TOC.

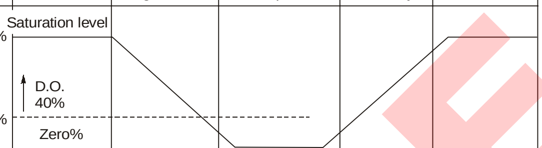
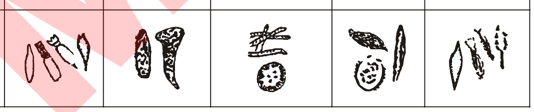
6.5 (c)

The carbonaceous stage, or first stage BOD, represents that portion of oxygen demand involved in the bacterial conversion of organic carbon to carbon dioxide. The nitrogenous stage, or second stage BOD, represents a combined carbonaceous plus nitrogenous demand, when organic nitrogen, ammonia, and nitrite are converted to nitrate by bacteria, a process that also consumes DO.

7. Disposal of Sewage Effluent

7.1 (d)

Table: Showing zone of pollution along a river stream

	Zones of pollution				
	Clear water	Zone of degradation	Zone of active decomposition	Zone of recovery	Zone of clearer water
Dissolved oxygen sag curve (100%, 40%)					
Physical Indices	Clear, water, no bottom sludge, no colour	Floating solids; bottom sludge present, colour getting turbid	Darker and greyish colour, evolution of gases like CH_4, CO_2, H_2S etc. lot of sludge coming to the surface forming an ugly scum layer at top	Turbid with bottom sludge	Clear water with no bottom sludge
Fish presence	Ordinary fish like game, pan, food & forage etc. present.	Tolerant fishes like carp, buffalo, gary, etc. present	No fish present	Tolerant fish like carp, buffalo, etc. are present	Ordinary fish like game, pan, food, and forage, etc. present
Bottom Animals					
Algae & Protozoa etc. called plankton					

7.2 (d)

$$(BOD_{stream})_{D/S} = \frac{Q_1 y_1 + Q_2 y_2}{Q_1 + Q_2}$$

$$= \frac{20 \times 10 + 1.5 \times 250}{20 + 1.5}$$

$$= 26.74 \text{ mg/L}$$

7.3 (b)

Eutrophication is caused by undesired increase in the concentration of nutrients in an ecosystem. Increased nutrient enrichment can arise from both point and non-point sources:

- **Point source pollution**: Pollution that comes from contaminants that enter a waterway from a single identifiable source such as stationary locations or fixed facilities. Examples are discharges from a sewage treatment plant or industrial plants and fish farms.
- **Non-point source pollution**: Pollution from widespread including human activities with no specific point of discharge or entry into receiving watercourses. Examples are leaching out of nitrogen compounds from fertilized agricultural lands and losses from atmospheric deposition.

7.4 (b)

Organisms that use organic carbon for the formation of new biomass are called heterotrophs, while organisms that derive cell carbon from carbon dioxide are called Autotrophs. The conversion of CO_2 to cellular complex compounds requires a reductive process, which requires a net input of energy. Therefore autotrophic organisms must spend more of their energy for synthesis, than do heterotrophs, resulting in generally lower yield of cell mass and growth rates. Eutrophication is caused by nutrients like carbon, nitrogen and phosphorous. It is a natural process of algal production and siltation of water body. The water body becomes shallower.

7.5 (b)

The major physical processes involved in self purification of watercourses are dilution, sedimentation and resuspension, gas transfer, and heat transfer. Gas transfer includes oxidation.

7.6 (d)

When sewage is applied continuously on a piece of land, the soil pores or voids may get filled up and clogged with sewage matter retained in them.

Thus free circulation of air will be prevented and anaerobic conditions will develop within the pores. Sewage sickness is the condition when soil pores get filled up and clogged with sewage matter due to continuous application of waste water effluents. This develops anaerobic conditions and foul gases like methane, carbon-dioxide and hydrogen sulphide are evolved.

In order to prevent sewage sickness:

(i) Sewage should be given primary treatment
(ii) The soil chosen for effluent irrigation/sewage farming should be sandy or loamy.
(iii) A proper under drainage system (open jointed drains) should be designed.
(iv) Land should be given rest for some time and ploughed thoroughly.
(v) Rotation of crops to be followed.
(vi) Shallow depths of water should be applied.

7.7 (b)
Refer Solution 8.1

7.8 (b)
The amount of DO an aquatic organism needs depends upon its species, the temperature of the water, pollutants present, and the state of the organism itself (adult or young, active or dormant).

The generally accepted minimum amount of DO that will support a large population of various fishes is from 4 to 5 mg/l. When the DO drops below 3 mg/l, even the hardy fish die.

8. Treatment of Waste Water

8.1 (b)
Imhoff tank and septic tanks have anaerobic bacteria for BOD removal and waste stabilization.

Oxidation ditch:

- An oxidation ditch is basically an extended aeration system of a modified activated sludge process.
- It is designed and operated on the same principle as of the activated sludge process.
- Activated sludge process is aerobic suspended culture.

Waste stabilisation pond:

- Stabilisation ponds may be classified as aerobic, facultative or anaerobic depending upon the mechanism of purification.

Rotating Biological Contractor (RBC):

- It is based on attached growth system.
- In RBC, aerobic bacteria is predominant.

8.2 (a)
Sludge volume index is the volume occupied in mL by one gm of solids in the mixed liquor after settling for 30 minutes. It indicates the physical state of sludge produced in a biological aeration system. It is used to decide the rate of recycle of sludge (Q) required to maintain the desired Mixed Liquor Suspended Solids (MLSS) and Food to Micro organism (F/M) ratio in the aeration tank to achieve the desired degree of purification. So by reducing recycling ratio SVI can be controlled.

The settled sludge volume

$$V_{ob} = 27 \text{ cm}^3/\text{lit} = 27 \text{ mL/lit}$$

The concentration of suspended solids in mixed liquor, $X_{ob} = 3$ g/lit

$$\therefore \quad \text{SVI} = \frac{V_{ob}}{X_{ob}} = \frac{27}{3} = 9 \text{ mL/gm}$$

8.3 (c)
The aerobic zone in stabilization pond gives complete purification by symbiotic relationship between algae and bacteria. The bacteria use oxygen as an electron acceptor to oxidize the waste water organics to stable end products such as CO_2, PO_4^{3-}. The algae in turn use these compounds as a material source and with sunlight as energy source, produce oxygen as an end product.

The bacterial action is achieved either by aerobic or anaerobic bacteria and not by photosynthetic bacteria. In fact it takes place only in plants.

8.4 (d)
Waste Stabilization Ponds (WSPs) are large, man-made water bodies in which blackwater , greywater or faecal sludge are treated by natural occurring processes and the influence of solar light, wind, microorganisms and algae. The ponds can be used individually, or linked in a series for improved treatment.

8.5 (a)

Preliminary treatment units are:

(i) Screening and communitor

(ii) Grit chamber

(iii) Flow equalization tank and flow meter constant.

8.6 (c)

Trickling filter is used to remove the dissolved organic matter from waste water.

Suspended solids that pass through screens and grit chambers are removed from the sewage in sedimentation tanks. These tanks, called **primary clarifiers**, provide about two hours of detention time for gravity settling to take place.

Grit chambers are long narrow tanks that are designed to slow down the flow so that suspended inorganic solids will settle out of the water.

Screens removes large floating matter.

8.7 (d)

$$\text{Surface Loading rate} = \frac{720}{12 \times 1.5}$$

$$= 40 \text{ m}^3/\text{hr/m}^2 = 40000 \text{ ltr/hr/m}^2$$

$$\text{Detention time} = \frac{V}{Q} = \frac{12 \times 1.5 \times 0.8}{720} \times 60$$

$$= 1.2 \text{ minutes}$$

8.8 (b)

An anaerobic digestion, supernatant liquor produced is of high BOD concentration. Hence it should be retracted along with the raw sewage. This is the disadvantage of anaerobic sludge digestion.

Advantages are:

(i) Sludge produced has excellent dewatering capacity.

(ii) Greater production of methane.

(iii) Lesser operating cost, because energy is recovered in the form of methane.

(iv) Lesser capital cost.

8.9 (a)

- Raw sludge can be disposed of without digestion using lagoons.
- Seeding is the process of introducing micro-organism from an already functioning plant into a newly constructed plant. Due to seeding, the micro-organisms take some time to acclimatize themselves to the new environment and this is called lag phase. This is true for all type of plants (Activated Sludge, trickling filter, sludge digestion, etc.) based on biological treatment. However it is more important factor in anaerobic sludge digestion process.
- Biofilters are high rate trickling filters based on recirculation of effluent from trickling filter to primary clarifier.
- Contact beds for filtration of sewer is based on aerobic decomposition.

8.10 (c)

Septic tanks are based on anaerobic process.

Stabilization means :

(i) Reduction of pathogens

(ii) Elimination of offensive odours and

(iii) Inhibitation, reduction or elimination of potential for putrefaction.

The principal methods for stabilization are:

(i) Alkaline stabilization

(ii) Anaerobic digestion

(iii) Aerobic digestion and

(iv) Composting.

In septic tanks digestion of settled solids reduces the sludge compared to that obtained from primary settling tank.

The dispersion trenches oxidize the effluent from septic tanks to reduce BOD.

8.11 (c)

The horizontal flow velocity is maintained within 24 to 30 cm/s, so as not to cause scouring.

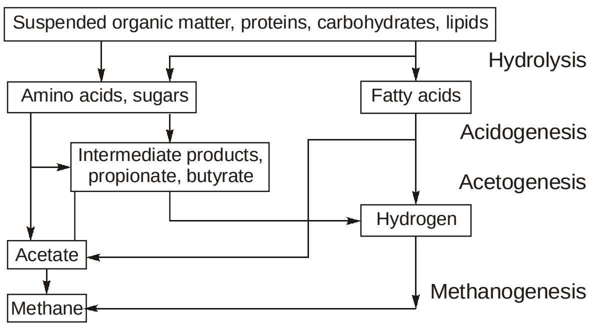
Removal of inorganic particle of size greater than 0.1 mm is essential not organic particle.

8.12 (d)

The factors that determine the removal efficiency of biodegradable organic matter are:

- The nature and composition of the organic matter to be removed.

- Suitability of environmental factors.
- Sludge retention time in the reactor.
- The intensity of mixing, hence contact between bacterial biomass and organic matter.
- Specific loading of organic matter with respect to bacterial sludge mass, and retention time.



Different steps are necessary for the anaerobic digestion of proteins, carbohydrates, and lipids. Four different phases can be distinguished in the overall conversion process of organic matter to biogas as (1) Hydrolysis, (2) Acidogenesis, (3) Acetogenesis and (4) Methanogenesis.

8.13 (c)

$$V_1(100 - p_1) = V(100 - p)$$

$$\Rightarrow \quad \frac{V_1}{V} = \frac{100-99}{100-96} = \frac{1}{4} = 0.25$$

$$\text{Volume reduction} = \frac{V - V_1}{V} \times 100 = 75\%$$

8.14 (c)

Oxidation ditch is based on extended aeration process. There is no need of separate sludge digester as the detention time is very large. So sludge can be directly taken to sludge drying beds.

8.15 (d)

The general flow sheet of liquid stream of a sewage treatment scheme consists of:

Screen Chamber → Grit Chamber → Primary Settling Tank → Trickling Filter → Secondary Settling Tank.

8.16 (c)

Oxidation pond is based on algae-bacteria symbiotic relationship.

8.17 (b)

Anaerobic digestion is a process by which microorganisms break down biodegradable material in the absence of oxygen.

8.18 (c)

Parshall flumes are proportioning weirs and they maintain constant flow velocity in grit chamber for settling (Type-I) of inorganic particles.

8.19 (c)

Type reactor	Applications in wastewater treatment
1. Batch	Activated sludge process
2. Complete-mix	Aerated lagoons, aerobic sludge digestion
3. Plug flow	Chlorine contact basin, natural treatment system
4. Packed bed	Non-submerged and submerged trickling filter, depth filtration, air stripping
5. Fluidized bed	Upflow sludge blanket.

8.20 (d)

Food to micro-organism ratio, and consequently proper proportion of return sludge from the secondary settling tank are important parameters. The return of sludge will be necessary to maintain adequate Mixed Liquor Suspended Solids (MLSS) concentration to achieve desired degree of treatment. Sludge volume index is calculated to evaluate the sludge settling characteristics. SVI values below 100 are desired and SVI values above 150 are typically associated with filamentous growth. The other measure of quantifying settling characteristics of activated sludge is zone settling rate. Oxygen is required in the activated sludge process in the aeration tank for oxidation of part of the influent organic matter, and also for endogenous respiration of the micro-organisms in the system. It should maintain specified level of DO in the waste-water i.e., 0.1-1.0 mg/L for conventional activated plants, 1-2 mg/L for extended aeration and above 2 mg/L for nitrification in the activated sludge plant.

8.22 (a)

Sludge bulking is caused by filamentous micro-organisms and sludge settling characteristics are very poor in this case.

It can be controlled by

(i) adjusting food to microorganism ratio

(ii) raising or lowering DO

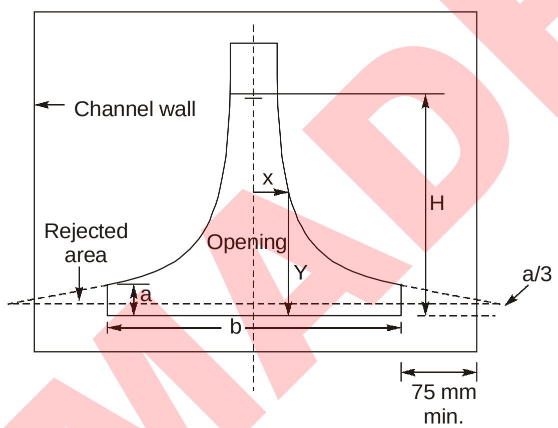
(iii) using disinfectant (chlorine)

The problem of rising sludge is caused by denitrification in the secondary clarifier.

8.23 (d)

With variation in sewage flow received at treatment plant, it is important that velocity of the wastewater in the grit chamber should be maintained nearly constant. Otherwise when flow is lower, deposition of not only inorganic solids but also organic solids will occur in grit chamber due to lowering of velocity. With flow higher than average, when the velocity will exceed the critical velocity, scouring of already deposited grit particles will occur leading to failure of performance. Hence for proper functioning, the velocity should not be allowed to change in spite of change in flow in the grit chamber. This can be achieved by provision of proportional weir or Parshall flume at the outlet end of grit chamber.

PROPORTIONAL WEIR:



8.24 (d)

There are three stages in sludge digestion:

(i) **Hydrolysis:** Particulate material is converted to soluble compounds that can be hydrolysed further to simple monomers.

(ii) **Fermentation (Acidogenesis):** Amino acids, sugars and some fatty acids are degraded further. Final products of fermentation (acetate, hydrogen and CO_2) are precursors of methane formation.

(iii) **Methanogenesis**

8.25 (d)

Stabilization (facultative) ponds are based on symbiotic relationship of bacteria in anaerobic zone and algae in the aerobic zone. The bacteria uses oxygen as an electron acceptor to oxidize the waste water organics to stable end products such as CO_2, NO_3^- and PO_4^{3-}. The algae in turn use these compounds as a material source and with sunlight as an energy source, produce oxygen as an end product.

The usual detention time is 7 to 30 days in facultative pond. The bacteria are facultative.

8.26 (c)

The daily BOD generated

$= 10{,}000 \times 200 \times 300 \times 10^{-6} = 600$ kg/day

Thus area requirement $= \dfrac{600}{300} = 2$ ha

8.27 (d)

Seepage pit is an absorption system for septic tank effluent. It does not have any vent pipe.

9. Design of Sewers & Sewerage System

9.1 (c)

All changes in size, shape, alignment, flow volume, free and submerged discharge at the end of sewer lines, passing of flow through measuring or diversion devices and sewer junctions etc. are known as sewer transitions.

- Manholes must be located at all such transitions.
- The transition from larger dia to smaller dia sewer should not be made. However, in other transitions, such as change from small dia sewer to large dia sewer or change of slope etc., the crowns of the sewers are always kept continuous. In no case, the hydraulic flow line (grade line) in the larger sewer should be higher then the incoming one.

9.2 (b)

For $\dfrac{d}{D} = 0.5;\quad \dfrac{v}{V} = 1.0$

where, d is depth of flow

v is flow velocity at depth d

D is diameter of sewer

V is flow velocity at full flow

$\therefore \quad v = 1.0$ m/s

9.3 (b)

Soil Pipe: It is a drain pipe that carries wastes from a plumbing fixture, especially from a toilet to sewer lines.

Intercepting Trap: The trap can be defined as fittings at the end of soil pipes or waste pipes to stop foul gases (odour) coming out of the soil pipe or waste pipe. It is a part of the drainage (sanitary) system. It is developed or designed such that it retains a small quantity of waste water from the discharge of fitting to which it is attached as a barrier to prevent foul gases or air entering the building.

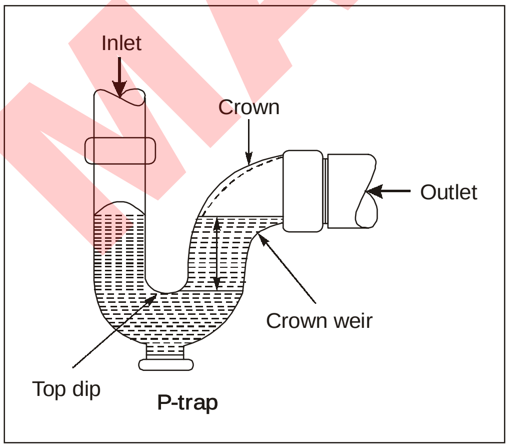
P-Trap: A P-trap is a plumbing fixture that traps debris that has drained from the sink and prevents it from forming a clog deep within the plumbing system, and stops sewer gases from passing into the home.

Cowl: It is used in ventilation pipe and prevents rainwater from entering the ventilation duct.

9.4 (b)

The entry of foul smelling gases into the house coming from the sewers can be prevented by:

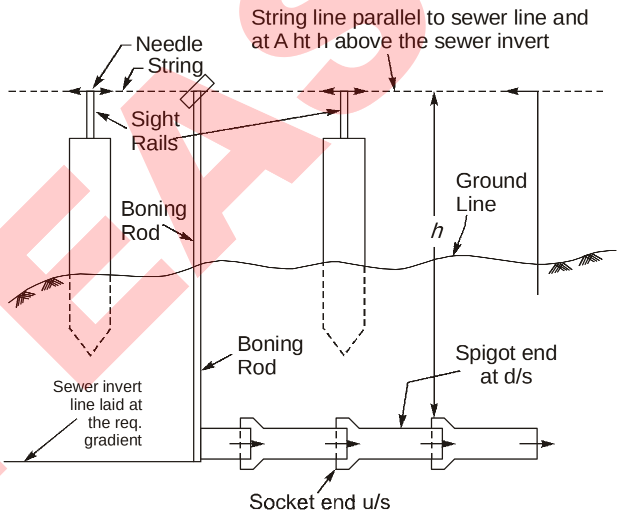
- Providing water seal in all fixtures.
- Vent pipe in plumbing system.



9.5 (d)

Laying of sewer:

- After the bedding concrete has been laid in the required alignment and levels, the sewer pipes are lowered down into the trench.
- The sewer pipe lengths are usually laid from the lowest point with their socket ends facing upstream.
- The spigot of each, is inserted in the socket of the laid pipe.
- After fitting the socket, spigot joining is done with lead calking or cement mortar.



9.6 (c)

- The flow velocity in a sewer should be such that neither the suspended solids in the sewage gets silt up nor the sewer pipe material gets scoured.
- First condition, limits the minimum velocity and second condition, limits the maximum velocity.
- The minimum velocity also called as self cleansing velocity is the velocity such that suspended solid cannot settle down.
- It must be developed at least once a day and a sewer is commonly designed to attain the self cleansing velocity at minimum hourly rate of flow.

9.7 (d)

First sight rails are set over the trench. Then pegs can be driven to the level of invert line and centre line of the sewer marked on sight rails can be transferred to the bottom of the trench. Finally, sewers should be placed in the trench.

9.8 (a)

Time of concentration (t_c) is the time taken by water droplet to reach the catchment outlet from farthest part. So whole catchment contributes to runoff only when the time of rainfall is greater than 't_c'. It is used to determine critical rainfall intensity.

9.9 (d)

- Gully trap is provided at the junction of the room or a roof drain and the other drain coming from bath, kitchen, etc. It may be P-trap or S-trap.
- Intercepting trap is provided at the junction of a house sewer and a municipal sewer, so as prevent the entry of the foul gases of the municipal sewer, into house drainage system.
- Water closets are fitted with P or S-trap.

9.10 (c)

The maximum flow in an egg shaped sewer occurs when the ratio of depth of flow to vertical diameter is 0.95 and maximum velocity occurs when ratio of depth of flow to vertical diameter is 0.81.

9.11 (c)

Time of concentration (t_c) is the time require fro the rain water to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. It is equal to inlet time (t_i) plus the time of flow in the sewer (t_f)

$$t_c = t_i + t_f$$

9.12 (a)

Given $D = 1$ m, $d = 0.75$ m

$$\frac{d}{D} = \frac{0.75}{1} = \frac{1-\cos\frac{\alpha}{2}}{2}$$

$$\alpha = 240^\circ$$

$$\frac{r}{R} = \left.\frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}\right|_{\alpha=240^\circ} = 1.206$$

$$r = 1.206R$$

$$= 1.206 \times \frac{D}{4}$$

$$= 1.206 \times \frac{1}{4} = 0.3 \text{ m}$$

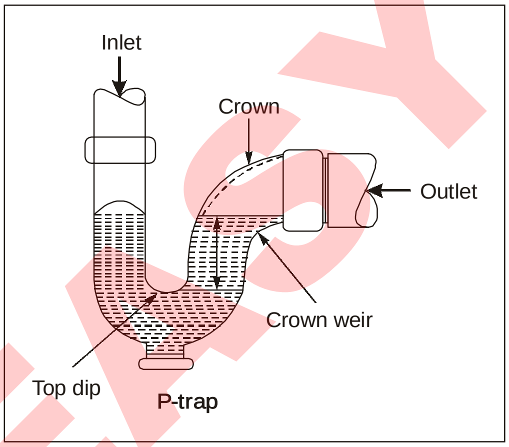
Note: At 0.5 m depth of flow

$$\frac{r}{R} = 1.0$$

$$\therefore \quad r = 0.25 \text{ m}$$

(r = hydraulic radius under partial flow)

9.13 (b)



9.14 (d)

Ventilation in sewers is needed to avoid

(i) the danger of asphyxiation of sewer maintenance employees

(ii) the buildup of odourous gases such as hydrogen sulphide, ammonia etc.

(iii) the development of explosive mixture of sewer gases principally methane and oxygen

Another reason for ventilating sewers is to ensure a continuous flow of sewage inside the sewer.

10. Municipal Solid Waste Management

10.1 (c)

The leachate from sanitary landfill tend to pollute ground water. Incineration and pyrolysis release air pollutants. Composting does not have any harmful effect.

10.2 (c)

Non-disposal of solid waste will result in biodegradation of organic matter. This will cause obnoxious odour and attract flies which are the chief agents of diseases like typhoid, dyphtheria, diarrhoea, etc.

10.3 (c)

Sealants are used of control for gas and leachate movement

Classification types	Representative
(i) Compacted clay	: Bentonites, illites, kaolinites.
(ii) Inorganic chemicals	: Sodium carbonate, silicate or pyrophosphate
(iii) Synthetic chemicals	: Polymers, rubber latex
(iv) Synthetic membrane	: PVC, butyl rubber, hypalon, poly-thene, nylon reinforced liners.
(v) Asphalt	: Modified asphalt, asphalt-covered polypropylene fabric, asphalt concrete.
(vi) Others	: Gunite concrete, soil cement, plastic soil cement.

The sealant material should be more impermeable than the soil. So sand will not be a suitable material. Flyash and lime themselves produce pollutants which dissolve in water. Therefore, these materials cannot be used as sealants.

10.4 (c)

When compacting a broad range of municipal solid wastes the typical density obtained is about 600-750 kg/m^3 irrespective of the starting density and applied pressure.

10.5 (d)

When Waste is burnt in absence of oxygen, then this method of solid waste disposal is called Pyrolysis. It is the second best option after recycling. The solids are separated from the volatile liquid and gaseous compounds that can be used as fuel. Thus it helps in reducing dependency on fossil fuel and geo-extraction.

10.6 (d)

Leachate movement should be controlled by well designed drainage system. So that ground water may not get polluted.

10.7 (c)

S.No.	Methods of solid waste disposal	Terms pertaining to the methods
(i)	Incineration (Method of disposal in which the waste is burnt in presence the oxygen)	• It involves first drying and then combustion of water. • This requires energy to be supplied in the process. • Hence, it has high operational and maintenance cost.
(ii)	Sanitary landfill	• It involves dumping the waste in layers and compacting them after each layer, hence tractor can be used very efficiently for this purpose. • Simple and economical but there is continuous evolution of foul gases which may be explosive in nature. • Also, it causes leachate in landfills which pollutes the nearby ground water thereby impacting the ecology of the area.
(iii)	Compositing	• It is a flow process whereby bacteria is used to decompose the solid waste. • Used to decompose the organic matter only. • It is perfectly natural phenomena and imposes least burden on the ecology of the area. • The entire process involving presorting, grinding, turning and bacterial conversion of organic solid wastes is known as compositing.
(iv)	Salvage by sorting	• It involves separting non-biodegradable and noncombustible material, hence is limited to special waste and selected materials.

11. Air Pollution

11.1(c)

- Carbon monoxide affect human aerobic metabolism by forming carboxyhaemoglobin (COHb).
- Oxides of nitrogen (NO_x) includes – nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), nitrogen sesquioxide (N_2O_3), Nitrogen tetroxide (N_2O_4) and nitrogen pentoxide (N_2O_5). NO and NO_2 are of primary

concern as air pollutants. NO_2 plays major role in the production of secondary air pollutant ozone (O_3).

- SO_2 is responsible for acid rains as it combines with water vapour to form secondary pollutants like H_2SO_4 which cause acidity.
- CO_2 is major contributor to green house effect (approximately 57%).

11.2 (b)

Scientists divided the atmosphere into four layers according to temperature: troposphere, stratosphere, mesosphere, and thermosphere. The temperature drops as we go up through the troposphere, but it rises as we move through the next layer, the stratosphere. The farther away from earth, the thinner the atmosphere gets.

Troposphere: This is the layer of the atmosphere closest to the Earth's surface, extending up to about 10-15 km above the Earth's surface. It contains 75% of the atmosphere's mass. The troposphere is wider at the equator than at the poles. Temperature and pressure drops as you go higher up the troposphere.

Stratosphere: This layer lies directly above the troposphere and is about 35 km deep. It extends from about 15 to 50 km above the Earth's surface.

Mesosphere: Directly above the stratosphere, extending from 50 to 80 km above the Earth's surface, the mesosphere is a cold layer where the temperature generally decreases with increasing altitude. Here in the mesosphere, the atmosphere is very rarefied nevertheless thick enough to slow down meteors hurtling into the atmosphere, where they burn up, leaving fiery trails in the night sky.

Thermosphere: The thermosphere extends from 80 km above the Earth's surface to outer space. The temperature is hot and may be as high as thousands of degrees as the few molecules that are present in the thermosphere receive extraordinary large amounts of energy from the Sun. However, the thermosphere would actually feel very cold to us because of the probability that these few molecules will hit our skin and transfer enough energy to cause appreciable heat is extremely low.

11.3 (d)

Photochemically, the hydrocarbons and NO_x are the necessary ingredients to produce photochemical smog.

$$\text{Unburnt Hydrocarbons} + NO_x \xrightarrow[\text{(Oxides of nitrogen)}]{\text{sunlight}} \text{smog}$$

The end product of these photochemical reactions is photochemical smog consisting of air contaminants such as O_3, PAN, aldehydes, ketones, alkyl nitrates and carbon monoxide. Thus, oxides of nitrogen and unburnt hydrocarbons are responsible for causing photochemical smog.

11.4 (b)

(i) Electrostatic precipitator (High voltage) is used for > 1 mm but can collect submicron particles also.

(ii) Cyclone collector (based on centrifugal force) is used for 5 to 25 μm size particle

(iii) Wet scrubber are used for gaseous pollutants

(iv) Adsorbers are specific to gases. A reactive liquid adsorbent (water or limestone) may be used to remove SO_2 from flue gases.

11.5 (a)

Carbon Monoxide (CO)

- Fuel combustion from vehicles and engines.
- Reduces the amount of oxygen reaching the body's organs and tissues; aggravates heart disease, resulting in chest pain and other symptoms.

Ground-level Ozone (O_3)

- Secondary pollutant formed by chemical reaction of volatile organic compounds (VOCs) and NOx in the presence of sunlight.
- Decreases lung function and causes respiratory symptoms, such as coughing and shortness of breath, and also makes asthma and other lung diseases get worse.

Lead (Pb)

- Smelters (metal refineries) and other metal industries; combustion of leaded gasoline in piston engine aircraft; waste incinerators (waste burners), and battery manufacturing.

- Damages the developing nervous system, resulting in IQ loss and impacts on learning, memory, and behavior in children. Cardiovascular and renal effects in adults and early effects related to anaemia.

Nitrogen Dioxide (NO_2)

- Fuel combustion (electric utilities, big industrial boilers, vehicles) and wood burning.
- Worsens lung diseases leading to respiratory symptoms, increased susceptibility to respiratory infection.

Particulate Matter (PM)

- This is formed through chemical reactions, fuel combustion (e.g., burning coal, wood, diesel), industrial processes, farming (plowing, field burning), and unpaved roads or during road constructions.
- Short-term exposures can worsen heart or lung diseases and cause respiratory problems. Long-term exposures can cause heart or lung disease and sometimes premature deaths.

Sulfur Dioxide (SO_2)

- SO_2 comes from fuel combustion (especially high-sulfur coal); electric utilities and industrial processes as well as natural occurrences like volcanoes.
- Aggravates asthma and makes breathing difficult. It also contributes to particle formation with associated health effects.

11.6 (b)

Aerosols or particulates or suspended particulate matter is defined as the liquid or solid particles when they are suspended in gaseous medium. The term aerosol is used during the time it is suspended in air. After the particle is settled down, the term ceases to be valid.

11.7 (c)

Refer Solution 10.1.

- Carbon monoxide affect human aerobic metabolism by forming carboxyhaemoglobin (COHb).
- Oxides of nitrogen (NO_x) includes – nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), nitrogen sesquioxide (N_2O_3), Nitrogen tetroxide (N_2O_4) and nitrogen pentoxide (N_2O_5). NO and NO_2 are of primary concern as air pollutants. NO_2 plays major role in the production of secondary air pollutant ozone (O_3).
- SO_2 is responsible for acid rains as it combines with water vapour to form secondary pollutants like H_2SO_4 which cause acidity.
- CO_2 is major contributor to green house effect (approximately 57%).

Particulate matter: Reduction is visibility due to scatter of light and act as allergy carriers.

11.8 (b)

For a threshold limit of 50 ppm of Co, let gravity of air required to delute the Co the such level be x m^3/min.

So, $$\frac{x}{10^6}\times 50 = 50 = 0.03$$

$$\left[1 \text{ ppm of Co} = \frac{1 \text{ m}^3 \text{ of Co}}{10^6 \text{ m}^3 \text{ of air}}\right]$$

$$x = 600 \text{ m}^3\text{/min}$$

12. Noise Pollution

12.1 (b)

For noise level of 90 dB

$$P_{rms_1} = 20\left\{\text{antilog}\left(\frac{90}{20}\right)\right\} = 632455.53$$

For noise level of 94 dB

$$P_{rms_2} = 20\left\{\text{antilog}\left(\frac{94}{20}\right)\right\} = 1002374.47$$

$$P_{\text{rms,equiv.}} = \sqrt{P_{rms_1}^2 + P_{rms_2}^2} = 1185223.429$$

Cumulative effect

$$= 20 \log \frac{1185223.43}{20} = 95.46 \text{ dB}$$

12.2 (c)

$$\text{Sound pressure level (dB)} = 20 \log_{10}\left(\frac{P}{P_0}\right)$$

P is sound pressure in N/m^2

P_0 is reference pressure (2×10^{-5} N/m^2)

For given sound pressure

$P = 2000\ \mu$ bar = 200 N/m^2 (1 bar = 10^5 N/mm^2)

$$\therefore \text{SPL} = 20 \log\left(\frac{200}{2\times 10^{-5}}\right) = 140 \text{ dB}$$

■■■■

UNIT

V

Soil Mechanics and Foundation Engineering

Syllabus

Soil Mechanics: Soil exploration - planning & methods, Properties of soil, classification, various tests and inter-relationships; Permeability & Seepage, Compressibility, consolidation and Shearing resistance, Earth pressure theories and stress distribution in soil; Properties and uses of geo-synthetics.

Foundation Engineering: Types of foundations & selection criteria, bearing capacity, settlement analysis, design and testing of shallow & deep foundations; Slope stability analysis, Earthen embankments, Dams and Earth retaining structures: types, analysis and design, Principles of ground modifications.

Contents

5 Soil Mechanics and Foundation Engineering

1. Properties of Soils

1.1 Match **List-I** (Type of soil) with **List-II** (Mode of transportation and deposition) and select the correct answer using the codes given below the lists:

List-I

A. Lacustrine soils
B. Alluvial soil
C. Aeolian soils
D. Marine soils

List-II

1. Transportation by wind
2. Transportation by running water
3. Deposited at the bottom of lakes
4. Deposited in sea water

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	1	4
(c)	3	2	4	1
(d)	1	3	2	4

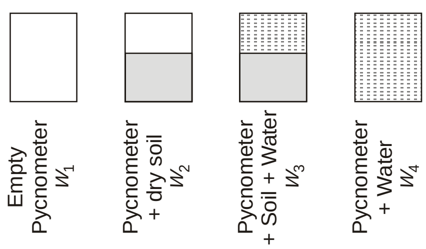
[ESE : 1995]

1.2 The liquid limit and plastic limit of sample are 65% and 29% respectively. The percentage of the soil fraction with grain size finer than 0.002 mm is 24. The activity ratio of the soil sample is

(a) 0.50 (b) 1.00
(c) 1.50 (d) 2.00

[ESE : 1995]

1.3 The given figure indicate the weights of different pycnometers:



The specific gravity of the solids is given by

(a) $\dfrac{W_2}{W_4 - W_2}$

(b) $\dfrac{W_1 - W_2}{(W_3 - W_4) - (W_2 - W_1)}$

(c) $\dfrac{W_2}{W_3 - W_4}$

(d) $\dfrac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$

[ESE : 1995]

1.4 A soil sample has a shrinkage limit of 10% and specific gravity of soil solids as 2.7. The porosity of the soil at shrinkage limit is

(a) 21.2% (b) 27%
(c) 73% (d) 78.8%

[ESE : 1995]

1.5 **Assertion (A):** If the water table is very near to the subgrade of the road, it will ultimately cause cracking of the road surface.

Reason (R): The consistency of the soil will change from plastic to liquid state leading to its volumetric decrease.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

1.6 In a wet soil mass, air occupies one-sixth of its volume and water occupies one-third of its volume. The void ratio of the soil is

(a) 0.25 (b) 0.5
(c) 1.00 (d) 1.50

[ESE : 1995]

1.7 Lacustrine soils are soils
(a) transported by rivers and streams
(b) transported by glaciers
(c) deposited in sea beds
(d) deposited in lake beds
[ESE : 1996]

1.8 A soil sample is having a specific gravity of 2.60 and a void ratio of 0.78. The water content in percentage required to fully saturate the soil at that void ratio would be
(a) 10 (b) 30
(c) 50 (d) 70
[ESE : 1996]

1.9 A dry soil has mass specific gravity of 1.35. If the specific gravity of solids is 2.7, then the void ratio will be
(a) 0.5 (b) 1.0
(c) 1.5 (d) 2.0
[ESE : 1996]

1.10 A clay sample has a void ratio of 0.50 in dry state and specific gravity of solids = 2.70. Its shrinkage limit will be
(a) 12% (b) 13.5%
(c) 18.5% (d) 22%
[ESE : 1996]

1.11 A soil has liquid limit of 60% plastic limit of 35% and shrinkage limit of 20% and it has a natural moisture content of 50%. The liquidity index of soil is
(a) 1.5 (b) 1.25
(c) 0.6 (d) 0.4
[ESE : 1996]

1.12 Consider the following statements in relation to the given table:

Volume (cc)	Content	Weight (g)
0.2	Air	0
0.3	Water	0.3
0.5	Solids	1.0

1. Soil is partially saturated at degree of saturation = 60%
2. Void ratio = 40%
3. Water content = 30%
4. Saturated unit weight = 1.5 g/cc

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 4
[ESE : 1996]

1.13 Consider the following statements in the context of aeolian soils:
1. The soil has low density and low compressibility.
2. The soil is deposited by wind.
3. The soil has large permeability.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 2 and 3
(c) 1 and 3 (d) 1 and 2
[ESE : 1997]

1.14 The dry density of a soil is 1.5 g/cc. If the saturation water content were 50% then its saturated density and submerged density would, respectively, be
(a) 1.5 g/cc and 1.0 g/cc
(b) 2.0 g/cc and 1.0 g/cc
(c) 2.25 g/cc and 1.25 g/cc
(d) 2.50 g/cc and 1.50 g/cc
[ESE : 1997]

1.15 The moisture content of a clayey soil is gradually decreased from a large value. What will be the correct sequence of the occurrence of the following limits?
1. Shrinkage limit
2. Plastic limit
3. Liquid limit

Select the correct answer using the codes given below:
(a) 1, 2, 3 (b) 1, 3, 2
(c) 3, 2, 1 (d) 3, 1, 2
[ESE : 1997]

1.16 A fill having a volume of 1,50,000 cum is to be constructed at a void ratio of 0.8. The borrow pit soil has a void ratio of 1.4. The volume of soil required (in cubic meters) to be excavated from the borrow pit will be
(a) 1,87,500 (b) 2,00,000
(c) 2,10,000 (d) 2,50,000
[ESE : 1997]

1.17 Given that Plasticity Index (*PI*) of local soil =15 and *PI* of sand = zero, for a desired *PI* of 6, the percentage of sand in the mix should be

(a) 70 (b) 60
(c) 40 (d) 30

[ESE : 1997]

1.18 A clayey soil has liquid limit = w_L; plastic limit = w_P and natural moisture content = w. The consistency index of the soil is given by

(a) $\dfrac{W_L - W}{W_L - W_P}$ (b) $\dfrac{W_L - W_P}{W_L - W}$

(c) $\dfrac{W_P - W}{W_L - W_P}$ (d) $\dfrac{W_L - W_P}{W_P - W}$

[ESE : 1998]

1.19 A soil has mass unit weight γ, water content 'w' (as ratio). The specific gravity of soil solids = G, unit weight of water = γ_w; S the degree of saturation of the soil is given by

(a) $S = \dfrac{1+w}{\dfrac{\gamma_w}{\gamma}(1+w) - \dfrac{1}{G}}$

(b) $S = \dfrac{w}{\dfrac{\gamma_w}{\gamma}(1+w) - \dfrac{1}{G}}$

(c) $S = \dfrac{(1+w)}{\dfrac{\gamma_w}{\gamma}(1+w) - \dfrac{1}{G}}$

(d) $S = \dfrac{w}{\dfrac{\gamma_w}{\gamma}(1+w) - \dfrac{1}{wG}}$

[ESE : 1998]

1.20 The saturated and dry densities of a soil are respectively 2000 kg/m^3 and 1500 kg/m^3. The water content (in percentage) of the soil in the saturated state would be

(a) 25 (b) 33.33
(c) 50 (d) 66.66

[ESE : 1999]

1.21 If a soil sample of weight 0.18 kg having a volume of 10^{-4} m^3 and dry unit weight of 1600 kg/m^3 is mixed with 0.02 kg of water then the water content in the sample will be

(a) 30% (b) 25%
(c) 20% (d) 15%

[ESE : 1999]

1.22 Match **List-I** (Terms) with **List-II** (Formulae) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Void Ratio	1. $\dfrac{V_V}{V}$
B. Porosity	2. $\dfrac{W_W}{W_S}$
C. Degree of saturation	3. $\dfrac{V_W}{V_V}$
D. Water content	4. $\dfrac{W}{V}$
	5. $\dfrac{V_V}{V_S}$

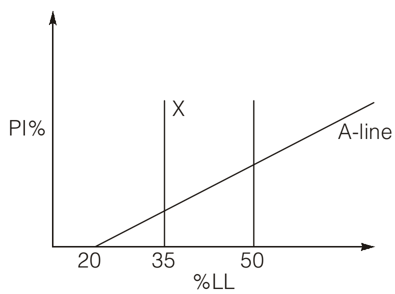
Codes:

	A	B	C	D
(a)	4	3	5	1
(b)	5	4	3	1
(c)	4	1	5	2
(d)	5	1	3	2

[ESE : 1999]

2. Classification of Soils

2.1 The standard plasticity chart to classify fine grained soils is shown in the given figure.



The area marked X represents

(a) silt of low plasticity
(b) clay of high plasticity
(c) organic soil of medium plasticity
(d) clay of intermediate plasticity

[ESE : 1996]

2.2 A soil has a liquid limit of 45% and lies above the A-line when plotted on a plasticity chart. The group symbol of the soil as per **IS** soil Classification is

(a) CH (b) CI
(c) CL (d) MI

[ESE : 1997]

2.3 Consider the following statements:
A well-graded sand should have

1. uniformity coefficient greater than 6
2. coefficient of curvature between 1 and 3
3. effective size greater than 1 mm

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3

[ESE : 1998]

2.4 If the proportion of soil passing 75 micron sieve is 50% and the liquid limit and plastic limit are 40% and 20% respectively, then the group index of the soil is

(a) 3.8 (b) 6.5
(c) 38 (d) 65

[ESE : 1999]

3. Effective Stresses and Permeability

3.1 If during a permeability test on a soil sample with a falling head permeameter, equal time intervals are noted for drop of head from 'h_1' to 'h_2' and again from 'h_2' to 'h_3', then which one of the following relations would hold good?

(a) $h_3^2 = h_1 h_2$
(b) $h_1^2 = h_2 h_3$
(c) $h_2^2 = h_1 h_3$
(d) $(h_1 - h_2) = (h_2 - h_3)$

[ESE : 1995]

3.2 If the saturated density of a given soil is 2.1 t/m^3, then the total stress (T in t/m^2) and the effective stress (E in t/m^2) of a saturated soil stratum at a depth of 4 m will be

	T	E
(a)	4.4	2.4
(b)	5.4	3.4
(c)	7.4	4.0
(d)	8.4	4.4

[ESE : 1995]

3.3 **Assertion (A):** At depth z below the surface of a submerged soil, water pressure is $\gamma_w z$ and it is the stress caused by the water which is called the "neutral stress".

Reason (R): The water pressure acts equally in all directions and transmits the same fully in grain to grain contact causing compression in the soil.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

3.4 A bed of sand consists of three horizontal layers of equal thickness. The value of Darcy's 'k' for the upper and lower layers is 1×10^{-2} cm/sec and that for the middle layer is 1×10^{-1} cm/sec. The ratio of the permeability of the bed in the horizontal direction to that in the vertical direction is

(a) 10.0 to 1 (b) 2.8 to 1
(c) 2.0 to 1 (d) 1 to 10

[ESE : 1996]

3.5 Due to rise in temperature, the viscosity and unit weight of percolating fluid are reduced to 70% and 90% respectively. Other things being constant, the change in coefficient of permeability will be

(a) 20.0% (b) 28.6%
(c) 63.0% (d) 77.8%

[ESE : 1996]

3.6 **Assertion (A):** Constant-head permeability test is not used for fine-grained soils.

Reason (R): The lesser the permeability of the soil, lesser is the discharge.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

3.7 Consider the following statements:

1. Constant head permeameter is best suited for determination of coefficient of permeability of highly impermeable soils.
2. Coefficient of permeability of a soil mass decreases with increase in viscosity of the pore fluid.
3. Coefficient of permeability of soil mass increases with increase in temperature of the pore fluid.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1998]

3.8 Match **List-I** (Processes) with **List-II** (Governing laws/equations) and select the correct answer using the codes given below the lists:

List-I

A. Flow of water in soil
B. Flow of water through pipe
C. Sedimentation of soil particles in water

List-II

1. Boussinesq's equation
2. Darcy's law
3. Poiseuille's equation
4. Skempton's equation
5. Stoke's law

Codes:

	A	B	C
(a)	2	4	5
(b)	2	3	5
(c)	1	3	5
(d)	2	3	4

[ESE : 1999]

4. Seepage Analysis

4.1 A flownet is drawn to obtain
(a) seepage, coefficient of permeability and uplift pressure
(b) coefficient of permeability, uplift pressure and exit gradient
(c) exit gradient, uplift pressure and seepage quantity
(d) exit gradient, seepage and coefficient of permeability

[ESE : 1995]

4.2 A uniform sand stratum 2.5 m thick has a specific gravity of 2.62 and a natural void ratio of 0.62. The hydraulic head required to cause quick sand condition in the sand stratum is
(a) 0.5 m (b) 1.5 m
(c) 2.5 m (d) 3.5 m

[ESE : 1995]

4.3 A soil has a discharge velocity of 6×10^{-7} m/s and a void ratio of 0.5. Its seepage velocity is
(a) 18×10^{-7} m/s (b) 12×10^{-7} m/s
(c) 6×10^{-7} m/s (d) 3×10^{-7} m/s

[ESE : 1995]

4.4 **Assertion (A):** Quick sand is not a type of sand but it is a condition arising in a sand mass.
Reason (R): When the upward seepage pressure becomes equal to the pressure due to submerged weight of a soil, the effective pressure becomes zero.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

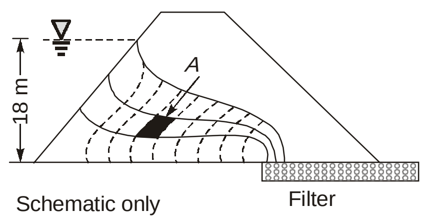
4.5 An upward hydraulic gradient i of a certain magnitude will initiate the phenomenon of boiling in granular soils. The magnitude of this gradient is
(a) $0 \leq i \leq 0.5$ (b) $0.5 \leq i \leq 1.0$
(c) $i \simeq 1.0$ (d) $1 < i \leq 2$

[ESE : 1996]

4.6 A deposit of fine sand has a porosity n and specific gravity of soil solids is G. The hydraulic gradient of the deposit to develop boiling condition of sand is given by
(a) $i_c = (G-1)(1-n)$
(b) $i_c = (G-1)(1+n)$
(c) $i_c = \dfrac{G-1}{1-n}$
(d) $i_c = \dfrac{G-1}{1+n}$

[ESE : 1996]

4.7 In the schematic flownet shown in the given figure, the hydraulic potential at point A is



(a) 5 m of water (b) 12 m of water
(c) 15 m of water (d) 25 m of water

[ESE : 1996]

4.8 Which one of the following equations correctly gives the relationship between the specific gravity of soil grains (G) and the hydraulic gradient (i) to initiate 'quick' condition in a sand having a void ratio of 0.5?

(a) $G = 0.5i + 1$ (b) $G = i + 0.5$
(c) $G = 1.5i + 1$ (d) $G = 1.5i - 1$

[ESE : 1997]

4.9 A sand deposit has a porosity of 1/3 and its specific gravity is 2.5. The critical hydraulic gradient to cause sand boiling in the stratum will be

(a) 1.5 (b) 1.25
(c) 1.0 (d) 0.75

[ESE : 1997]

4.10 A flownet constructed to determine the seepage through an earth dam which is homogeneous but anisotropic, gave four flow channels and sixteen equipotential drops. The coefficients of permeability in the horizontal and vertical directions are 4.0×10^{-7} m/s and 1×10^{-7} m/s respectively. If the storage head was 20 m, then the seepage per unit length of the dam (in m^3/s) would be

(a) 5×10^{-7} (b) 10×10^{-7}
(c) 20×10^{-7} (d) 40×10^{-7}

[ESE : 1997]

4.11 To make certain that the backfill material is more pervious than the soil to be drained, the relationship used is

(a) $(D_{15})_{\text{filter}} \le 5\,(D_{85})_{\text{protected soil}}$
(b) $(D_{15})_{\text{filter}} \ge 5\,(D_{85})_{\text{protected soil}}$
(c) $(D_{15})_{\text{filter}} \le 5\,(D_{15})_{\text{protected soil}}$
(d) $(D_{15})_{\text{filter}} \ge 5\,(D_{15})_{\text{protected soil}}$

[ESE : 1997]

4.12 The configuration of flow nets depends upon

(a) the permeability of the soil
(b) the difference in the head between upstream and downstream sides
(c) the boundary condition of flow
(d) the amount of seepage that takes place

[ESE : 1998]

4.13 Consider the following statements:
Phreatic line in an earth dam is

1. elliptical in shape
2. an equipotential line
3. the topmost flow line with zero water pressure
4. approximately a parabola

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 3 and 4 (d) 1 alone

[ESE : 1998]

4.14 A sand deposit has a porosity of 0.375 and a specific gravity of 2.6, the critical hydraulic gradient for the sand deposit is

(a) 2.975 (b) 2.225
(c) 1 (d) 0.75

[ESE : 1999]

4.15 A flownet for an earth dam on impervious foundation consists of 4 flow channels and 15 equipotential drops. The full reservoir level is 15 m above the downstream horizontal filter. Given that horizontal permeability is 9×10^{-6} m/s and vertical permeability is 1×10^{-6} m/s, the quantity of seepage through the dam will be

(a) 36 mL/s/m (b) 25 mL/s/m
(c) 20 mL/s/m (d) 12 mL/s/m

[ESE : 1999]

5. Compaction of Soil

5.1 For conducting a Standard Proctor Compaction Test, the weight of hammer (P in kg), the fall of hammer (Q in mm), the number of blows per layer (R) and the number of layers (S) required are respectively

	P	Q	R	S
(a)	5.89	550	50	3
(b)	4.89	450	25	3
(c)	3.60	310	35	4
(d)	2.60	310	25	3

[ESE : 1995]

5.2 Sheep-foot rollers are recommended for compacting

(a) granular soils (b) cohesive soils
(c) hard rock (d) any type of soil

[ESE : 1996]

5.3 Consider the following statements:
1. 'Relative compaction' is not the same as 'relative density'.
2. Vibrofloatation is not effective in the case of highly cohesive soils.
3. 'Zero air void line' and 100% saturation line are not identical.

Which of these statements is/are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 alone
[ESE : 1998]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

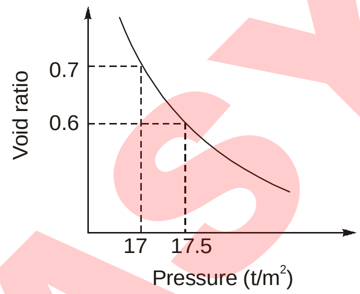
5.4 **Assertion (A):** Permeability continues to decrease with the increase in dry density of a compacted soil.
Reason (R): Soil particles in water surroundings may be mutually attracted or repulsed.
[ESE : 1998]

6. Compressibility and Consolidation

6.1 The natural void ratio of a saturated clay strata, 3 m thick is 0.90. The final void ratio of the clay at the end of consolidation is expected to be 0.71. The total consolidation settlement of the clay strata is
(a) 30 cm (b) 25 cm
(c) 20 cm (d) 15 cm
[ESE : 1995]

6.2 The identical clay samples of the same size, designated as *A* and *B* are subjected to consolidation test under identical loading conditions. Drainage takes place through one face in sample *A* and through both the faces in sample *B*. 50% consolidation of sample *A* occurs in 10 minutes. The time required for 50% consolidation to occur in sample *B* will be
(a) 40 minutes (b) 10 minutes
(c) 5 minutes (d) 2.5 minutes
[ESE : 1995]

6.3 The void ratio-pressure diagram is shown in the given figure. The coefficient of compressibility is



(a) 0.0050 m^2/t (b) 0.073 m^2/t
(c) 0.20 m^2/t (d) 0.25 m^2/t
[ESE : 1995]

6.4 A clay layer 5 m thick in field takes 300 days to attain 50% consolidation with condition of double drainage. If the same clay layer is underlain by hard rock then the time taken to attain 50% consolidation will be
(a) 300 days (b) 600 days
(c) 900 days (d) 1200 days
[ESE : 1996]

6.5 The change that take place during the process of consolidation of a saturated clay would include
(a) an increase in pore water pressure and an increase in effective pressure
(b) an increase in pore water pressure and a decrease in effective pressure
(c) a decrease in pore water pressure and a decrease in effective pressure
(d) a decrease in pore water pressure and an increase in effective pressure
[ESE : 1997]

6.6 Match **List-I** (Property) with **List-II** (Slope of the curve) and select the correct answer using the codes given below the lists:

List-I
A. Coefficient of compressibility
B. Compression index
C. Coefficient of subgrade modulus

List-II
1. Stress-deformation
2. Stress-void ratio
3. Volume-pressure
4. Log stress-void ratio

Codes:

	A	B	C
(a)	4	2	1
(b)	4	3	2
(c)	2	4	1
(d)	3	4	1

[ESE : 1997]

6.7 The initial and final void ratios of a clay sample in a consolidation test are 1 and 0.5, respectively. If initial thickness of the sample is 2.4 cm, then its final thickness will be
(a) 1.3 cm (b) 1.8 cm
(c) 1.9 cm (d) 2.2 cm

[ESE : 1997]

6.8 Match **List-I** (Effect) with **List-II** (Reason) and select the correct answer using the codes given below the lists:

List-I
A. Excessive settlement
B. High expansivity
C. Reduction of bearing capacity
D. Acceleration of consolidation

List-II
1. Rise of water table
2. High compressibility
3. Montmorillonite
4. Sand drains

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	2	3	4	1
(c)	4	1	3	2
(d)	2	3	1	4

[ESE : 1997]

6.9 Which one of the following soils has stress-strain response similar to that of dense sand? (OCR stands for over consolidation ratio)
(a) Over consolidated clays having high OCR
(b) Over consolidated clays having low OCR
(c) Normally consolidated clays
(d) Unconsolidated clays

[ESE : 1998]

6.10 In the consolidated drained test on a saturated soil sample, pore water pressure is zero during
(a) consolidation stage only
(b) shearing stage only
(c) both consolidation and shearing stages
(d) loading stage

[ESE : 1998]

6.11 Consider the following statements:
1. The degree of saturation of a saturated soil mass subjected to pressure remains unchanged during the process of consolidation.
2. Secondary consolidation is due to the plastic deformation of the soil when the pore fluid is not subjected to any excess pressure.
3. Primary consolidation is independent of the coefficient of permeability of the soil but depends on the decrease in void volume due to air escape.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1998]

6.12 Terzaghi's consolidation theory is applicable to one-dimensional consolidation test
(a) for small load increment ratios
(b) for large load increment ratios
(c) for a load increment ratio of nearly one
(d) in situations where there is no excess pore pressure

[ESE : 1998]

6.13 Which one of the following pairs of parameters and expression is NOT correctly matched?
(a) Coefficient of consolidation

$$\dots \frac{T_v H^2}{t}$$

(b) Coefficient of volume compressibility

$$\dots \frac{e_0 - e}{(1+e_0)(p-p_0)}$$

(c) Over consolidation ratio

$$\dots \sqrt{\frac{\text{Maximum previous effective pressure}}{\text{Existing effective pressure}}}$$

(d) Modulus of volume change ... $\dfrac{a_v}{1+e_0}$

[ESE : 1999]

6.14 Consider the following:

1. Initial consolidation
2. Primary consolidation
3. Secondary consolidation
4. Final consolidation

The three stages which would be relevant to consolidation of a soil deposit includes

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 4

[ESE : 1999]

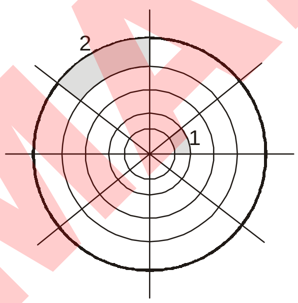
6.15 Assertion (A): Terzaghi's theory of consolidation considers only primary consolidation.

Reason (R): Secondary consolidation takes place only at the end of the primary consolidation.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1999]

7. Stress Distribution in the Soil

7.1 Standard Newmark's influence chart is shown in the given figure. If loaded equally the areas marked 1 and 2 will yield pressures at the centre such that



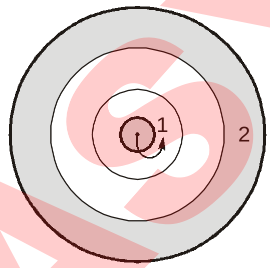
(a) 1 yield more than 2
(b) 2 yield more than 1
(c) 1 and 2 yield the same
(d) 1 yield exactly half of that of 2

[ESE : 1995]

7.2 A concentrated load of 50 t acts vertically at a point on the soil surface. If Boussinesq's equation is applied for computation of stress, then the ratio of vertical stresses at depths of 3 m and 5 m respectively vertically below the point of application of load will be

(a) 0.36 (b) 0.60
(c) 1.66 (d) 2.77 [ESE : 1995]

7.3 A part of the Newmark's influence chart with four concentric circles is shown in the figure below. If the hatched areas 1 and 2 are loaded separately with the same intensity of loading, then the intensity of pressure yielded



(a) by 1 will be more than that yielded by 2
(b) by 2 will be more than that yielded by 1
(c) by 1 and 2 will be equal
(d) at the centre will be inversely proportional to the radii of the two circles

[ESE : 1997]

7.4 For a vertical concentrated load acting on the surface of a semi-infinite elastic soil mass, the vertical normal stress at depth 'z' is proportional to

(a) z (b) $1/z$
(c) z^2 (d) $1/z^2$

[ESE : 1997]

7.5 With a vertical point load on the surface when considering the vertical plane passing through the load, the stress gets reduced by 52.3% at a depth of

(a) 0.25 of unit length (b) 0.5 of unit length
(c) 0.75 of unit length (d) 1 of unit length

[ESE : 1999]

8. Shear Strength of Soil

8.1 In an unconfined compression test on a saturated clay, the undrained shear strength was found to be 6 t/m^2. If a sample of the same soil is tested in an undrained condition in triaxial compression at a cell pressure of 20 t/m^2, then the major principal stress at failure will be

(a) 48 t/m^2 (b) 32 t/m^2
(c) 24 t/m^2 (d) 12 t/m^2

[ESE : 1995]

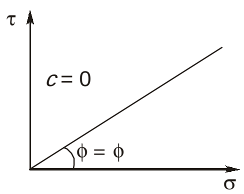
8.2 A laboratory vane shear test apparatus is used to determine the shear strength of a clay sample and only one end of the vane takes part in shearing the soil. If T = applied torque, H = height of vane and D = diameter of the vane, then shear strength of the clay is given by

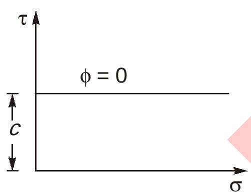
(a) $\dfrac{T}{\pi D^2\left(H+\dfrac{D}{6}\right)}$ (b) $\dfrac{T}{\pi D^2\left(\dfrac{H}{2}+\dfrac{D}{12}\right)}$

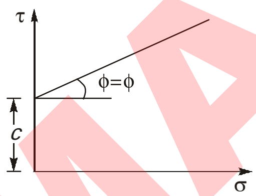
(c) $\dfrac{T}{\pi D^2\left(H+\dfrac{D}{10}\right)}$ (d) $\dfrac{T}{\pi D^2\left(H+\dfrac{D}{12}\right)}$

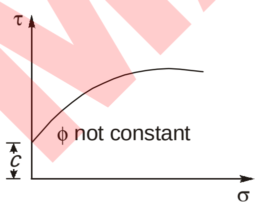
[ESE : 1995]

8.3 Which one of the following figure gives the failure envelope for a normally consolidated saturated clay sample tested in triaxial test under drained conditions?

(a)


(b)


(c)


(d)


[ESE : 1996]

8.4 Match **List-I** (Type of shear tests) with **List-II** (Mohr circle and its envelope) and select the correct answer using the codes given below the lists:

List-I

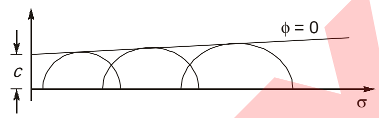
A. Undrained test on normally consolidated saturated clays

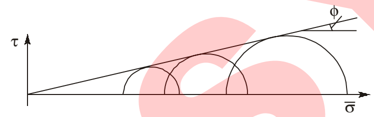
B. Consolidated undrained test on normally consolidated saturated clays

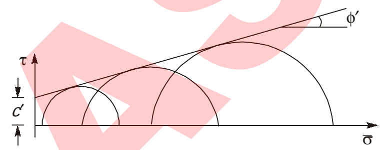
C. Drained tests on saturated cohesive soil

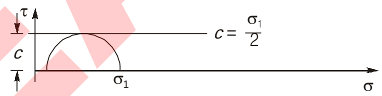
D. Unconfined test on clays

List-II

1.


2.


3.


4.


Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	1	2	3	4
(c)	4	3	2	1
(d)	3	2	1	4

[ESE : 1996]

8.5 A soil fails under an axial vertical stress of 100 kN/m^2 in unconfined compression test. The failure plane makes an angle of 50° with the horizontal. The shear parameters 'c' and 'ϕ' respectively will be

(a) 41.9 kN/m^2, 0° (b) 50.0 kN/m^2, 0°
(c) 41.9 kN/m^2, 10° (d) 50.0 kN/m^2, 10°

[ESE : 1996]

8.6 A and B are Skempton's pore pressure coefficients. For saturated normally consolidated soils,

(a) $A > 1$ and $B > 1$ (b) $A > 1$ and $B < 1$
(c) $A < 1$ and $B > 1$ (d) $A < 1$ and $B = 1$

[ESE : 1997]

8.7 A clay soil specimen when tested in unconfined condition gave an unconfined compressive strength of 100 kN/m^2. A specimen of the same clay with the same initial condition is subjected to a UU triaxial test under a cell pressure of 100 kN/m^2. Axial stress (in kN/m^2) at failure would be

(a) 150 (b) 200
(c) 250 (d) 300

[ESE : 1997]

8.8 If 's' is the shear strength, 'c' and ϕ are shear strength parameters, and 'σ_n' is the normal stress at failure, then Coulomb's equation for shear strength of the soil can be represented by

(a) $c = s + \sigma_n \tan\phi$ (b) $c = s - \sigma_n \tan\phi$
(c) $s = \sigma_n + c \tan\phi$ (d) $s = c - \sigma_n \tan\phi$

[ESE : 1997]

8.9 A dry sand specimen is put through a triaxial test. The cell pressure is 50 kPa and the deviator stress at failure is 100 kPa, the angle of internal friction for the sand specimen is

(a) 15° (b) 30°
(c) 37° (d) 45°

[ESE : 1997]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

8.10 Assertion (A): In box shear test, the failure plane is predetermined and is horizontal.

Reason (R): The shear stress is applied in the vertical direction.

[ESE : 1997]

8.11 Assertion (A): In the case of unconfined compression test, Mohr's circle passes through the origin.

Reason (R): The major principal stress is zero.

[ESE : 1997]

8.12 Shear failure of soils takes place when

(a) the angle of obliquity is maximum
(b) maximum cohesion is reached in cohesive soils
(c) ϕ reaches its maximum value in cohesionless soils
(d) residual strength of the soil is exhausted

[ESE : 1998]

8.13 A triaxial test was conducted on a granular soil. At failure $\dfrac{\sigma_1}{\sigma_3} = 4$. The effective minor principal stress at failure was 100 kPa. The values of approximate ϕ and the principal stress difference at failure are, respectively

(a) 45° and 570 kPa (b) 40° and 400 kPa
(c) 37° and 300 kPa (d) 30° and 200 kPa

[ESE : 1998]

8.14 In a Mohr's diagram, a point above Mohr's envelope indicates

(a) imaginary condition
(b) safe condition
(c) imminent failure condition
(d) condition of maximum obliquity

[ESE : 1998]

8.15 Which one of the following is the reason for the likelihood of erroneous results of a Direct Shear Test on a saturated clay sample?

(a) The test amounts to undrained test
(b) Failure plane is predetermined
(c) Progressive failure might take place
(d) Drainage conditions are not controllable

[ESE : 1998]

8.16 Which one of the following tests CANNOT be done without undisturbed sampling?

(a) Shear strength of sand
(b) Shear strength of clay
(c) Determination of compaction parameters
(d) Atterberg limits

[ESE : 1998]

8.17 Assertion (A): For a fully saturated soil, the pore pressure parameter is equal to zero.

Reason (R): The compressibility of water is much smaller than the coefficient of volume compressibility.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

8.18 Match **List-I** (Field problems) with **List-II** (Type of laboratory shear test) and select the correct answer using the codes given below the lists:

List-I

A. Stability of a clay foundation of an embankment, whose rate of construction is such that some consolidation occurs
B. Initial stability of a footing on saturated clay
C. Long-term stability of a slope in stiff, fissured clay
D. Foundation on soft marine clay deposits.

List-II

1. Undrained triaxial test
2. Drained triaxial test
3. Consolidated undrained test
4. Quick vane shear test

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	1	3	2	4
(c)	3	1	2	4
(d)	3	1	4	2

[ESE : 1999]

8.19 In a direct shear test, the shear stress and normal stress on a dry sand sample at failure are 0.6 kg/cm^2 and 1 kg/cm^2 respectively. The angle of internal friction of the sand will be nearly
(a) 25° (b) 31°
(c) 37° (d) 43°

[ESE : 1999]

8.20 Match **List-I** (Investigator) with **List-II** (Equation) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Skempton	**1.** $v = ki$
B. Coulomb	**2.** $\sigma' = \sigma - u$
C. Stokes	**3.** $v = \dfrac{D^2(\gamma_s - \gamma_w)}{18\eta}$
D. Terzaghi	**4.** $s = c + \sigma \tan\phi$
	5. $u = B[\sigma_3 + A(\sigma_1 - \sigma_3)]$

Codes:

	A	B	C	D
(a)	4	5	3	2
(b)	5	4	3	2
(c)	4	5	1	3
(d)	5	4	2	3

[ESE : 1999]

8.21 If an unconfined compressive strength of 4 kg/cm^2 in the natural state of clay reduces by four times in the remoulded state, then its sensitivity will be
(a) 1 (b) 2
(c) 4 (d) 8

[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

8.22 Assertion (A): Shear parameters 'c' and ϕ vary with drainage conditions of shear test.
Reason (R): Shear parameter 'c' and ϕ are dependent on water content of soil.

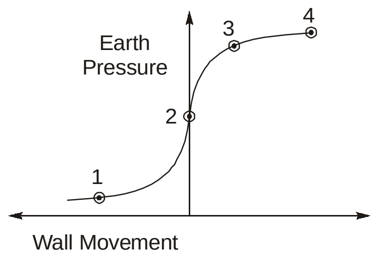
[ESE : 1999]

9. Retaining Wall/Earth Pressure Theories

9.1 A retaining wall retains a sand strata with ϕ = 30° up to its top. If a uniform surcharge of 12 t/m^2 is subsequently put on the sand strata, then the increase in the lateral earth pressure intensity on the retaining wall will be
(a) 1 t/m^2 (b) 2 t/m^2
(c) 4 t/m^2 (d) 8 t/m^2

[ESE : 1995]

9.2 The variation of earth pressure with wall movement is shown in the figure by the points labelled



(a) 1 and 2 (b) 2 and 3
(c) 2 and 4 (d) 1 and 4

[ESE : 1995]

9.3 No tension should develop at the base of the rectangular well foundation or at any horizontal section within the well. For no tension at the base, the resultant of P_a (Total active thrust) and W (Weight of soil and well above the base) must pass through middle

(a) half of the base
(b) third of the base
(c) quarter of the base
(d) of the base

[ESE : 1995]

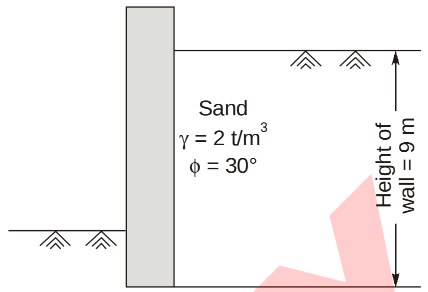
9.4 **Assertion (A):** The safe height ($2z_0$) to which an unsupported vertical cut in clay can be made is $4c/\gamma$.

Reason (R): Active earth pressure of cohesive backfill shows that the negative pressure (tension) is developed at top level. This tension decrease to zero at depth z_0 and total net pressure up to a depth $2z_0$ is zero.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

9.5 Active earth pressure per metre length on the retaining wall with a smooth vertical back as shown in the given figure will be



(a) 81 t (b) 27 t
(c) 2 t (d) 1 t

[ESE : 1996]

9.6 A retaining wall with vertical back retains a cohesionless dry backfill at an inclination of β with the horizontal. The backfill has an angle of internal friction ϕ, unit weight γ and height of the wall is H. The passive earth pressure on the wall is given by (where P_p = Total passive earth pressure)

(a) $P_p = \frac{1}{2}\gamma H^2 \cos\beta\left[\frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}\right]$

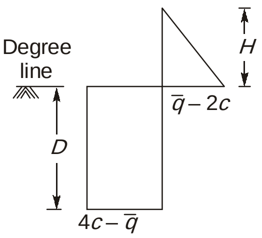
(b) $P_p = \frac{1}{2}\gamma H^2 \cos\beta\left[\frac{\cos\beta - \sqrt{\cos^2\beta + \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta + \cos^2\phi}}\right]$

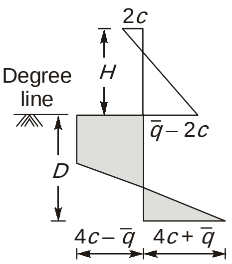
(c) $P_p = \frac{1}{2}\gamma H^2 \cos\beta\left[\frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}\right]$

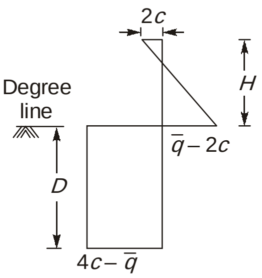
(d) $P_p = \frac{1}{2}\gamma H^2 \cos\beta\left[\frac{\cos\beta + \sqrt{\cos^2\beta + \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta + \cos^2\phi}}\right]$

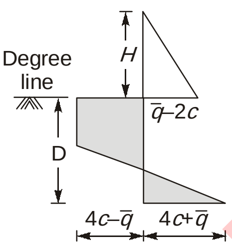
[ESE : 1996]

9.7 In the following figures, if
H = height of wall above dredge line,
$\bar{q}$ = effective vertical stress at any depth,
c = unit cohesion,
and passive pressure is shown hatched in the figures, then the earth pressure distribution diagram used for analysis of a cantilever sheet pile embedded to a depth D in a purely cohesive soil will be as in

(a) 

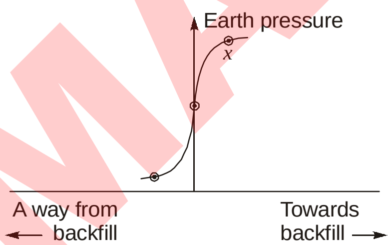
(b) 

(c) 

(d) 

[ESE : 1996]

9.8 Earth pressure and resultant possibilities of wall movement are shown in the diagram below.



Lateral movement of retaining wall

The point marked X in the diagram denotes

(a) earth pressure at rest
(b) active earth pressure
(c) arching active pressure
(d) passive earth pressure [ESE : 1997]

9.9 In a cohesionless soil deposit having a unit weight of 1.5 t/m^3 and an angle of internal friction of 30°, the active and passive lateral earth pressure intensities (in t/m^2) at a depth of 10 m will, respectively, be

(a) 15 and 5 (b) 5 and 15
(c) 10 and 20 (d) 20 and 10

[ESE : 1997]

9.10 Given that for a soil deposit,

K_o = earth pressure coefficient at rest
K_a = active earth pressure coefficient
K_p = passive earth pressure coefficient
μ = Poisson's ratio.

The value of $(1-\mu)/\mu$ is given by

(a) K_a/K_p (b) K_o/K_a
(c) K_p/K_a (d) $1/K_o$

[ESE : 1997]

9.11 Consider the following statements:
Rankine's theory and Coulomb's theory give same values of coefficients of active and passive earth pressures when

1. the retaining wall has a vertical back
2. the backfill is cohesionless
3. angle of slope of backfill is equal to the angle of internal friction
4. angle of slope of backfill is 0°
5. angle of wall friction δ is 0°
6. angle of wall friction δ is equal to ϕ

Which of these statements is/are correct?

(a) 1, 2, 3 and 5
(b) 1, 2, 4 and 5
(c) 2, 3, and 6
(d) 1, 4 and 6 [ESE : 1998]

9.12 Consider the following statements:

1. Coulomb's earth pressure theory does not take the roughness of wall into consideration.
2. In case of non-cohesive soils, the coefficients of active earth pressure and earth pressure at rest are equal.
3. Any movement of retaining wall away from the fill corresponds to active earth pressure condition.

Which of these statements is/are correct?

(a) 1 alone (b) 1 and 2
(c) 2 alone (d) 3 alone

[ESE : 1998]

9.13 Match **List-I** (Type of structure) with **List-II** (Type of pressure exerted by sandy back fill) and select the correct answer using the codes given below the lists:

List-I

A. A masonry retaining wall founded on compressible clay

B. Pressure on the back of a cantilever sheet pile wall near the embedded end

C. A masonry retaining wall founded on rock

List-II

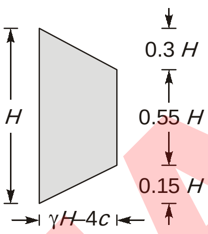
1. Active pressure
2. Earth pressure at rest
3. Passive earth pressure

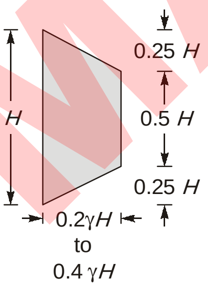
Codes:

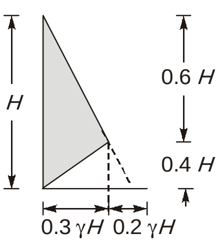
	A	B	C
(a)	1	3	2
(b)	3	2	1
(c)	3	1	2
(d)	2	3	1

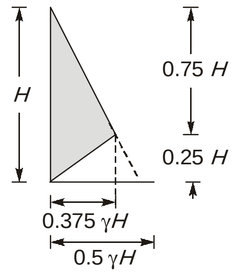
[ESE : 1999]

9.14 Which one of the following typical pressure distribution diagrams represents the lateral pressure distribution on braced sheeting in stiff clay with temporary support, as given by Tschebotarioff?

(a)


(b)


(c)


(d)


[ESE : 1999]

9.15 Given that c = 2 t/m^2, ϕ = 0° and γ = 2 t/m^3, the depth of tension crack developing in a cohesive soil backfill would be

(a) 1 m (b) 2 m
(c) 3 m (d) 4 m

[ESE : 1999]

10. Stability Analysis of Slopes

10.1 Consider the following assumptions for slope stability analysis:

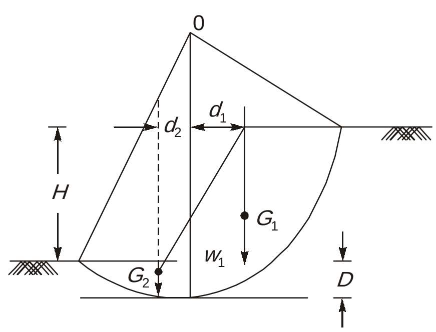
1. Friction is fully mobilized.
2. Effective stress analysis is adopted.
3. Total stress analysis is used.
4. Resultant 'R' passes through the centre of the circle.
5. Resultant 'R' is tangential to the friction circle.

The assumptions necessary for friction circle method of analysis would include

(a) 1, 3 and 4 (b) 1, 3 and 5
(c) 2 and 4 (d) 2 and 5

[ESE : 1995]

10.2 The depth factor D_f in slope failure in the situation shown in the figure will be



(a) greater than one (b) less than one
(c) equal to one (d) equal to zero

[ESE : 1999]

10.3 If an infinite slope of clay at a depth 5 m has cohesion of 1 t/m^2 and unit weight of 2 t/m^3, then the stability number will be
(a) 0.1 (b) 0.2
(c) 0.3 (d) 0.4
[ESE : 1999]

11. Shallow Foundation and Bearing Capacity

11.1 Bearing capacity of a soil strata supporting a footing of size 3 m × 3 m will not be affected by the presence of ground water table located at a depth which is
(a) 1.0 m below the base of the footing
(b) 1.5 m below the base of the footing
(c) 2.5 m below the base of the footing
(d) 3 m below the base of the footing
[ESE : 1995]

11.2 **Assertion (A):** Terzaghi's bearing capacity theory is not applied to deep foundations.
Reason (R): Shear strength is mobilized on the sides of deep foundations.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1995]

11.3 A raft foundation is to be constructed on a sandy soil. The maximum differential settlement and limiting maximum settlement as recommended by Indian Standard code are:

	Max. differential settlement	Limiting max. settlement
(a)	40 mm	65 mm to 100 mm
(b)	40 mm	40 mm to 65 mm
(c)	25 mm	65 mm to 100 mm
(d)	25 mm	40 mm to 65 mm

[ESE : 1996]

11.4 A rectangular footing 1 m × 2 m is placed at a depth of 2 m in a saturated clay having an unconfined compressive strength of100 kN/m^2. According to Skempton, the net ultimate bearing capacity is
(a) 420 kN/m^2 (b) 412.5 kN/m^2
(c) 385 kN/m^2 (d) 350 kN/m^2
[ESE : 1996]

11.5 If the actual observed value of standard penetration resistance, *N*, is greater than 15 in a fine sand layer below water table, then the equivalent penetration resistance will be
(a) $15+\left(\dfrac{N+15}{2}\right)$ (b) $15-\left(\dfrac{N+15}{2}\right)$
(c) $15+\left(\dfrac{N-15}{2}\right)$ (d) $15+\left(\dfrac{15-N}{2}\right)$
[ESE : 1997]

11.6 Match **List-I** (Field test) with **List-II** (Parameters measured) and select the correct answer using the codes given below the lists:

List-I
A. Plate Load Test
B. Standard Penetration Test
C. Static Dutch Cone Penetration Test
D. Dynamic Penetration Test

List-II
1. Total and frictional resistances
2. Load intensity and settlement values
3. N_{CD} values
4. SPT values

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	4	2	3	1
(c)	2	4	1	3
(d)	4	2	1	3

[ESE : 1997]

11.7 In standard penetration test, the split spoon sampler is penetrated into the soil stratum by giving blows from a drop weight whose weight (in kg) and free fall (in cm) are, respectively
(a) 30 and 60 (b) 60 to 30
(c) 65 to 75 (d) 75 to 65
[ESE : 1997]

11.8 **Assertion (A):** In the case of sand deposits with uniform density, *N* values are found to increase with depth.
Reason (R): Overburden pressure increases with depth below ground level.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

11.9 A rectangular footing $L \times B$ is to be placed at a depth D below ground level such that $\frac{D}{B} < 2.5$.

The factor N_C to be used in deciding of the allowable bearing capacity for the footing as given by Skempton is calculated using the equation
(where $N_{CR} = N_C$ for rectangular footing, $N_{CS} = N_C$ at surface)

(a) $N_{CR} = 1.4\, N_{CS}$

(b) $N_{CR} = \left(1 + 0.2\frac{D}{B}\right) N_{Cs}$

(c) $N_{CR} = \left(1 + 0.2\frac{B}{L}\right) N_{Cs}$

(d) $N_{CR} = \left(1 + 0.2\frac{B}{L}\right)\left(1 + 0.2\frac{D}{B}\right) N_{Cs}$

[ESE : 1998]

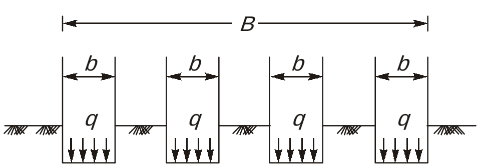
11.10 Consider the following statements associated with local shear failure of soils:
1. Failure is sudden with well-defined ultimate load.
2. This failure occurs in highly compressible soils.
3. Failure is preceded by large settlement.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1998]

11.11 Four square footings, $b \times b$, each carrying a loading intensity of q are spaced close enough as shown in the given figure:



The significant depth D_s, i.e., depth of vertical stress contour, having a value of $0.2q$ will be

(a) 1.5 b (b) 6.0 b
(c) 1.5 $(B - 4b)$ (d) 1.5 B **[ESE : 1998]**

11.12 Rafts resting on sands can be allowed double of the allowable soil pressure when
(a) permissible settlement is doubled
(b) length is doubled
(c) depth factor is increased
(d) water table is lowered **[ESE : 1998]**

11.13 Consider the following statements:
The Standard Penetration Test (SPT) in soils is the most commonly used field test. SPT is used to determine
1. consistency of clay
2. undrained shear strength of soft sensitive clays
3. relative density of sands
4. drained shear strength of fine loose sand

Which of these statements are correct?

(a) 1 and 2 (b) 2 and 4
(c) 1 and 3 (d) 3 and 4

[ESE : 1998]

11.14 Consider the following statements:
1. Dynamic cone penetration test for site investigation is based on the principle that elastic shock waves travel in different materials at different velocities.
2. Electrical resistivity method of subsurface investigation is capable of detecting only the strata having different electrical resistivity.
3. In-situ vane shear test is useful for determining the shear strength of very soft soil and sensitive clays and is unsuitable for sandy soil.

Which of these statements is/are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 2 alone

[ESE : 1998]

11.15 As per **IS:1904-1986** the permissible angular distortion with respect to steel structures in isolated foundations resting on plastic clay is

(a) $\frac{2}{3000}$ (b) $\frac{1}{3000}$

(c) $\frac{1}{300}$ (d) $\frac{2}{300}$ **[ESE : 1999]**

11.16 Influence factor for immediate settlement of footing depends on its
(a) size and shape
(b) rigidity alone
(c) location and size
(d) size, shape, rigidity and location
[ESE : 1999]

11.17 As per Terzaghi's equation, the bearing capacity of strip footing resting on cohesive soil (c = 10 kN/m^2) for unit depth and unit width (assume N_c as 5.7) is
(a) 47 kN/m^2 (b) 57 kN/m^2
(c) 67 kN/m^2 (d) 77 kN/m^2
[ESE : 1999]

11.18 A raft of 6 m × 9 m is founded at a depth of 3 m in a cohesive soil having c = 120 kN/m^2. The ultimate net bearing capacity of the soil using the Terzaghi's theory will be nearly
(a) 820 kN/m^2 (b) 920 kN/m^2
(c) 1036 kN/m^2 (d) 1067 kN/m^2
[ESE : 1999]

11.19 The standard penetration resistance N of a granular deposit is found to be 20. The soil can be classified approximately in terms of ϕ and density index respectively as
(a) 20° and 10% for very loose condition
(b) 32° and 50% for medium condition
(c) 32° and 30% for loose condition
(d) 38° and 65% for dense condition
[ESE : 1999]

12. Deep Foundation, Sheet Pile Walls and Machine Foundation

12.1 Consider the following statements regarding negative skin friction in piles:
1. It is developed when the pile is driven through a recently deposited clay layer.
2. It is developed when the pile is driven through a layer of dense sand.
3. It is developed due to a sudden drawdown of the water table.

Which of these statements is/are correct?
(a) 1 alone (b) 2 alone
(c) 2 and 3 (d) 1 and 3
[ESE : 1995]

12.2 Efficiency of a pile group is defined as
(a) $\dfrac{\text{Load carried by the largest pile in the group}}{\text{Load carried by the smallest pile in the group}}$
(b) $\dfrac{\text{Maximum load carried by a pile in the group}}{\text{Minimum load carried by a pile in the group}}$
(c) $\dfrac{\text{Minimum load carried by a pile in the group}}{\text{Maximum load carried by a pile in the group}}$
(d) $\dfrac{\text{Average load carried by a pile in the group}}{\text{Load carried by a single pile}}$
[ESE : 1995]

12.3 Match **List-I** (Soil property measured) with **List-II** (In-situ test) and select the correct answer using the codes given below the lists:

List-I
A. Modulus of subgrade reaction
B. Relative density and strength
C. Skin friction and point bearing
D. Elastic constants

List-II
1. Cyclic pile load test
2. Pressuremeter test
3. Plate load test
4. Standard penetration test

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	1	2	4	3
(c)	2	4	1	3
(d)	3	4	1	2

[ESE : 1995]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

12.4 **Assertion (A):** Bearing capacity of an under-reamed pile is less than that of a straight bored pile of the same diameter.
Reason (R): Under-reamed piles have enlarged bulbs.
[ESE : 1995]

12.5 Assertion (A): Franki pile has an enlarged base of mushroom shape which gives the effect of spread footing.

Reason (R): The Franki pile is best suited for granular soil.

[ESE : 1995]

12.6 Assertion (A): Negative skin friction will act on piles in filled up soils, which should be considered in design of pile foundations.

Reason (R): The filled up soils start consolidating and develop a drag force on the pile.

[ESE : 1996]

12.7 A 30 cm diameter friction pile is embedded 10 m into a homogeneous consolidated deposit. Unit adhesion developed between clay and pile shaft is 4 t/m^2 and adhesion factor is 0.7. The safe load for factor of safety 2.5 will be

(a) 21.50 t (b) 11.57 t
(c) 10.55 t (d) 6.35 t

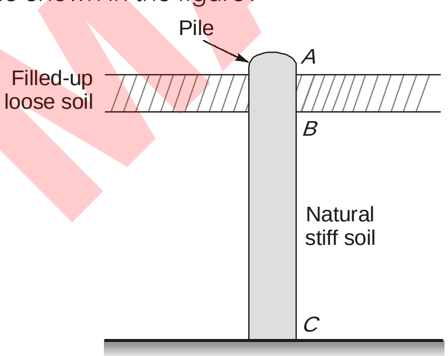
[ESE : 1996]

12.8 In case of well foundation, grip length is defined as the

(a) length below the top of the well cap to the cutting edge
(b) length between the bottom of the well cap to the cutting edge
(c) depth of the bottom of the well below the minimum scour level
(d) depth of the bottom of the well below the maximum scour level

[ESE : 1996]

12.9 Which of the following statements are true for the pile shown in the figure?



1. Frictional resistance acts upwards throughout the length of the pile.
2. Negative skin friction acts over the length AB.
3. Frictional resistance acts upwards over the length BC.
4. There is point resistance at level C.

Select the correct answer using the codes given below:

(a) 1, 3 and 4 (b) 2, 3 and 4
(c) 1 and 2 (d) 2 and 3

[ESE : 1997]

12.10 Consider the following statements regarding under reamed piles:

1. They are used in expansive soils.
2. They are of precast reinforced concrete.
3. The ratio of bulb to shaft diameters is usually 2 to 3.
4. Minimum spacing between the piles should not be less than 1.5 times the bulb diameter.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 4

[ESE : 1997]

12.11 Minimum centre to centre spacing of friction piles of diameter (D) as per BIS code is

(a) 1.5D (b) 2D
(c) 2.5D (d) 3D

[ESE : 1998]

12.12 Consider the following statements:

1. In case of pile groups in cohesive soil, block failure occurs for smaller spacing between the piles.
2. According to Feld's rule for determining pile group efficiency, the load carrying capacity of each pile is increased by 1/16 owing to the effect of the nearest pile.
3. In medium dense sand, settlement of a pile group is more than settlement of single pile.

Which of these statements is/are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1,2 and 3

[ESE : 1998]

12.13 For four free standing pile group having arc tan value of 18.3, the efficiency as per Converse Labarre formula, would be

(a) 76% (b) 78%
(c) 80% (d) 82%

[ESE : 1999]

12.14 Ratio of bearing capacity of double Under Reamed (UR) pile to that of single reamed pile is nearly

(a) 2 (b) 1.5

(c) 1.2 (d) 1.7

[ESE : 1999]

12.15 Match **List-I** (Sheet piles with various conditions and methods of analysis) with **List-II** (Earth pressure distribution) and select the correct answer using the codes given below the lists:

List-I

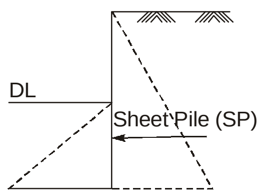
A. Cantilever sheet pile, granular soil and approximate analysis

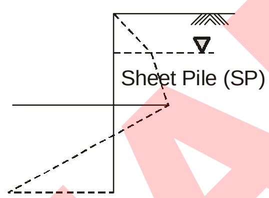
B. Anchored sheet pile, granular soil and fixed method

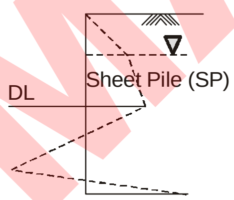
C. Anchored sheet pile, granular soil and free earth method

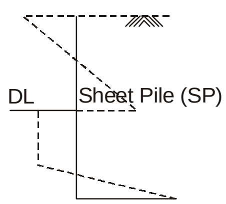
D. Cantilever sheet pile, cohesive soil and approximate analysis

List-II

1. 

2. 

3. 

4. 

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	4	2	3	1
(d)	1	3	2	4

[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

12.16 **Assertion (A):** Anchored sheet pile wall is supported near its top by rods or cables anchored in soil.

Reason (R): The anchor system reduces the depth of penetration and the thickness of section of pile.

[ESE : 1999]

13. Soil Stabilization and Soil Exploration

13.1 Consider the following properties for a soil sampler:

1. Area ratio should be low.
2. Cutting edge should be thick.
3. Inside clearance should be high.
4. Outside clearance should be low.

The properties necessary for a good quality soil sampler would include

(a) 1 and 4 (b) 1, 2 and 4

(c) 2, 3 and 4 (d) 1, 3 and 4

[ESE : 1995]

13.2 Consider the following statements:

In subsoil exploration programme the term "significant depth of exploration" is up to

1. the width of foundation
2. twice width of foundation

3. the depth where the additional stress intensity is less than 20% of overburden pressure
4. the depth where the additional stress intensity is less than 10% of the overburden pressure
5. hard rock level

Which of these statements is/are correct?

(a) 1, 3 and 5 (b) 2, 3 and 5
(c) 1 and 4 (d) 2 and 4

[ESE : 1996]

13.3 A good quality undisturbed soil sample is one which is obtained using a sampling tube having an area ratio of

(a) 8% (b) 16%
(c) 24% (d) 32%

[ESE : 1998]

13.4 Consider the following statements:

1. Increase in volume of a soil sample without external constraints on submergence in water is termed as the 'free swell of soil.'
2. Clay soil rich in montmorillonite exhibits very low swelling characteristic.
3. Generally, free swell of soil sample ceases when its water content reaches the plastic limit.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1998]

13.5 **Assertion (A):** Wash boring is recommended to obtain undisturbed soil sample above ground water table.

Reason (R): In wash boring, water pumped through the hollow drill rods emerges through the ports of the chopping bit carrying disintegrated soil fragments.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

Answers Soil Mechanics and Foundation Engineering

1.1	(b)	1.2	(c)	1.3	(d)	1.4	(a)	1.5	(c)	1.6	(c)	1.7	(d)	1.8	(b)	1.9	(b)
1.10	(c)	1.11	(c)	1.12	(b)	1.13	(b)	1.14	(c)	1.15	(c)	1.16	(b)	1.17	(b)	1.18	(a)
1.19	(b)	1.20	(b)	1.21	(b)	1.22	(d)	2.1	(d)	2.2	(b)	2.3	(b)	2.4	(b)	3.1	(c)
3.2	(d)	3.3	(c)	3.4	(b)	3.5	(b)	3.6	(a)	3.7	(c)	3.8	(b)	4.1	(c)	4.2	(c)
4.3	(a)	4.4	(a)	4.5	(c)	4.6	(a)	4.7	(b)	4.8	(c)	4.9	(c)	4.10	(b)	4.11	(d)
4.12	(c)	4.13	(c)	4.14	(c)	4.15	(d)	5.1	(d)	5.2	(b)	5.3	(a)	5.4	(a)	6.1	(a)
6.2	(d)	6.3	(c)	6.4	(d)	6.5	(d)	6.6	(c)	6.7	(b)	6.8	(d)	6.9	(a)	6.10	(c)
6.11	(a)	6.12	(a)	6.13	(c)	6.14	(a)	6.15	(b)	7.1	(c)	7.2	(d)	7.3	(c)	7.4	(d)
7.5	(d)	8.1	(b)	8.2	(b)	8.3	(a)	8.4	(b)	8.5	(c)	8.6	(d)	8.7	(b)	8.8	(b)
8.9	(b)	8.10	(c)	8.11	(c)	8.12	(a)	8.13	(c)	8.14	(a)	8.15	(b)	8.16	(b)	8.17	(d)
8.18	(c)	8.19	(b)	8.20	(b)	8.21	(c)	8.22	(b)	9.1	(c)	9.2	(d)	9.3	(b)	9.4	(a)
9.5	(b)	9.6	(c)	9.7	(b)	9.8	(d)	9.9	(b)	9.10	(d)	9.11	(b)	9.12	(d)	9.13	(a)
9.14	(c)	9.15	(b)	10.1	(b)	10.2	(a)	10.3	(a)	11.1	(d)	11.2	(a)	11.3	(d)	11.4	(c)
11.5	(c)	11.6	(c)	11.7	(c)	11.8	(a)	11.9	(d)	11.10	(c)	11.11	(d)	11.12	(a)	11.13	(c)
11.14	(c)	11.15	(c)	11.16	(d)	11.17	(b)	11.18	(a)	11.19	(b)	12.1	(d)	12.2	(d)	12.3	(d)
12.4	(d)	12.5	(b)	12.6	(a)	12.7	(c)	12.8	(d)	12.9	(b)	12.10	(b)	12.11	(d)	12.12	(b)
12.13	(c)	12.14	(b)	12.15	(d)	12.16	(a)	13.1	(a)	13.2	(d)	13.3	(a)	13.4	(b)		
13.5	(d)																

Explanations Soil Mechanics and Foundation Engineering

1. Properties of Soils

1.1 (b)

Alluvial soil is a fine grained fertile soil deposited by water flowing over flood plains or in river beds.

Lacustrine Soil is deposited at bottom of lakes. The soil material consists of a clay and silt mixture.

Aeolian soils are wind deposited materials that consist primarily of sand or silt-sized particles. These materials tend to be extremely well sorted and free of coarse fragments.

Marine soils are sediments that accumulate in a marine (ocean or sea) environment. These sediments are later exposed and subjected to soil development because either the ocean floor was uplifted or the water receded.

1.2 (c)

Activity

$$= \frac{\text{Plasticity index}}{\text{Percent of clay particles finer than } 2\mu\text{m}}$$

$$= \frac{65-29}{24} = \frac{36}{24}$$

$$= 1.5 > 1.25$$

$\therefore$ The soil is active.

1.3 (d)

Specific Gravity of solids is given by

$$G_s = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

1.4 (a)

At shrinkage limit ($S = 100\%$)

$$\therefore \quad e = wG_s$$
$$w = 10\%$$
$$G_s = 2.7$$

Porosity, $$n = \frac{e}{1+e} \times 100$$

$$= \frac{0.27}{1+0.27} \times 100 = 21.2\%$$

1.5 (c)

The volume of soil increases from plastic limit to liquid limit. The cracking in soil is due to reduction in bearing capacity and consequent failure and heaving.

1.6 (c)

Void ratio, $$e = \frac{V_V}{V_S}$$

V_v = air void + water filled voids

$$= \frac{1}{6}V + \frac{1}{3}V = \frac{V}{2}$$

$$V_s = V - V_v = \frac{V}{2}$$

$$\therefore \quad e = \frac{V/2}{V/2} = 1.0$$

1.7 (d)

Lacustrine soils are silt and clays which have been deposited in still, fresh water of lakes.

1.8 (b)

Given, $S = 100\%$

$$\therefore \quad w = \frac{Se}{G} = \frac{100 \times 0.78}{2.60} = 30\%$$

1.9 (b)

$$G_m = G_s(1-n) = \frac{G_s}{1+e}$$

G_m is mass specific gravity

G_s is specific gravity of solids

$$\therefore \quad e = \frac{G_s}{G_m} - 1$$

$$\Rightarrow \quad e = \frac{2.7}{1.35} - 1 = 1$$

1.10 (c)

At shrinkage limit, soil is fully saturated.

$$\therefore \quad w_s = \frac{e}{G} \times 100 = \frac{0.5}{2.7} \times 100$$
$$= 18.5\%$$

1.11 (c)

Liquidity Index

$$= \frac{w - w_P}{w_L - w_P} = \frac{50-35}{60-35}$$

$$= \frac{15}{25} = 0.6$$

Note: Consistency Index = 1 – 0.6 = 0.4

1.12 (b)

Degree of saturation,

$$S = \frac{V_w}{V_V} \times 100$$

$$= \frac{0.3}{0.2+0.3} \times 100 = 60\%$$

and void ratio $$= \frac{V_v}{V_s} = \frac{0.2+0.3}{0.5}$$
$$= 1 \times 100 = 100\%$$

1.13 (b)

Aeolian soils are deposited by winds. It consist of uniformly graded particles. The void ratio and permeability of soil are high. They are non-plastic and can withstand deep vertical cuts due to slight cementation between particles. These soils have high compressibility and density is low in natural states.

Example: Fine sand in dunes; loess.

1.14 (c)

$$\gamma_{sat} = \gamma_d(1+w) = 1.5 \times 1.5$$
$$= 2.25 \text{ g/cc}$$
$$\gamma_{sub} = \gamma_{sat} - \gamma_w = 2.25 - 1.0$$
$$= 1.25 \text{ g/cc}$$

1.15 (c)

As the moisture content of a clayey soil is reduced from a large value, the alterberg limits are encountered in following sequence.

Liquid limit → Plastic limit → Shrinkage limit

1.16 (b)

The volume of soil solids from borrow pit soil and from fill should be equated.

$$V_s = \frac{V_1}{1+e_1} = \frac{V_2}{1+e}$$

$$\therefore \quad V_1 = V_2 \times \frac{1+e_1}{1+e_2}$$

$$= 150000 \times \frac{1+1.4}{1+0.8}$$

$$= 200{,}000\ \text{m}^3$$

1.17 (b)

Let percentage of sand is x. So plasticity of mix is

$x \times 0 + (1 - x) \times 15 = 6$

$$x = \frac{9}{15} = 0.6 \text{ or } 60\%$$

1.18 (a)

The consistency index indicates the consistency (firmness) of a soil. Soil at the liquid limit will have a consistency index of 0, while soil at the plastic limit will have a consistency index of 1.

1.19 (b)

$$\gamma = \frac{G(1+w)}{1+e}\gamma_w$$

$$1 + e = \frac{G(1+w)\gamma_w}{\gamma}$$

and $\quad Gw = Se$

$$\frac{Gw}{S} = \frac{G(1+w)\gamma_w}{\gamma} - 1$$

Dividing both sides by G, we get

$$\Rightarrow \quad \frac{w}{S} = (1+w)\frac{\gamma_w}{\gamma} - \frac{1}{G}$$

$$S = \frac{w}{\frac{\gamma_w}{\gamma}(1+w) - \frac{1}{G}}$$

1.20 (b)

$$\gamma_d = \frac{\gamma_{sat}}{\left(1+\frac{w}{100}\right)}$$

$$1 + \frac{w}{100} = \frac{2000}{1500}$$

$$\therefore \quad w = 33.33\%$$

1.21 (b)

Dry weight of sample

$$= 1600 \times 10^{-4} = 0.16 \text{ kg}$$

Weight of water in soil before mixing additional quantity

$$= 0.18 - 0.16 = 0.02 \text{ kg}$$

After mixing water the total quantity of water

$$= 0.02 + 0.02$$

$$= 0.04 \text{ kg water}$$

Thus, water content $= \frac{0.04}{0.16} \times 100 = 25\%$

1.22 (d)

Degree of saturation,

$$S = \frac{V_w}{V_v} \times 100 = \frac{W_w}{V_V} \times 100$$

Void ratio, $\quad e = \frac{V_V}{V_S}$

Water content, $\quad w = \frac{W_W}{W_s}$

Porosity, $\quad n = \frac{V_V}{V}$

2. Classification of Soils

2.1 (d)

% LL (Liquid Limit)	Plasticity
< 35	Low
35 – 50	Intermediate
> 50	High

Soils above A-line are clays and soils below A-line are silts and organic soils.

Equation of A-line is

$$PI = 0.73(w_L - 20)$$

2.2 (b)

Liquid limit 45% lies between 35% to 50% for intermediate plasticity. The soil above A line should be given symbol CI.

2.3 (b)

For well graded sand $C_u > 6$ and $1 < C_c < 3$

For well graded gravel $C_u > 4$ and $1 < C_c < 3$

2.4 (b)

Group Index, GI $= 0.2\,a + 0.005ac + 0.01bd$

$a =$ %passing 75 mm sieve greater than 35 but not exceeding 75 (between 0 to 40)

$b =$ %passing 75 mm sieve greater than 15 but not exceeding 55 (between 0 to 40)

c = Liquid limit greater than 40 not exceeding 60 (between 0 to 20)

d = Plasticity index greater than 10 and not exceeding 30 (between 0 to 20)

$$a = 50 - 35 = 15 < 40$$
$$b = 50 - 15 = 35 < 40$$
$$c = 40 - 40 = 0$$
$$d = 20 - 10 = 10 < 20$$
$$\therefore \quad \text{G.I.} = 0.2 \times 15 + 0.005 \times 40 \times 0 + 0.01 \times 35 \times 10$$
$$= 3 + 0 + 3.5$$
$$= 6.5$$

3. Effective Stresses and Permeability

3.1 (c)

In falling head permeability test,

$$\text{Permeability,} \quad k = \frac{2.3aL}{At}\log\left(\frac{h_1}{h_2}\right)$$
$$= \frac{2.3aL}{At}\log\left(\frac{h_2}{h_3}\right)$$
$$\therefore \quad \frac{h_1}{h_2} = \frac{h_2}{h_3}$$
$$\Rightarrow \quad h_2^2 = h_1 h_3$$

3.2 (d)

$$\text{Total stress} = \gamma_{sat} Z = 2.1 \times 4$$
$$= 8.4 \text{ t/m}^2$$
$$\text{Pore pressure} = \gamma_w Z = 1 \times 4 = 4 \text{ t/m}^2$$
$$\text{Effective stress} = 8.4 - 4 = 4.4 \text{ t/m}^2$$

3.3 (c)

The pore pressure prevents the compression of the soil mass. Pore water pressure is known as neutral pressure because it cannot resist shear stress.

3.4 (b)

$$\frac{k_{ex}}{k_{ez}} = \frac{(k_1h_1 + k_2h_2 + k_3h_3)}{(h_1 + h_2 + h_3)^2}\left(\frac{h_1}{k_1} + \frac{h_2}{k_2} + \frac{h_3}{k_3}\right)$$

for $h_1 = h_2 = h_3$

$$\frac{k_{ex}}{k_{ez}} = \frac{(k_1 + k_2 + k_3)}{9}\left(\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}\right)$$

$$k_1 = k_3 = 1 \times 10^{-2} \text{ cm/s}$$
$$k_2 = 10 \times 10^{-2} \text{ cm/s}$$

$$\frac{k_{ex}}{k_{ez}} = \frac{(1+10+1)}{9}\left(\frac{1}{1} + \frac{1}{10} + \frac{1}{1}\right)$$
$$= \frac{12 \times 2.1}{9} = 2.8$$

3.5 (b)

Taylor's equation based on Poiseuille's law for laminar flow through circular tube is given by

$$k = \frac{\gamma}{\mu}\frac{e^3}{1+e}CD_s^2$$

$\therefore$ Change in coefficient of permeability,

$$k' = \frac{0.9\gamma}{0.7\mu}\frac{e^3}{1+e}CD_s^2$$
$$\therefore \quad \frac{k'}{k} = \frac{0.9}{0.7} \times 100 = 128.57\%$$
$$\text{Change} = 28.57\%$$

3.6 (a)

Constant head-permeability is used for coarse grained soil and not for fine-grained soils, because the discharge through the fine soils will be very small.

3.7 (c)

Constant head permeameter is best suited for high permeability soils.

3.8 (b)

Darcy's law states that there is a linear relationship between flow velocity (v) and hydraulic gradient (i) for any given saturated soil under steady laminar flow conditions

Stoke's Law – Sedimentation of soil particles in water with a constant velocity is known as terminal velocity. It is applicable to spheres of diameter between 0.2 mm and 0.0002 mm.

Poiseuille's equation relates pressure drop between two points to the discharge in a pipe flow system.

4. Seepage Analysis

4.1 (c)

Once a flow net is constructed, its graphical properties can be used to obtain solutions for many seepage problems such as the estimation of seepage losses from reservoirs, determination of seepage pressures, uplift pressures below dams, to check against the possibility of piping and many others.

4.2 (c)

Critical hydraulic gradient,

$$i_c = \frac{G-1}{1+e} = \frac{2.62-1}{1+0.62} = 1.0$$

Head required $= i_c \times$ thickness of sand stratum

$= 1 \times 2.5 = 2.5$ m

4.3 (a)

$$\text{Porosity} = \frac{e}{1+e} = \frac{0.5}{1.5} = \frac{1}{3}$$

$$\text{Seepage velocity} = \frac{\text{Discharge velocity}}{\text{Porosity}}$$

$$= \frac{6\times10^{-7}}{(1/3)} = 18\times10^{-7}\text{ m/s}$$

4.4 (a)

Quick sand condition corresponds to zero effective pressure due to upward seepage.

4.5 (c)

Critical hydraulic gradient, $i_{cr} = \frac{G-1}{1+e}$

$G = 2.65$, $e = 0.7$

So on solving $i_{cr} \simeq 1$

4.6 (a)

$$i_c = \frac{G-1}{1+e} = (G-1)(1-n)$$

4.7 (b)

The number of equipotential drops are 9.

Drop in head per drop $= \frac{18}{9} = 2$ m of water.

The point A is after three drops so head at point A is $h_A = 18 - 3 \times 2 = 12$ m of water

4.8 (c)

Critical hydraulic gradient,

$$i_c = \frac{G-1}{1+e} = \frac{G-1}{1+0.5}$$

$$\therefore \quad G = 1.5\,i + 1$$

4.9 (c)

$i_c = (G-1)(1-n)$

$$= (2.5-1)\times\left(1-\frac{1}{3}\right) = 1.0$$

4.10 (b)

Seepage is given by

$$q = \sqrt{k_x k_z} \times \frac{N_f}{N_d} \times H$$

$$= \sqrt{4\times10^{-7}\times1\times10^{-7}} \times \frac{4}{16} \times 20$$

$= 10 \times 10^{-7}$ m^3/s/m

4.12 (c)

A **flow net** is a graphical solution to the equations of steady groundwater flow. A flow net consists of two sets of lines which must always be orthogonal (perpendicular to each other): flow lines, which show the direction of groundwater flow, and equipotentials lines (lines of constant head), which show the distribution of potential energy.

4.13 (c)

Phreatic line is the top flow line which separates saturated zone from unsaturated zone and below which positive hydrostatic pressure exists in the dam section. Along the phreatic line, the atmospheric pressure exists. It's shape is approximately of a parabola.

4.14 (c)

Critical hydraulic gradient,

$$i_c = \frac{G-1}{1+e} = (G-1)(1-n)$$

$$= (2.6-1)\times(1-0.375)$$

$$= 1.0$$

4.15 (d)

Equivalent permeability,

$$k_e = \sqrt{k_x k_z}$$

$$= \sqrt{9\times10^{-6}\times1\times10^{-6}}$$

$= 3 \times 10^{-6}$ m/s

Seepage, $q = k_e \times \frac{N_f}{N_d} \times H$

$= 12 \times 10^{-6}$ m^3/s/m

$= 12$ mL/s/m

5. Compaction of Soil

5.1 (d)

The Indian Standard Equivalent of the Standard Proctor Test is called the light compaction test **(IS : 2720 Part VII-1974)**. The values of the respective parameters of this test are :

$$P = 2.6 \text{ kg},$$
$$Q = 310 \text{ mm},$$
$$R = 25, S = 3$$

The Indian Standard Equivalent of the Modified Proctor Test is called the heavy compaction test (**IS : 2720 Part VIII-1983**). The values of the respective parameters of this test are :

$$P = 4.9 \text{ kg},$$
$$Q = 450 \text{ mm},$$
$$R = 25, S = 5$$

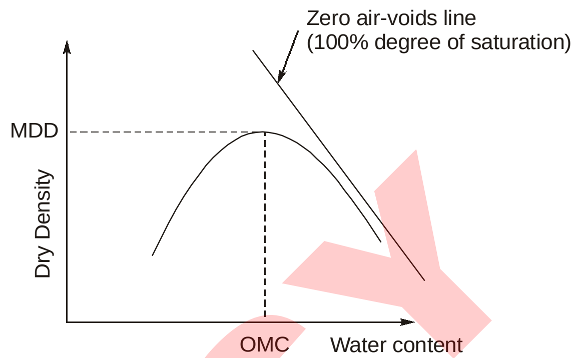
5.2 (b)

Sheepsfoot rollers are used for compacting fine grained soils such as heavy clays and silty clays. Sheepsfoot rollers are used for compaction of soils in dams, embankments, subgrade layers in pavements and rail road construction projects. These are of static and vibratory types. Vibratory types rollers are used for compaction of all fine grained soils and also soil with sand-gravel mixes. Generally this roller is used for compaction of subgrade layers in road and rail projects.

5.3 (a)

Relative compaction is defined as the ratio of the in-situ, wet density of a soil or aggregate to the test maximum wet density of the same soil or aggregate when **compacted** by a specific test method.

Soil densification techniques are used for reducing liquefaction hazards is to avoid large increases in pore water pressure during earthquake shaking. **Vibrofloatation** involves the use of a vibrating probe that can penetrate granular soil to depths of over100 feet. The vibrations of the probe cause the grain structure to collapse thereby densifying the soil surrounding the probe. To treat an area of potentially liquefiable soil, the vibrofloat is raised and lowered in a grid pattern. The relation between moisture content and dry unit weight for a saturated soil is the **zero air-voids line.**



5.4 (a)

The structure of soil changes from flocculated (attraction force) to dispersed (repulsive force) as the moisture content increases up to optimum moisture content. In this case the permeability decreases and dry density increases due to change of structure.

6. Compressibility and Consolidation

6.1 (a)

Total consolidation,

$$\Delta H = \frac{H(e_0 - e_f)}{1 + e_0}$$
$$= \frac{3 \times 10^{-2} \times (0.9 - 0.71)}{1 + 0.9}$$
$$= 30 \text{ cm}$$

6.2 (d)

The sample *A* is single drained and sample *B* is double drained. The sample *B* will take only $\frac{1}{4}$ of time that required in sample *A*.

6.3 (c)

Coefficient of compressibility,

$$a_v = -\frac{\Delta e}{\Delta \sigma} = -\left(\frac{0.6 - 0.7}{17.5 - 17}\right)$$
$$= 0.2 \text{ m}^2/\text{t}$$

6.4 (d)

Since $T_v = \frac{C_v t}{d^2}$, therefore for same values of T_v and C_v,t is proportional to d^2 where d is length of drainage path. Therefore the time taken in single drainage will be four times that in the double drainage.

6.5 (d)

When stresses are increased, the excess pore pressure is equal to stress increment at $t = 0$. Naturally effective stresses decrease by the same stress increment. With the onset of consolidation excess pore pressure starts dissipating and effective stresses increase. Finally at the end of consolidation the stress increment is completely transferred to soil grains and only hydrostatic pore pressure exists. So effective stress is maximum at the end of consolidation.

6.6 (c)

Coefficient of compressibility,

$$a_v = -\frac{\Delta e}{\Delta \sigma}$$

$$= \frac{\text{Change in void ratio}}{\text{Change in stress}}$$

Compression index,

$$C_c = \frac{e_0 - e}{\log(\sigma / \sigma_0)}$$

6.7 (b)

$$\frac{H_f}{H_i} = \frac{1+e}{1+e_0}$$

$$H_f = \left(\frac{1+0.5}{1+1}\right) \times 2.4$$

$$= 1.5 \times 1.2 = 1.8 \text{ cm}$$

6.8 (d)

- Sand drains reduce the length of drainage path resulting in acceleration of consolidation.
- High compressibility leads to excessive settlement.
- Rise of water table reduces the bearing capacity of soil.
- High volume change (expansivity and shrinkage) in clay is due to Montmorillonite.

6.9 (a)

Normally consolidated clays behave in a manner similar to loose sand. Heavily over consolidated soils behave similar to dense sand.

6.10 (c)

Consolidated means drainage is allowed in first stage. Drained means drainage is allowed in second stage. So in case of consolidated drained test, drainage is allowed in both stages so pore pressure is zero.

6.11 (a)

During primary consolidation degree of saturation = 100% and void ratio reduces. There are no air voids in the soil i.e., it does not depend on the decrease in void volume due to air escape. During secondary consolidation only plastic deformation occurs.

6.12 (a)

Terzaghi's theory considers that certain soil properties such as permeability and modulus of volume change are constant. The pressure versus void ratio relationship is linear. These assumptions hold good for small load increments only.

6.13 (c)

Coefficient of consolidation,

$$C_v = \frac{k}{\gamma_w m_v} = \frac{T_v H^2}{t}$$

Coefficient of volume compressibility or modulus of volume change,

$$m_v = \frac{a_v}{1+e_0} = \frac{(e_0 - e)}{(1+e_0)(p - p_0)}$$

Over consolidation ratio,

$$= \frac{\text{Maximum previous effective pressure}}{\text{Existing effective pressure}}$$

6.14 (a)

Initial consolidation or elastic compression due to expulsion of pore air or rapid dissipation of pore water with application of stress. This is significant in non-saturated clays, silts and granular soils.

Primary consolidation due to slow expulsion of excess pore pressure over a period of time.

Secondary consolidation due to viscous layer around particles resulting in rearrangement of particles.

7. Stress Distribution in the Soil

7.1 (c)

Any sub area of Newmark's chart has same influence value. Therefore 1 and 2 will yield same pressure at the centre.

7.2 (d)

Vertical stress below point load,

$$\sigma_z = 0.4775\frac{Q}{z^2}$$

$$\therefore \quad \frac{\sigma_3}{\sigma_5} = \left(\frac{5}{3}\right)^2 = 2.77$$

7.3 (c)

In Newmark's chart each annular area will have same influence value. Therefore both area 1 and 2 will produce same intensity of pressure.

7.4 (d)

According to Boussinesq's theory,

$$\sigma_z = \frac{3Q}{2\pi z^2}\left[\frac{1}{1+(r/z)^2}\right]^{5/2} = K_B\frac{Q}{z^2}$$

7.5 (d)

For the vertical plane passing through the load, the vertical stress is

$$\sigma_z = 0.4775\frac{Q}{z^2}$$

z (unit length)	σ_z	% reduction
0.25	$7.64Q$	more than Q
0.5	$1.91Q$	more than Q
0.75	$0.84Q$	16% reduction
1.0	$0.4775Q$	52.25% reduction

8. Shear Strength of Soil

8.1 (b)

In an UCS test on clay

Undrained shear strength (C_u) = 6 t/m^2

For same soil, i.e., clay

in triaxial test

σ_{3f} = (Cell pressure) = 20 t/m^2

σ_{1f} = (Major principal stress) = ?

We know that, for c-ϕ soil

$$\sigma_{1f} = \sigma_{3f}\tan^2\left(45° + \frac{\phi}{2}\right) + 2c_u\tan\left(45° + \frac{\phi}{2}\right)$$

For clay, $\phi = 0°$

$$\therefore \quad \sigma_{1f} = \sigma_{3f} + 2C_u$$

$$= 20 + 2 \times 6 = 32 \text{ t/m}^2$$

8.2 (b)

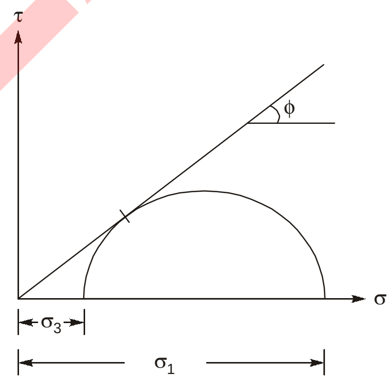
For vane shear test with one end in shearing,

$$\tau = \frac{T}{\pi D^2\left(\frac{H}{2} + \frac{D}{12}\right)}$$

When both ends take part in shearing,

$$\tau = \frac{T}{\pi D^2\left(\frac{H}{2} + \frac{D}{6}\right)}$$

8.3 (a)



For drained condition, ϕ will be mobilized, for normally consolidated clay failure envelope passes through origin so $C = 0$.

8.4 (b)

UU (unconsolidated undrained) test: In this, cell pressure is applied without allowing drainage. Then keeping cell pressure constant, deviator stress is increased to failure without drainage.

CU (consolidated undrained) test: In this, drainage is allowed during cell pressure application. Then without allowing further drainage, deviator stress is increased keeping cell pressure constant.

CD (consolidated drained) test: This is similar to **CU test** except that as deviator stress is increased, drainage is permitted. The rate of loading must be slow enough to ensure no excess pore water pressure develops.

8.5 (c)

The angle of failure from horizontal,

$$\alpha = 45° + \frac{\phi}{2}$$

$$\Rightarrow \quad \phi = (50° - 45°) \times 2$$

$$\Rightarrow \quad \phi = 10°$$

In this case $\sigma_1 = 100\ \text{kN/m}^2$ and $\sigma_3 = 0$

$$\sigma_1 = \sigma_3 \tan^2\left(45° + \frac{\phi}{2}\right) + 2c\tan\left(45° + \frac{\phi}{2}\right)$$

$$\sigma_1 = 2c\tan\left(45 + \frac{\phi}{2}\right)$$

$$\Rightarrow c = \frac{100}{2\tan 50°} = 41.9\ \text{kN/m}^2$$

8.6 (d)

For saturated normally consolidated soil

$$B = 1,\ A < 1.$$

For heavily over-consolidated soil A can be less than zero. For saturated fine sand in loose condition A may be as high as 2 to 3.

8.7 (b)

Unconfined compressive strength

$$q_u = 100\ \text{kN/m}^2$$

For UU test,

$$\sigma_1 - \sigma_3 = q_u$$

$$\therefore \quad \sigma_1 = 100 + 100 = 200\ \text{kN/m}^2$$

8.8 (b)

$s = c + \sigma_n \tan\phi$ [Coulomb's equation]

$\therefore \quad c = s - \sigma_n \tan\phi$

8.9 (b)

For sand cohesion, $c = 0$

$$\sigma_1 = \sigma_3 N\phi$$

$$N\phi = \tan^2\left(45 + \frac{\phi}{2}\right)$$

$$\sigma_1 = 100 + 50 = 150\ \text{kPa}$$

$$\sigma_3 = 50\ \text{kPa}$$

Now $150 = 50 N\phi$

$$\Rightarrow \quad N\phi = 3$$

$$\Rightarrow \quad \tan\left(45 + \frac{\phi}{2}\right) = \sqrt{3}$$

$$\Rightarrow \quad 45 + \frac{\phi}{2} = 60°$$

$$\Rightarrow \quad \phi = 30°$$

8.10 (c)

Normal stress is in vertical direction and shear stress is applied in horizontal direction.

8.11 (c)

In unconfined compression test minor principal stress $\sigma_3 = 0$.

8.12 (a)

When the Mohr's circle touches the failure envelope, the soil fails by shearing. This failure may occur at one point only along the failure plane or at all the points on failure plane. It means that shear strength may or may not be fully mobilized.

8.13 (c)

$$\sigma'_{3f} = 100\ \text{kPa}$$

$$\therefore \quad \sigma'_{1f} = 4\sigma'_{3f} = 400\ \text{kPa}$$

Principal stress difference

$$= \sigma'_{1f} - \sigma'_{3f} = 300\ \text{kPa}$$

and

$$\sin\phi = \frac{\sigma'_{1f} - \sigma'_{3f}}{\sigma'_{1f} + \sigma'_{3f}} = \frac{300}{500} = 0.6$$

$$\phi = 36.86° \simeq 37°$$

8.14 (a)

Point above Mohr's Envelope indicates that shear stress is more than shear strength of soil which is an imaginary condition.

8.15 (b)

In the case of saturated clay sample, the quick test condition of box shear test will not allow drainage so $\phi = 0$. It means that the weakest plane will lie at an angle 45° from the horizontal plane. However in this case failure plane is pre-determined which is not the weakest plane.

8.16 (b)

- Clay is more sensitive on remoulding and strength changes drastically. Thus for calculating the shear strength of clay, undisturbed sample is required.
- Compaction parameters, i.e, optimum moisture content and dry density are calculated on disturbed sample.

- Shear strength of soil is not affected by remoulding.
- For atterberg limit, we take the soil sample and mix with water so the sample is disturbed.

8.17 (d)

The pore pressure parameter B is equal to one for fully saturated condition because the compressibility of water is small compared to coefficient of volume compressibility of soil sample.

$$B = \frac{1}{1+n(C_v/C_s)}$$

8.18 (c)

For initial stability → Undrained Test
Long term Stability → Drained Test
For Soft Marine Clay → Vane Shear Test

8.19 (b)

$$\tau = \sigma \tan\phi; \ \tan\phi = \frac{0.6}{1} = 0.6$$

$$\tan 30° = \frac{1}{\sqrt{3}} = 0.577$$

as $\tan\phi > \tan 30°$

$\therefore \quad \phi > 30°; \quad \phi = 31°$

8.20 (b)

Terzaghi gave effective stress principle. Effective stress,

$$\sigma' = \sigma - u$$

where σ is total stress and u is pore pressure.

Skemptpon pore water pressure parameters

$$\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$$

Stoke's equation for terminal velocity of particles

$$V = \frac{D^2(\gamma_s - \gamma_w)}{18.\eta}$$

Coulomb equation to find shear stress

$$\tau = C + \bar{\sigma}_n \tan\phi.$$

8.21 (c)

$$\text{Sensitivity} = \frac{(UCC)_{\text{natural}}}{(UCC)_{\text{remoulded}}} = \frac{4}{(4/4)} = 4$$

8.22 (b)

The shear parameters c and ϕ are empirical. They depend upon the effective stress in soil and vary with drainage conditions of the test. The pore pressure in the soil specimen depends upon degree of saturation during first stage of the test. Thus water content also affects the parameters c and ϕ. However drainage conditions and water content are two independent factors affecting shear parameters.

9. Retaining Wall/Earth Pressure Theories

9.1 (c)

Increase in lateral earth pressure

$$\Delta\sigma_h = K_a q$$

Active earth pressure coefficient,

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30}{1+\sin 30} = \frac{1}{3}$$

$$\therefore \quad \Delta\sigma_h = \frac{1}{3} \times 12 = 4 \ \text{t/m}^2$$

9.2 (d)

Point 1 represents active earth pressure due to wall movement away from soil and point 4 represents passive earth pressure due to wall movement towards the fill.

9.3 (b)

For no tension to develop at base of foundation,

$$\sigma_{min} > 0$$

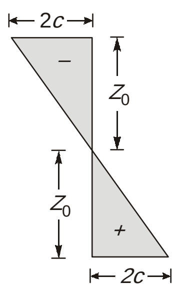
$$\frac{P}{B^2}\left[1 - \frac{6e}{B}\right] > 0$$

$$e > \frac{B}{6}$$

So point load must lie within $\left(\frac{B}{6} + \frac{B}{6}\right) = \frac{B}{3}$ i.e within middle third of base.

9.4 (a)

Tension is shown as negative and compression as positive.



For pure clay $K_a = 1.0$

$\therefore$ Lateral pressure $= \gamma z - 2c$.

At $z_0 = \frac{2c}{\gamma}$ lateral pressure will be zero.

9.5 (b)

Active earth pressure coefficient

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°}$$
$$= \frac{1}{3}$$

Active earth pressure per unit length

$$= \frac{1}{2}K_a\gamma H^2$$
$$= \frac{1}{2}\times\frac{1}{3}\times 2\times 9\times 9$$
$$= 27 \text{ t/m}$$

9.7 (b)

Cantilever sheet piling walls depend on the passive resisting capacity of the soil below the depth of excavation to prevent overturning. The depth of sheet piling walls below the bottom of the excavation is determined by using the difference between the passive and active pressures acting on the wall. The theoretical depth of pile penetration below the depth of excavation is obtained by equating horizontal forces and by taking moments about an assumed bottom of piling. The theoretical depth of penetration represents the point of rotation of the piling. Additional penetration is needed to obtain some fixity for the piling. Computed piling depths are generally increased 20% to 40% to obtain some fixity and to prevent lateral movement at the bottom of the piling.

9.8 (d)

When wall moves towards the earthfill, then maximum earth pressure acting on wall before failure is known as passive earth pressure.

9.9 (b)

Maximum active pressure,

$$p_A = K_A\sigma_z$$

where $$K_A = \frac{1-\sin\phi}{1+\sin\phi}$$

Maximum passive pressure,

$$p_P = K_P\sigma_z$$

where $$k_P = \frac{1+\sin\phi}{1-\sin\phi}$$

For $\phi = 30°$, $K_A = \frac{1}{3}$

and $K_P = 3$

$\sigma_z = 1.5 \times 10 = 15 \text{ t/m}^2$

$$\therefore \quad p_A = \frac{1}{3}\times 15 = 5 \text{ t/m}^2$$
$$p_P = 3\times 15 = 45 \text{ t/m}^2$$

In the case of passive pressure full strain mobilization may not take place and so actual passive pressure will be less than maximum value.

9.10 (d)

$$K_o = \frac{\mu}{1-\mu}$$
$$\Rightarrow \quad \frac{1}{K_o} = \frac{1-\mu}{\mu}$$

9.11 (b)

From Coulomb's theory

$$K_a = \frac{\sin^2(\alpha+\phi)}{\sin^2\alpha\sin(\alpha-\delta)\left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta)}{\sin(\phi-\delta)\sin(\phi+\beta)}}\right]}$$

For smooth vertical wall retaining a backfill with horizontal surface

$$\alpha = 90°, \delta = 0, \beta = 0$$
$$K_a = \frac{1-\sin\phi}{1+\sin\phi}$$

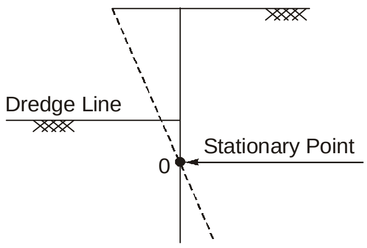
Rankine's active earth pressure coefficient
Same can be shown for passive case also.

9.12 (d)

By considering the wall friction, the Coulomb's theory eventually considers the wall to be rough. The relative movement of the wall and the soil on the back develops frictional forces that influence the direction of the resultant pressure.

In Coulomb's theory, the failure surface is assumed to be plane surface which pases through heel of the wall. This assumption introduces only a negligible error in the case of active pressure. However in the case of passive pressure, the error involved remains small only for values of δ less then $\phi/3$.

9.13 (a)



Above the dredge line, the pressure is active on the back of the wall. Near the embedded end the pressure on the back of the wall will be passive as the wall moves towards the fill.

The retaining wall made of masonry is gravity retaining wall. If the wall is founded on rock there will not be any stretching of soil mass so earth pressure conditions will be at rest. Similarly on a compressible clay active earth pressure conditions will develop.

9.14 (c)

Fig.	Case	Proposed by
(a)	Braced sheeting in clay	Terzaghi & Peck
(b)	Apparent pressure diagram for braced cuts in firm clay	Peck, Hanson and Thornburn
(c)	Braced pile with temporary support in stiff clay	Tschebotarioff
(d)	Braced pile with permanent support in medium clay	Tschebotarioff

9.15 (b)

Depth of tension crack,

$$Z_c = \frac{2c}{\gamma\sqrt{K_a}}$$

For $\phi = 0;\quad K_a = 1$

$$\therefore \quad Z_c = \frac{2\times 2}{2} = 2\,\text{m}$$

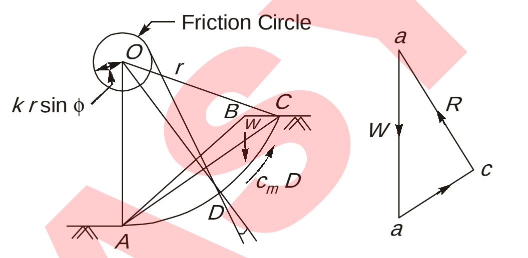
The unsupported depth, $H_c = 2Z_c$

10. Stability Analysis of Slopes

10.1 (b)

The friction circle method of stability analysis of slope is applicable to c-ϕ soils. Following are the assumptions:

- Method is based on total stress analysis.
- Enables the angle of shearing resistance to be taken into account.
- Slip surface is circular.
- Frictional resistance is fully mobilized along the slip surface.
- Resultant R is tangential to the friction circle.



(a) (b) Force triangle

10.2 (a)

Depth factor,

$$D_f = \frac{D+H}{H}$$

$D_f = 1.0$ for toe failure, $D_f > 1$ for base failure

10.3 (a)

$$\text{Stability number} = \frac{C}{\gamma H} = \frac{1}{2\times 5} = 0.1$$

11. Shallow Foundation and Bearing Capacity

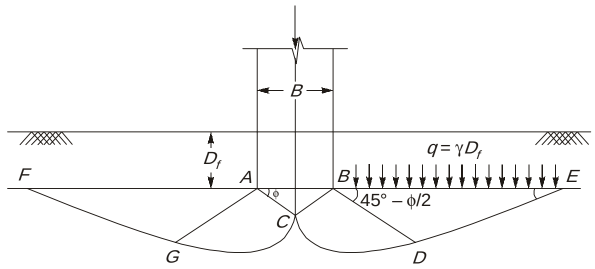
11.1 (d)

When the water table is B depth below the base of the footing there is no effect of ground water table on bearing capacity. (B is the width of footing)

11.2 (a)

Terzaghi's bearing capacity theory is for general shear failure. While the load capacity of piles is sum of shaft resistance (friction) and end bearing resistance.

As per Terzaghi's theory the stress zone extends upto foundation level only, therefore resistance of soil above the foundation level is ignored (side resistance neglected). Therefore this theory is applicable for shallow foundation only.



Terzaghi system for ideal soil, rough base and surcharge

11.3 (d)

For Raft foundation on sand maximum permissible settlement is 40 to 65 mm. The permissible differential settlement is 25 mm.

For raft foundation on clay, limiting maximum settlement 65 to 100 mm. Maximum differential settlement 40 mm.

11.4 (c)

$$q_{\text{net, ult}} = cN_c$$

$$N_c = 5\left(1+0.2\frac{B}{L}\right)\left(1+0.2\frac{D_f}{B}\right)$$

for $\dfrac{D_f}{B} < 2.5$

$$= 5\times\left(1+0.2\times\frac{1}{2}\right)\left(1+0.2\times\frac{2}{1}\right) = 7.7$$

$$c = q_u/2 = 100/2$$

$$= 50 \text{ kN/m}^2$$

$$\therefore \quad q_{\text{net,ult}} = 50 \times 7.7 = 385 \text{ kN/m}^2$$

11.5 (c)

Saturated fine or silty dense or very dense sand deposits below water table have a tendency to dilate during shear under undrained conditions. Therefore the observed N value is more than actual value and dilatancy correction should be applied as

$$N' = 15 + \left(\frac{N-15}{2}\right) = \frac{N+15}{2}$$

It is based on the assumption that critical void ratio occurs at $N = 15$.

11.6 (c)

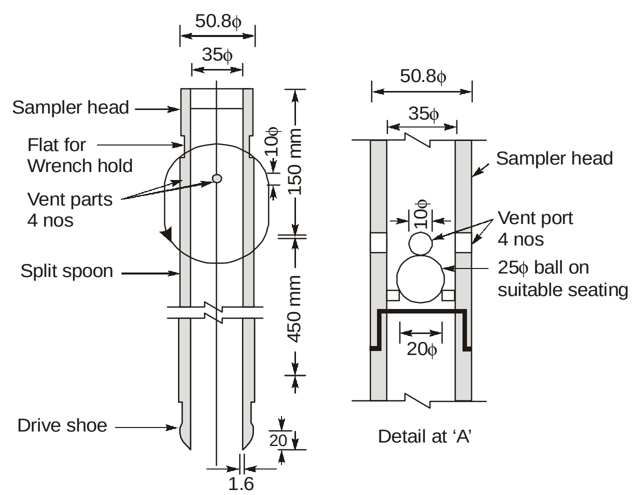
Plate Load Test is a field test for determining the ultimate bearing capacity of soil and the likely settlement under a given load. The Plate Load Test basically consists of loading a steel plate placed at the foundation level and recording the settlements corresponding to each load increment.

The **Standard Penetration Test (SPT)** provides a disturbed sample of soil and a blow count which approximately correlates to density/strength of soil, by driving a hollow split spoon sampler into the ground.

Static Cone Penetration Test – Also known as Dutch Cone for CPT, it gives a continuous record of variation of both cone resistance and friction resistance with depth. CPT however does not yield any sample. It is suitable for soft clay and silts & fine to medium sand deposits.

11.7 (c)

A **standard split spoon sampler** consists of a thick wall tube having outer diameter of 50.8 mm and internal diameter of 35 mm and a length of 600 mm. The tube has a drive shoe attached to its bottom and coupling head at top to accommodate the drill rod, used for testing. The drill rod is coupled to sampler head and the sampler is lowered into the clean hole, made in the ground in advance. The sampler is driven into the undisturbed soil at the bottom of the hole, with the help of a driving weight assembly consisting of a driving head and a **650 N weight with 750 mm free fall**. The blows from the driving weight fall on the drill rod which drives the sampler into the soil. The sampler is first driven through 150 mm in the hole. This is known as seating drive. The sampler is then driven further through 300 mm and the number of blows required for 300mm penetration are recorded. This number of blows is termed as penetration resistance of soil and is represented by symbol N.



11.8 (a)

With the increase of overburden pressure with increasing depth, the *N* value also increase.

11.9 (d)

According to Skempton's analysis of cohesive soils, it has been shown that the bearing capacity factor tends to increase with depth for a cohesive soil.

Skempton bearing capacity factor values:

Case-1: When $\frac{D_f}{B} = 0$, i.e., footing at GL

$N_{CS} = 5.0$ ...for strip footing

$= 6.0$ .. for square/circular/rectangular/raft

Case-2: When $0 < \frac{D_f}{B} < 2.5$

$$N_c = N_{CS}\left(1+0.2\frac{D_f}{B}\right) \quad \text{...for strip footing}$$

$$= N_{CS}\left(1+0.2\frac{D_f}{B}\right) \quad \text{...for square/circular}$$

$$= N_{CS}\left(1+0.2\frac{B}{L}\right)\left(1+0.2\frac{D_f}{B}\right)$$

...for rectangular footing.

Case-3: When $\frac{D_f}{B} \geq 2.5$

$N_C = 7.5$ ...for strip footing

$= 9.0$ ...for square/circular/rectangular/raft

11.10 (c)

Sudden and well defined failure occurs in dense sand having relative density (> 70%)

Foundations on sand of relative density between 35 to 70 % do not show sudden failure. As the settlements are about 15% of the foundation width, a visible boundary of sheared zones appear at the surface. However, the peak of the base resistance may never be reached. This type of failure is called as local shear failure.

11.11 (d)

Significant depth = 1.5 *B*

The region within the 0.20 *q* - isobar is called by Terzaghi the "seat of settlement". The depth below centre of footing in active zone (i.e., in "seat of settlement") is 1.5*B*. For a larger footing more area will be affected so the settlement will be more.

11.12 (a)

According to Terzaghi and Peck the allowable soil pressure in cohesionless soils is directly proportional to allowable settlement. So to double the allowable soil pressure, permissible settlement should be doubled.

11.13 (c)

Standard Penetration Test (SPT) gives N-value which can be corrected for energy, overburden pressure and dilatancy in sequence. The corrected *N*-value is correlated with relative density and angle of shearing resistance for cohesionless soils; and unconfined compressive strength and consistency of cohesive soils.

11.14 (c)

Dynamic cone penetration test is used to obtain continuous record of soil resistance by driving the cone using 65 kg falling weight and counting the number of blows for every 10 cm penetration.

11.15 (c)

As per **IS:1904-1986**

Type of footing	MS (mm)	DS (mm)	AD
A. Isolated footing on plastic clay			
(i) for steel structures	50	0.0033L	$\frac{1}{300}$
(ii) for RCC structures	75	0.0015L	$\frac{1}{666}$
B. Raft foundation on plastic clay			
(i) for steel structures	100	0.0033L	$\frac{1}{300}$
(ii) for RCC structures	100	0.002L	$\frac{1}{500}$
MS: Maximum Settlement DS: Differential Settlement AD : Angular Distortion			

11.16 (d)

Influence factor for immediate settlement depends upon the shape of the loaded area and the distribution of contact pressure. Thus following factors can be listed :

(i) Shape of footing

(ii) Size of rectangular footing

(iii) Location of point
(iv) Rigidity of footing
For a perfectly flexible square footing immediate settlement at centre is 2 times the immediate settlement at the corners.

11.17 (b)

Bearing capacity,

$$q_{ult} = cN_c + qN_q + \frac{\gamma B}{2} N_\gamma$$

For cohesive soil,

$$N_q = 1.0 \text{ and } N_\gamma = 0$$

$$\therefore \quad q_{net,ult} = q_{ult} - q$$
$$= cN_c = 10 \times 5.7$$
$$= 57 \text{ kN/m}^2$$

11.18 (a)

$$q_{net,ult} = s_c \, c \, N_c$$

where shape factor,

$$s_c = 1 + 0.3 \, B/L$$
$$= 1 + 0.3 \times \frac{6}{9} = 1.2$$

$$\therefore \quad q_{net,\, ult} = 1.2 \times 120 \times 5.7$$
$$= 820.8 \text{ kN/m}^2$$

11.19 (b)

N-Value	Density Index	Condition	ϕ
0 – 4	0 – 15%	Very loose	< 28°
4 –10	15 – 35%	Loose	28° – 30°
10 – 30	35 – 65%	Medium dense	30° – 36°
30 – 50	65 – 85%	Dense	36° – 42°
> 50	> 85%	Very Dense	> 42°

N = 20 means medium condition soils with

$$\phi = 32°$$
$$D_r = 50\%$$

12. Deep Foundation, Sheet Pile Walls and Machine Foundation

12.1 (d)

Negative Skin Friction:

- It is downward drag action on the piles due to relative movement between pile and the surrounding soil. This condition occurs when the soil in upper portion is loose/soft whereas in lower portion dense/stiff.
- It reduces load carrying capacity of pile.
- Negative skin may develop under following condition:
  - (i) A cohesive fill is placed over a non-cohesive soil layer and a pile is driven into such a medium.
  - (ii) Increase in surcharge over surrounding soil.
  - (iii) Lowering of ground water table.
  - (iv) Disturbance due to dynamic or seismic effect.

12.2 (d)

The efficiency of pile group depends on the following factors:

1. Spacing of piles
2. Total number of piles in a row and number of rows in a group, and
3. Characteristics of pile (material, diameter and length)

The efficiency of the pile group can be calculated by using the following formula:

$$\eta_g = \frac{Q_{g(u)}}{NQ_u} \times 100$$

Thus, the pile group efficiency is equal to the ratio of the average load per pile in the group at which the failure occurs to the ultimate load of a comparable single pile.

12.3 (d)

Pressuremeter can be used for in-situ measurement of shear modulus (G) of the soil. In this pressure is applied to water by compressed gas (usually nitrogen) in a control cylinder at the surface.

12.4 (d)

The bearing capacity of under-reamed pile is more than driven or bored pile of the same diameter.

12.5 (b)

Franki pile is uncased cast-in-situ pile. Franki pile has enlarged base of mushroom shape which gives the effect of a spread footing. This pile is more useful where a bearing stratum of limited thickness is reached at reasonable depth. Also, this type of pile is best suited to granular soil.

12.6 (a)

When the rate of consolidation of filled up soil or weak soil is more than the rate of settlement of pile, a downward drag force acts on the pile. This is called negative skin friction and reduces load carrying capacity of pile. It should be considered in the design of pile foundation.

12.7 (c)

The friction load capacity,

$$q_f = \alpha \times c_u \times PL$$

Given $\alpha = 0.7$; $c_u = 4\ \text{t/m}^2$

$P = \pi \times 0.3\ \text{m}$; $L = 10\ \text{m}$

$$\therefore \quad q_f = 0.7 \times 4 \times \pi \times 0.3 \times 10 = 26.4$$

$$\text{Safe load} = \frac{26.4}{2.5} = 10.55\ \text{t}$$

12.8 (d)

A well needs to be embedded or sunk below the maximum scour level to a required depth so that the resistance from the sides of well is able to withstand the lateral forces acting on the well. The depth of the bottom portion of well from the scour level is called the grip length. At the time of the selection of depth of foundation, the grip length and bearing capacity of soil strata must be considered. The maximum and minimum base pressures during the drastic or critical loading conditions have to remain under the permissible range.

12.9 (b)

Negative skin friction will act over *AB* length and it is in the downward direction. In part *BC* the frictional resistance is in upward direction. At point *C* the end resistance develops. So 2, 3 and 4 are correct.

12.10 (b)

Under reamed piles are bored cast-in-situ concrete piles having one or more number of bulbs formed by enlarging the pile stem. These piles are best suited in soils where considerable ground movements occur due to seasonal variations, filled up grounds or in soft soil strata. Provision of under reamed bulbs has the advantage of increasing the bearing and uplift capacities. It also provides better anchorage at greater depths. These piles are efficiently used in machine foundations, over bridges, electrical transmission tower foundation sand water tanks. According to the code the diameter of under reamed bulbs may vary from 2 to 3 times the stem diameter depending upon the feasibility of construction and design requirements. The code suggests a spacing of 1.25 to 1.5 times the bulb diameter for the bulbs.

12.11 (d)

IS:2911 (Part–I)–1979 recommends a minimum spacing of 2.5 times the shaft diameter for point bearing piles, 3 times the shaft diameter for friction piles, whereas in loose sands or fill deposits, a minimum spacing of 2 times the diameter of the shaft is suggested. In the case of piles of non-circular cross-section, the diameter of the circumscribing circle shall be adopted.

12.12 (b)

The mode of failure of pile groups in cohesive soils depends primarily upon spacing of piles. For smaller spacings 'block failure' may occur. In other words the group capacity as a block will be less than sum of individual pile capacities.

For larger spacings failure of individual piles may occur.

For medium dense sand the settlement of pile group is more than settlement of single piles and group settlement ratio (settlement of group to settlement of individual pile) increases with increase in B/d where B is the width of the pile group and d is the diameter of the pile.

12.13 (c)

Efficiency by Converse Labarre formula

$$\eta_g = 1 - \frac{\phi}{90}\left[\frac{m(n-1)+n(m-1)}{mn}\right]$$

Given $m = n = 2$

For four free standing pile group

$$\phi = \text{arc}\tan\left(\frac{d}{s}\right) = 18.3$$

$$\eta_g = 1 - \frac{18.3}{90}\left[\frac{2\times1+2\times1}{2\times2}\right]$$

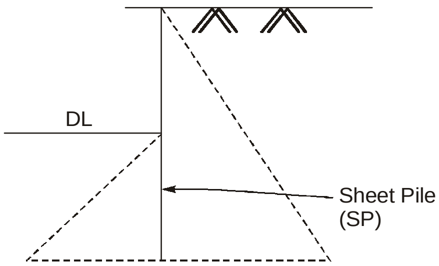
$$= 0.797 \simeq 80\%$$

12.14 (b)

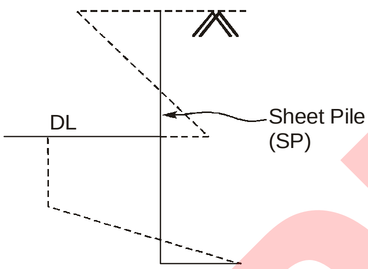
According to **IS. 2911 : Part III 1973**, the ratio of bearing resistance for double under-reamed pile to that of single under-reamed pile is 1.5 for sandy and clayey soils including black cotton soils.

12.15 (d)

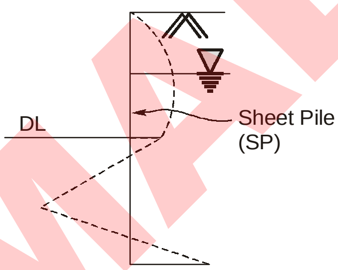
Cantilever Sheet Pile, Granular Soil – Approximate analysis



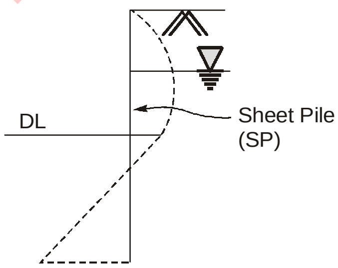
Cantilever Sheet Pile, Cohesive Soil – Approximate analysis



Anchored Sheet Pile, Granular Soil – Fixed Method

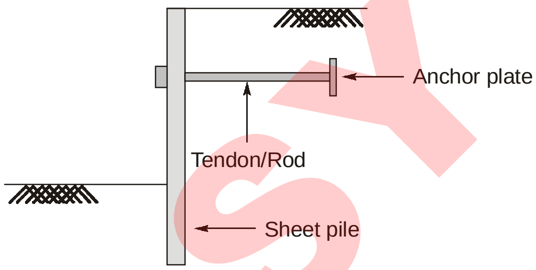


Anchored Sheet Pile, Granular Soil – Free Earth Method



12.16 (a)

Anchored sheet pile walls are held above the driven depth by anchors provided at suitable level. The anchors provide forces for the stability of the sheet pile, in addition to the lateral passive resistance of the soil into which the sheet piles are driven.



13. Soil Stabilization and Soil Exploration

13.1 (a)

Area ratio is the most critical factor which affects sample disturbance. It indicates the ratio of displaced volume of soil to that of the soil sample collected. If A_r is less than 10%, the sample disturbance is supposed to be small. Inside clearance should be 1 to 3%. Outside clearance should not be much greater than inside clearance and its value should lie between 0 to 2%.

13.2 (d)

Twice the width of foundation corresponds to additional stress intensity less than 10% of the overburden pressure. The additional stress intensity as 20% of the overburden pressure corresponds to 1.5 times the width of foundation.

13.4 (b)

Free swell or differential free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water. It is determined as per IS: 2720 (Part XL) - 1977.

13.5 (d)

Wash boring gives unrepresentative and disturbed soil sample which are almost valueless for interpreting the correct geotechnical properties of soil. Wash boring is commonly used for exploration below ground water table for which auger method is unsuitable. This method can be used in all kinds of soils except those mixed with gravel and boulders.

■■■■

UNIT

VI

Surveying and Geology

Syllabus

Surveying: Classification of surveys, various methodologies, instruments & analysis of measurement of distances, elevation and directions; Field astronomy, Global Positioning System; Map preparation; Photogrammetry; Remote sensing concepts; Survey Layout for culverts, canals, bridges, road/railway alignment and buildings, Setting out of Curves.

Geology: Basic knowledge of Engineering geology & its application in projects.

Contents

6 Surveying and Geology

1. Fundamental Concepts of Surveying and Linear Measurement

1.1 It is required to produce a small-scale map of an area in magnetic zone by directly plotting and checking the work in the field itself. Which one of the following surveys will be most appropriate for purpose?
(a) Chain (b) Theodolite
(c) Plane Table (d) Compass
[ESE : 1995]

1.2 A 30 m metric chain is found to be 0.1 m too short throughout the measurement. If the distance measured is recorded as 300 m, then the actual distance measured will be
(a) 300.1 m (b) 301.0 m
(c) 299.0 m (d) 310.0 m
[ESE : 1995]

1.3 Offsets are
(a) lateral measurements made with respect to main survey lines
(b) perpendiculars erected from chain lines
(c) taken to avoid unnecessary walking between stations
(d) measurements which are not made at right angles to the chain line
[ESE : 1995]

1.4 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Correction for sag	1. Tacheometer
B. Least count 30′	2. Aerial photograph
C. Overlap	3. Base line
D. Additive constant	4. Prismatic compass

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	3	4	2	1
(c)	1	2	3	4
(d)	3	4	1	2

[ESE : 1995]

1.5 The following steps are necessary to obtain sufficient accuracy with the tape:
1. Keeping uniform tension on tape for each measurement.
2. "Breaking" tape on slopes are necessary to keep the tape level.
3. Keeping accurate count of the stations.
4. Keeping the tape on the line being measured.

The correct sequence of these steps is
(a) 4, 2, 1, 3 (b) 2, 3, 4, 1
(c) 4, 1, 2, 3 (d) 3, 2, 1, 4
[ESE : 1997]

1.6 The true length of a line is known to be 200 m. When this is measured with a 20 m tape, the length is 200.80 m. The correct length of the 20 m tape is
(a) 19.92 m (b) 19.98 m
(c) 20.04 m (d) 20.08 m
[ESE : 1998]

1.7 A line of true length 500 m when measured by a 20 m tape is reported to be 502 m long. The correct length of the tape is
(a) 19.92 m (b) 20.08 m
(c) 20.80 m (d) 21 m
[ESE : 1999]

2. Compass Surveying and Traverse Surveying

2.1 If fore bearing of a line is $S49°52'E$ (assuming there is no local attraction), the back bearing of the line will be
(a) $S52°49'E$ (b) $S49°52'E$
(c) $N49°08'E$ (d) $N49°52'W$
[ESE : 1995]

2.2 **Assertion (A):** The vertical angles cannot be measured by the method of repetition.
Reason (R): There is only one rotation that is possible in the vertical plane.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1996]

2.3 In a closed traverse, the sum of south latitudes exceeds the sum of north latitudes and the sum of east departures exceeds the sum of west departures. The closing line will lie in the
(a) *N-W* quadrant (b) *N-E* quadrant
(c) *S-E* quadrant (d) *S-W* quadrant
[ESE : 1997]

2.4 The direction of the magnetic meridian is established at each traverse station and the direction of the line is determined with reference to the magnetic meridian. This method of traversing is called
(a) fast needle method
(b) loose needle method
(c) bearing method
(d) fixed needle method
[ESE : 1998]

2.5 The true bearing of a line is 34°20′40″ and the magnetic declination at the place of observation is 2°00′20″*W* on the date of observation. The magnetic bearing of the line is
(a) 36°21′00″ (b) 34°20′20″
(c) 32°20′20″ (d) 32°00′20″
[ESE : 1999]

2.6 Consider the following assumptions of Bowditch method:
1. Angular measurements are more precise than linear measurements.
2. Linear measurements are more precise than angular measurements.
3. Errors in linear measurements are proportional to $\sqrt{L}$.
4. Correction to latitude or departure of any side

$$= \begin{matrix}\text{Total error} \\ \text{in } L \text{ (or } D)\end{matrix} \times \frac{\text{Length of that side}}{\text{Perimeter of traverse}}$$

Which of these statements are correct?
(a) 1 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 3 and 4
[ESE : 1999]

3. Levelling and Contouring

3.1 To find the *RL* of a roof slab of building, staff readings were taken from a particular set-up of the levelling instrument. The readings were 1.050 m with staff on the Bench Mark and 2.300 m with staff below the roof slab and held inverted. Taking the *RL* of the Bench Mark as 135.15 m, the *RL* of the roof slab will be
(a) 129.800 (b) 131.900
(c) 134.400 (d) 138.500
[ESE : 1995]

3.2 The combined correction of curvature and refraction for a distance of 1400 m is
(a) 0.153 m (b) 0.132 m
(c) 0.094 m (d) 0.021 m
[ESE : 1997]

3.3 An observer standing on the deck of a ship just sees the top of a lighthouse which is 30 m above the sea level. If the height of the observer's eye is 10 m above the sea level, then the distance of the observer from the lighthouse will be nearly
(a) 22.5 km (b) 24.3 km
(c) 33.3 km (d) 59.7 km
[ESE : 1998]

3.4 **Assertion (A):** When a contour survey of a steeply sloping area is envisaged, tacheometric methods are often used.
Reason (R): Stadia tacheometry leads to more accurate computation of lengths compared to steel tapes measured in however cautious and careful manner.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1998]

3.5 Two points A and B are 1530 m apart across a river. The reciprocal levels measured are:

Level at	Readings on (in m)	
	A	B
A	2.165	3.810
B	0.910	2.355

The true difference in level between A and B would be
(a) 1.255 m (b) 1.355 m
(c) 1.545 m (d) 1.645 m
[ESE : 1999]

3.6 A lighthouse is visible just above the horizon at a certain station at the sea level. The distance between the station and the lighthouse is 40 km. The height of the lighthouse is approximately
(a) 187 m (b) 137.7 m
(c) 107.7 m (d) 87.3 m
[ESE : 1999]

4. Calculation of Area and Volume

4.1 Which one of the following methods estimates best the area of an irregular and curved boundary?
(a) Trapezoidal method
(b) Simpson's method
(c) Average ordinate method
(d) Mid-ordinate method
[ESE : 1998]

5. Engineering Instruments, Theodolites and Plane Table Surveying

5.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Clinometer
B. Pantagraph
C. Tellurometer
D. Ghat tracer

List-II
1. Area measuring instrument
2. Gradient finding instrument
3. Angle measuring instrument
4. Plan enlarging instrument
5. Microwave instrument

Codes:

	A	B	C	D
(a)	1	2	5	3
(b)	1	5	4	3
(c)	3	4	1	2
(d)	3	4	5	2

[ESE : 1995]

5.2 For locating an inaccessible point with the help of only a Plane table, one should use
(a) traversing (b) resection
(c) radiation (d) intersection
[ESE : 1995]

5.3 The method of plane tabling commonly used for establishing the instrument station is the method of
(a) radiation (b) intersection
(c) resection (d) traversing
[ESE : 1996]

5.4 Consider the following operations in a spire test:
1. Depress telescope and sight a point on the ground nearer to the instrument.
2. Clamp horizontal plates.
3. Sight a well-defined high point on a high building.
4. Change face and repeat the procedure.

The correct sequence of these operations is
(a) 1, 2, 3, 4 (b) 3, 1, 2, 4
(c) 3, 2, 1, 4 (d) 2, 1, 3, 4
[ESE : 1996]

5.5 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Sextant
B. Sounding
C. Fathometer
D. Range

List-II
1. Measurement of depth below the water surface
2. The line on which soundings are taken
3. The lines which are usually used for depths above about 6 m
4. Instrument used for measuring angles from a boat
5. Instrument used for measuring depth in ocean

Codes:

	A	B	C	D
(a)	5	1	4	2
(b)	4	2	5	3
(c)	5	3	4	1
(d)	4	1	5	2

[ESE : 1997]

5.6 The three-point problem in hydrographic surveying considers the data on the location of three shore signals *A*, *B* and *C* and the angles α and β subtended by *AB* and *BC* at the boat *P*; and then proceeds to plot the position of *P*. The problem may become indeterminate in special cases when

(a) *B* and *P* are on opposite sides of the line *AC*
(b) Both *B* and *P* are on the same side of the line *AC*
(c) *P* is within the triangle *ABC*
(d) *P* is very close to the extension of one of the edges of the triangle *ABC*

[ESE : 1997]

5.7 Match **List-I** (Statement) with **List-II** (Situation) and select the correct answer using the codes given below the lists:

List-I

A. Accurate centering in plane table surveying is necessary for
B. Exact orientation is more important than accurate centering for
C. The intersection method of plane table surveying is particularly employed for
D. Plane table survey is useful for

List-II

1. Inaccessible points
2. Open country with good intervisibility
3. Large scale maps
4. Small scale maps
5. Hilly regions

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	2	5
(c)	5	4	3	1
(d)	3	1	4	2

[ESE : 1998]

6.Tacheometric, Curve, Hydrographic Survey, Tides & Triangulation

6.1 In an external focussing tacheometer, the fixed interval between stadia hairs is 5 mm, the focal length of the objective is 25 cm, and the distance of the vertical axis of the instrument from the optical centre of the objective is 15 cm. Which one of the following is the set of constants of the tacheometer?

(a) 30, 0.15 (b) 30, 0.40
(c) 50, 0.25 (d) 50, 0.40

[ESE : 1997]

6.2 A lemniscate curve between the tangents is transitional throughout, if the polar deflection angle of its apex is equal to (ϕ is the deflection angle between the initial and final tangents)

(a) $\phi/2$ (b) $\phi/4$
(c) $\phi/6$ (d) ϕ

[ESE : 1997]

6.3 For a chord of 60 m, the mid-ordinate for a circular curve of 50 m radius will be

(a) 10 m (b) 12.5 m
(c) 15 m (d) 18.75 m

[ESE : 1998]

7. Theory of Errors

7.1 **Assertion (A):** The weight of a quantity indicates the relative precision of a quantity within a set of observations.

Reason (R): The weights are generally taken as directly proportional to the variance of the standard errors.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

7.2 The number of observations required of an operation to produce results having a specified accuracy

(a) varies inversely with the square of the confidence interval
(b) varies directly with the square of the confidence interval
(c) increases with the possible magnitude of the average expected value
(d) increases with the range of observed values, namely, the difference between the maximum and the minimum values of the observations

[ESE : 1996]

8. Field Astronomy, Photogrammetic Survey, Remote Sensing, GPS & Geology

8.1 The standard time meridian in India is 82°30′ *E*. If the standard time at any instant is 20 hours 10 minutes, the local mean time for the place at a longitude of 20°*E* would be
(a) 4 h PM (b) 4 h10 m PM
(c) 1 h 20 m PM (d) 0 h 20 m PM
[ESE : 1996]

8.2 In a tilted aerial photograph, if the swing is 230°, then the rotation angle is equal to
(a) 140° (b) 130°
(c) 50° (d) 25°
[ESE : 1996]

8.3 An image of the top of the hill is 96 mm from the principal point of the photograph. The elevation of the top of the hill is 500 m and the flying height is 4000 m above the datum. The relief displacement will be
(a) 768 mm (b) 88 mm
(c) 12 mm (d) 8 mm
[ESE : 1997]

8.4 Which one of the following methods would give accurate results in determining the direction of the observer's meridian?
(a) Observation of circumpolar stars on the same vertical
(b) Observation of circumpolar stars at culmination
(c) Extra-meridian observation of a circumpolar star
(d) Observation of the Sun at equal altitudes
[ESE : 1997]

8.5 If an overlapping pair of vertical photo-graphs taken with a 150 mm focal length camera has an air base of 2100 m and the elevation of the control point A on it is 900 m above MSL and the parallax of the point is 75 mm, then the flying height above MSL of the stereopair will be
(a) 3000 m (b) 3150 m
(c) 5100 m (d) 5250 m
[ESE : 1998]

8.6 Given that δ denotes declination, θ the latitude of the place of observation and α the altitude of a star at the prime vertical, then
(a) $\sin\theta = \sin\delta \cos\alpha$
(b) $\sin\theta = \sin\delta \operatorname{cosec}\alpha$
(c) $\cos\alpha = \cos\delta \sin\theta$
(d) $\sin\delta = \sin\alpha \cos\theta$
[ESE : 1998]

8.7 The declination of a star is 21°15′N at a latitude of 43°30′N. The zenith distance at the upper culmination is
(a) 22°15′ (b) 21°15′
(c) 64°45′ (d) 43°30′
[ESE : 1999]

■■■■

Answers Surveying and Geology

1.1 (c)	1.2 (c)	1.3 (a)	1.4 (b)	1.5 (c)	1.6 (a)	1.7 (a)	2.1 (d)	2.2 (a)
2.3 (c)	2.4 (b)	2.5 (a)	2.6 (d)	3.1 (d)	3.2 (b)	3.3 (c)	3.4 (a)	3.5 (c)
3.6 (c)	4.1 (b)	5.1 (d)	5.2 (d)	5.3 (c)	5.4 (c)	5.5 (d)	5.6 (d)	5.7 (a)
6.1 (d)	6.2 (c)	6.3 (a)	7.1 (c)	7.2 (a)	8.1 (a)	8.2 (c)	8.3 (c)	8.4 (b)
8.5 (c)	8.6 (b)	8.7 (a)						

Explanations Surveying and Geology

1. Fundamental Concepts of Surveying and Linear Measurement

1.1 (c)

Chain survey is used for moderately small areas and measurement of ill defined details e.g. edge of a marsh or for filling in details between already established points. Chain is used to measure the length of the line and tape is employed for measurement of offsets.

Compass survey is conducted mainly for angular measurements. It is done for large areas with rough ground having many details. However, magnetic zone affects the accuracy of compass by introducing local attraction errors. The details can be plotted in the office only.

Theodolite can be used for horizontal and vertical angle measurement.

Plane table survey is most suitable for small and medium scale mapping. The observations and plotting of details can be done simultaneously. The errors and mistakes in plotting can be checked by drawing check lines.

1.2 (c)

Actual length of chain

$$= 30 - 0.1 = 29.9 \text{ m}$$

$$\text{Actual distance} = \frac{29.9}{30} \times 300 = 299 \text{ m}$$

1.3 (a)

The distance measured right or left of the chain line to locate details like boundaries, culverts etc. are called offsets.

1.4 (b)

In triangulation base line is measured very precisely. Sag correction is used for base line measurement. Temperature correction is applied by measuring the temperature at least at three places. Finally slope correction is also needed on steep slopes.

The overlap of the photographs is maintained to ensure complete coverage of the area. The overlap in the direction of flight is known as longitudinal or forward overlap (about 60%). The overlap between the adjacent flights is known as side overlap (about 30%). It is used to:

(i) Orient points so as to form a continuous flight strip

(ii) View the photographs by stereoscope.

1.5 (c)

The correct sequence to obtain sufficient accuracy with tapes is:

(i) Keeping the tape on line being measured

(ii) Keeping uniform tension on tape for each measurement.

(iii) "Breaking" tape on slopes to keep tape level.

(iv) Keeping accurate count of stations.

1.6 (a)

$$\frac{\text{Correct length of tape}}{\text{Designated length of tape}} = \frac{\text{Correct length of line}}{\text{Length of line observed with the tape}}$$

$$\therefore \text{Correct length of tape} = \frac{200}{200.80} \times 20 = 19.92 \text{ m}$$

1.7 (a)

Correct length of the tape

$$= \frac{\text{Actual length of the tape}}{\text{Nominal length of the tape}} \times \text{Measured length}$$

$$500 = \frac{l}{20} \times 502$$

$$l = 19.92 \text{ m}$$

2. Compass Surveying and Traverse Surveying

2.1 (d)

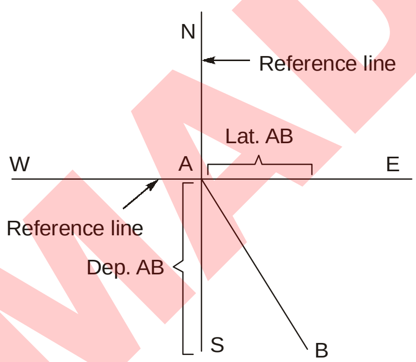
If the fore bearinssg of a line is given as the quadrantal bearing, then back bearing is numerically equal to the fore bearing. However *N* changes to *S* and *E* changes to *W* and vice versa.

2.2 (a)

Method of repetition is preferred for the measurement of a single angle and when the accuracy is desired beyond the least count of the instrument with a coarsely graduated circle. It is used for horizontal angles.

In the case of vertical angles face left and face right readings are taken.

2.3 (c)



Closing error is given by:

$\Sigma L_{south} - \Sigma L_{north} = 0$

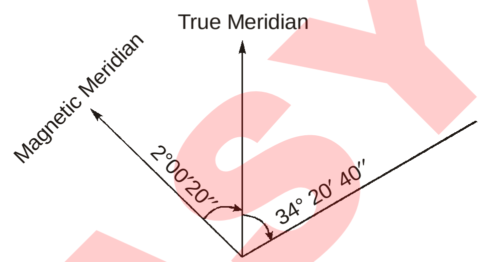
$\Sigma D_{east} - \Sigma D_{west} = 0$

Closing error will lie in south east quadrant.

2.4 (b)

In the loose needle method, the direction of the magnetic meridian is established at each traverse station and the direction of the line is determined with reference to the magnetic meridian. In other words, the magnetic bearing of each line is determined directly. A theodolite fitted with a compass is used for determining the magnetic bearing of the traverse line. The loose needle method is also known as free needle method.

2.5 (a)



When magnetic declination is west, then

$$\text{True bearing} = \text{Magnetic bearing} - \text{Magnetic declination}$$

$$\Rightarrow \quad 34^\circ\, 20'\, 40'' = \text{Magnetic bearing} - 2^\circ\, 00'\, 20''$$

$$\Rightarrow \quad \text{Magnetic bearing} = 36^\circ 21'\, 00''$$

2.6 (d)

Bowditchs rule is used to balance a traverse when the linear and angular measurements are equally precise. It is assumed that angular and linear measurement errors are proportional to $\frac{1}{\sqrt{L}}$ and $\sqrt{L}$ respectively.

3. Levelling and Contouring

3.1 (d)

RL of roof slab = *RL* of *BM* + Staff reading with Staff on *BM* + Inverted Staff reading

$$= 135.15 + 1.050 + 2.300$$

$$= 138.500 \text{ m}$$

3.2 (b)

Correction due to curvature and refraction,

$$C = 0.0673\, D^2$$

but $D = 1400 \text{ m} = 1.4 \text{ km}$

$\therefore$ $C = 0.0673 \times (1.4)^2$

$$= 0.132 \text{ m}$$

3.3 (c)

The distance of the observer from the light-house is given by

$$D = D_1 + D_2$$

$$= \sqrt{\frac{h_1}{0.0673}} + \sqrt{\frac{h_2}{0.0673}}$$

$$= \sqrt{\frac{30}{0.0673}} + \sqrt{\frac{10}{0.0673}}$$

$$= 21.11 + 12.19$$

$$= 33.3 \text{ km}$$

3.4 (a)

The primary object of a tacheometric survey is the preparation of a contoured plan. It is particularly suitable for filling in details on topographical maps, preliminary location survey and surveying steep grounds, broken boundaries and water stretches, etc. Also in surveys of higher accuracy it may be used to provide a ready check on distances measured with a chain or tape.

3.5 (c)

True difference in levels,

$$h = \frac{(3.810 - 2.165) + (2.355 - 0.910)}{2}$$

$$= 1.545 \text{ m}$$

Error in collimation adjustment,

$$e = \frac{(3.810 - 2.165) - (2.355 - 0.910)}{2}$$

$$= 0.1 \text{ m}$$

When the level is at A, the reading on the staff at A is correct. While reading on the staff at B is incorrect. When the level is at B, the reading on the staff at B is correct while reading on the staff at A is incorrect.

Correct readings are:

Level at	Readings on (in m)	
	A	B
A	2.165	3.710
B	0.810	2.355

3.6 (c)

Height of lighthouse

$$= 0.0673 \times D^2$$

$$= 0.0673 \times (40)^2$$

$$= 107.68 \text{ m}$$

4. Calculation of Area and Volume

4.1 (b)

Mid-ordinate and Average ordinate methods are used with the assumption that the boundaries between the extremities of the ordinates are straight lines.

Trapezoidal method is based on the assumption that the figures are trapezoids. The method is more accurate than the above two methods.

Simpson's method assumes that the short lengths of the boundaries between the ordinates are parabolic arcs. This method is more useful when the boundary line departs considerably from the straight line. The results obtained by use of Simpson's method in all cases are more accurate.

5. Engineering Instruments, Theodolites and Plane Table Surveying

5.1 (d)

Pantagraph is used for enlarging, reducing or reproducing the plans. Its working is based on principle of similar triangles. Planimeter is used for measurement of area of cross-sections for the highways and railways, and checking computed areas in property surveys and property divisions. The area determined with a planimeter is more accurate when the area is larger and particularly when the plotting scale is large.

5.2 (d)

(i) **Radiation** method is suitable only when the area to be surveyed is small and all the stations are visible and accessible from the instrument station.

(ii) **Traversing** is most suited when a narrow strip of terrain is to be surveyed e.g. survey of roads, railway etc.

(iii) **Intersection** method is preferred when the distance between stations is large or the stations are inaccessible or the ground is undulating.

(iv) **Resection** is used when some important details can be plotted easily by choosing any station other than the triangulation station.

5.3 (c)

There are three methods of orienting plane table :

(i) **By trough compass:** It is a crude method and cannot be used where local attraction is suspected.

(ii) **By back sighting:** It is the most accurate method of orientation.

(iii) **By resection**

5.4 (c)

Spire test is known as the test for the adjustment of standards. The horizontal axis should be perpendicular to the axis. First the theodolite is set up and levelled carefully at about 50 m from a high building. A point on the building is bisected with a vertical angle greater than 30°. The telescope is then lowered and a point is set near the ground. Before lowering the telescope, the horizontal plates should be clamped so that the ground point may fall exactly below the building point.

5.5 (d)

A sextant is an instrument used for measurement of the horizontal and vertical angles. The distinguishing feature of a sextant is the arrangement of two mirrors which enables the observer to sight two different objects simultaneously. There are two types of sextants viz. Nautical sextant and Box sextant.

The process of determination of the bed depth of a water body is called sounding. In other words, sounding is the measurement of depth of bed below the water surface.

Fathometer (also called Echo-sounder) is an instrument which is used for sounding in an ocean where the depth of water is great.

Range line is a line along which the sounding are taken. The range lines are generally marked perpendicular to the shore line. However, if the shore is irregular, the range lines are usually marked radiating from some prominent object shore signal.

5.7 (a)

Accurate orientation is more important in small scale maps whereas accurate centering is required for large scale maps. Plane table is useful in open area having good intervisibility between points. Method of intersection is employed for plotting of inaccessible points.

6. Tacheometric, Curve, Hydrographic Survey, Tides & Triangulation

6.1 (d)

Tacheometric distance equation

$$D = ks + C$$

where

k is multiplying constant $= \frac{f}{i}$

C is additive constant $= f + d$

k is also known as stadia interval factor

f is focal length of the object glass

i is stadia interval

d is distance between the vertical axis of the tacheometer and the optical centre

Given, $f = 25$ cm; $i = 5$ mm; $d = 15$ cm

$$\therefore \quad k = \frac{25}{0.5} = 50$$

and

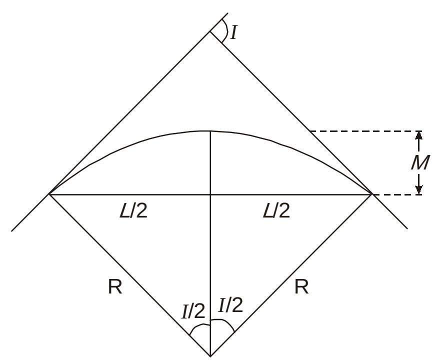
$$C = \frac{25+15}{100} = 0.40 \text{ m}$$

6.2 (c)

$$\alpha_n = \frac{\phi}{6}$$

For the curve to be transitional throughout, the maximum polar deflection angle must be equal to $\frac{1}{6}$ of the deflection angle between the initial tangents.

6.3 (a)



Mid ordinate, $M = R - \sqrt{R^2 - (L/2)^2}$

$$= 50 - \sqrt{(50)^2 - (60/2)^2}$$

$$= 10 \text{ m}$$

Alternatively,
Length of long chord,

$$L = 2R \sin \frac{I}{2}$$

$$\Rightarrow \quad 60 = 2 \times 50 \sin \frac{I}{2}$$

$$\Rightarrow \quad \sin \frac{I}{2} = 0.6$$

$$\Rightarrow \quad \frac{I}{2} = 36.87°$$

Mid ordinate, $M = R\left(1 - \cos\frac{I}{2}\right)$

$$= R \operatorname{versin} \frac{I}{2}$$
$$= 50 \times (1 - \cos 36.87°)$$
$$= 50 \times 0.2$$
$$= 10 \text{ m}$$

7. Theory of Errors

7.1 (c)

The weight of an observation is a measure of its relative trustworthiness. The more reliable the result, the higher its weight. The weights of the measurement results are assumed to be inversely proportional to the square of their respective mean square error.

7.2 (a)

Probable error of single observation of unit weight

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma e^2}{(n-1)}}$$

where
e is residual error
n is number of observations
So number of observations (n) vary inversely with square of confidence interval (E_s)

$$n = \left(\frac{0.6745}{E_s}\right)^2 \Sigma e^2 + 1$$

8. Field Astronomy, Photogrammetic Survey, Remote Sensing, GPS & Geology

8.1 (a)

Difference in longitude = 82°30′ – 20°
= 62°30′

$$1 \text{ h} = 15°;\ 1 \text{ m} = 15'$$

and $1 \text{ s} = 15''$

$\therefore \quad 62° = 4 \text{ h } 8 \text{ m}$

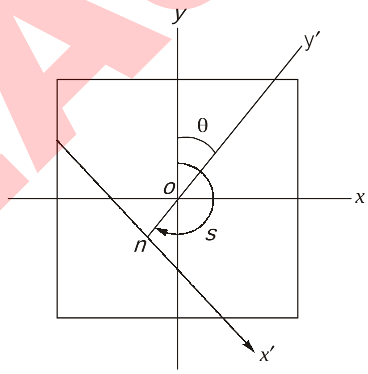
$30' = 2 \text{ m}$

$\therefore \quad 62°30' = 4 \text{ h } 10 \text{ m}$

Local mean time (LMT)
= Standard time – Difference in longitude
= 20 h 10 m – 4 h 10 m
= 16 h = 4 h PM

8.2 (c)

The swing angle (s) is the clockwise angle measured in the plane of photograph from the positive y-axis the photographic nadir point (n).



Thus, the rotation angle,

$$\theta = s - 180°$$
$$= 230° - 180°$$
$$= 50°$$

8.3 (c)

Relief displacement,

$$d = \frac{r_t h_t}{H} = \frac{96 \times 500}{4000} = 12 \text{ mm}$$

8.4 (b)

Terrestrial meridian (observer's meridian) is the great circle that passes through the terrestrial poles and point of observation.
Stars having polar distances less than the latitude of the place of observation are called circumpolar star. They are always above the horizon and therefore do not set.
When a celestial body crosses the observer's meridian, it is said to culminate or transit.

8.5 (c)

Given
$$f = 150 \text{ mm}$$
$$B = 2100 \text{ m}; \; h = 900 \text{ m};$$
$$p = 75 \text{ mm}$$
$$\frac{p}{f} = \frac{B}{H-h}$$
$$\Rightarrow \quad H - 900 = \frac{2100 \times 150}{75}$$
$$\therefore \quad H = 5100 \text{ m}$$

8.6 (b)

A vertical circle which is at right angles to the meridian is called prime vertical. It intersects the horizon in the east and west points.
$$\sin\delta = \cos(90-\theta)\cos(90-\alpha)$$
$$= \sin\theta\sin\alpha$$
$$\therefore \quad \sin\theta = \sin\delta \operatorname{cosec}\alpha$$

8.7 (a)

At upper culmination
$$\text{zenith distance} = \delta - \theta = 90 - \alpha$$
At lower culmination
$$\text{zenith distance} = 180 - (\delta + \theta) = 90 - \alpha$$
Given declination,
$$\delta = 21° \, 15'\text{N}$$
When $\delta < \theta$, it means that the upper culmination occurs the south of the zenith.
$$\text{Zenith distance} = \theta - \delta = 43°30' - 21°15'$$
$$= 22°15'$$

UNIT

VII

Highway Engineering

Syllabus

Planning & construction methodology, Alignment and geometric design; Traffic Surveys and Controls; Principles of Flexible and Rigid pavements design.

Contents

■■■■

7 Highway Engineering

1. Highway Development & Planning

1.1 **Assertion (A):** Level grades may be used in fill sections for roads in rural areas.

Reason (R): On fill sections in rural areas, crowned pavements and sloping shoulders can take care of surface drainage.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

1.2 Which one of the following is the chronological sequence in regard to road construction/design/development?

(a) Telford, Tresaguet, CBR, Macadam
(b) Tresaguet, Telford, Macadam, CBR
(c) Macadam, CBR, Tresaguet, Telford
(d) Tresaguet, Macadam, Telford, CBR

[ESE : 1998]

2. Highway Geometric Design

2.1 The maximum super elevation to be provided on a road curve is 1 in 15. If the rate of change of super elevation is specified as 1 in 120 and the road width is 10 m, then the minimum length of the transition curve on either end will be

(a) 180 m (b) 125 m
(c) 80 m (d) 30 m

[ESE : 1995]

2.2 A summit curve is formed at the intersection of a 3% up gradient and 5% down gradient. To provide a stopping distance of 128 m, the length of summit curve needed will be

(a) 271 m (b) 298 m
(c) 322 m (d) 340 m

[ESE : 1995]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2.3 **Assertion (A):** For mixed traffic conditions, the super elevation should fully counteract the centrifugal force for the full design speed.

Reason (R): Super elevation needed to maintain the design speed in full may exceed the limiting value of 0.07. Further, as it is not possible to increase the radius, the speed has to be restricted.

[ESE : 1995]

2.4 **Assertion (A):** Rotating parts of the surface of the road with the crown as the pivot is not generally preferred for achieving the needful cant at horizontal curves.

Reason (R): Lowering of the lower edge interferes with the drainage system of the road.

[ESE : 1996]

2.5 Which of the following are the criteria associated with the design of sag vertical curve?

1. Provision of minimum stopping distance during day time.
2. Adequate drainage.
3. Comfortable operation
4. Pleasant appearance.

Select the correct answer using the codes given below:

(a) 1, 2 and 4 (b) 2 and 3
(c) 2, 3 and 4 (d) 1 and 3

[ESE : 1996]

2.6 Assuming the safe stopping sight distance to be 80 m on a flat highway section and with a setback distance of 10 m, what would be the radius of the negotiable horizontal curve?

(a) 800 m (b) 160 m
(c) 80 m (d) 70 m

[ESE : 1996]

2.7 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists: (adopting standard notations)

List-I

A. Cubic parabola equation
B. Shifting transition curve
C. Valley curve
D. Summit curve

List-II

1. $\frac{NS^2}{4.4}$
2. $\frac{L^2}{24R}$
3. $\frac{NS^2}{1.50+0.035S}$
4. $\frac{x^3}{6RL}$
5. $\frac{v^2}{gR}$

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	4	1	2
(c)	1	5	2	4
(d)	4	2	3	1

[ESE : 1996]

2.8 A parabolic vertical curve is to be set out connecting two uniform grades of + 0.6% and +1.0%. The rate of change of grade is to be 0.06% per 30 m. The length of the curve will be

(a) $66\frac{2}{3}$ m (b) $133\frac{1}{3}$ m
(c) 200 m (d) $266\frac{2}{3}$ m

[ESE : 1997]

2.9 A vehicle was stopped in two seconds by fully jamming the breaks. The skid marks measured 9.8 metres. The average skid resistance coefficient will be

(a) 0.7 (b) 0.5
(c) 0.4 (d) 0.25

[ESE : 1997]

2.10 Which of the criteria given below are used for the design of valley vertical curves on roads?

1. Rider comfort
2. Headlight sight distance
3. Drainage

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2

[ESE : 1998]

2.11 Assertion (A): It is general practice to provide cant to the road surface with inner edge forming the pivot point.

Reason (R): It does not change centre line levels which have already been fixed at the design stage.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

2.12 For a circular curve of radius 200 m, the coefficient of lateral friction of 0.15 and the design speed is 40 kmph. The equilibrium super elevation (for equal pressure on inner and outer wheel) would be

(a) 21.3 (b) 7
(c) 6.3 (d) 4.6

[ESE : 1999]

2.13 If a descending gradient of 1 in 25 meets an ascending gradient of 1 in 40, then the length of valley curve required for a headlight sight distance of 100 m will be

(a) 30 m (b) 130 m
(c) 310 m (d) 630 m

[ESE : 1999]

2.14 An ascending gradient of 1 in 100 meets a descending gradient of 1 in 50. The length of summit curve required to provide overtaking sight distance of 500 m will be
(a) 938 m (b) 781 m
(c) 470 m (d) 170 m
[ESE : 1999]

2.15 Which one of the following expressions gives intermediate sight distance as per IRC standards?
(a) 2 SSD (b) $\frac{(SSD + OSD)}{2}$
(c) $\frac{(OSD - SSD)}{2}$ (d) 2 OSD
[ESE : 1999]

2.16 Brake is applied on a vehicle which then skids a distance of 16 m before coming to stop. If the developed average coefficient of friction between the tyres and the pavement is 0.4, then the speed of the vehicle before skidding have been nearly
(a) 20 kmph (b) 30 kmph
(c) 40 kmph (d) 50 kmph
[ESE : 1999]

3. Traffic Engineering

3.1 In desire-line diagram
(a) width of desire-line is proportional to the number of trips in one direction
(b) length of the desire-line is proportional to the number of trips in both directions
(c) width of desire-line is proportional to the number of trips in both directions
(d) both length and width of desire-line are proportional to the number of trips in both directions
[ESE : 1995]

3.2 Consider the following situations:
1. Traffic volume entering from all roads is less than 3000 vehicles per hour.
2. Pedestrian volume is high.
3. Total right turning traffic is high.
4. A road in a hilly region.

A rotary will be more suitable than control by signals, in situations listed against
(a) 1 and 3 (b) 1 and 4
(c) 2 and 4 (d) 2 and 3
[ESE : 1995]

3.3 Ratio of the width of the car parking area required at kerb for 30° parking relative to 60° parking is approximately
(a) 0.5 (b) 0.7
(c) 0.8 (d) 2.0
[ESE : 1996]

3.4 For the relationship u = 55 – 0.44k, where ‘u’ is the speed in kmph and ‘k’ is the density in vpkm, what will be the maximum flow in vph?
(a) 1718 (b) 1250
(c) 625 (d) 125
[ESE : 1996]

3.5 Consider the following statements:
Collision diagram is used to
1. study accident pattern
2. eliminate accidents
3. determine remedial measures
4. make statistical analysis of accidents

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 3 and 4 (d) 2 and 4
[ESE : 1996]

3.6 In which one of the following grades of a highway is an emergency escape ramp provided?
(a) 1 in 200 (b) Zero grade
(c) Down grade (d) Up grade
[ESE : 1996]

3.7 Consider the following parameters related to a rotary intersection:
1. Width of the weaving section.
2. Length of the weaving section.
3. Proportion of weaving traffic.
4. Weaving angle.
5. Width of the carriageway at entry.

Capacity is generally expressed in terms of
(a) 1, 2, 3 and 4 (b) 1, 2, 3 and 5
(c) 1, 2 and 3 (d) 4 and 5
[ESE : 1997]

3.8 It is a common practice to design a highway to accommodate the traffic volume corresponding to
(a) 30th hour (b) Peak hour
(c) ADT (d) 15 min-peak period
[ESE : 1998]

3.9 It was noted that on a section of road, the free speed was 80 kmph and the jam density was 70 vpkm. The maximum flow in vph that could be expected on this road is
(a) 800 (b) 1400
(c) 2800 (d) 5600
[ESE : 1998]

3.10 If the normal flows on two approach roads at an intersection are respectively 500 pcu per hr and 300 pcu per hr, the saturation flows are 1600 pcu per hr on each road and the total lost time per signal cycle is 16 s, then the optimum cycle time by Webster's method is
(a) 72.5 s (b) 58 s
(c) 48 s (d) 19.3 s
[ESE : 1999]

3.11 When two roads with two-lane, two-way traffic, cross at an uncontrolled intersection, the total number of potential major conflict points would be
(a) 32 (b) 24
(c) 16 (d) 4
[ESE : 1999]

3.12 Assertion (A): IRC suggest that the maximum volume of traffic of 3000 vehicles per hour entering from all legs of the rotary intersection can be handled efficiently.
Reason (R): Traffic rotaries may be provided where the intersecting traffic is about 50% of the total traffic or fast turning traffic is at least 30% of the total traffic.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

4. Pavement Design

4.1 Given that
r = radius of load distribution
E = modulus of elasticity of concrete
K = modulus of subgrade reaction
μ = Poisson's ratio of concrete
h = thickness of slab
P = wheel load
The combination of parameters required for obtaining the radius of relative stiffness of cement concrete slab is
(a) E, K, μ, r (b) h, K, μ, r
(c) E, h, K, μ (d) P, h, K, μ
[ESE : 1995]

4.2 Assertion (A): Most flexible design procedures are based on Bankelman beam deflection measurements.
Reason (R): Elastic deflection is a practical non-destructive measure of pavement stiffness which relates well to fatigue failure.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1996]

4.3 The plasticity index of the fraction passing 425 micron IS sieve in case of sub-base/base course should be
(a) less than 6 (b) greater than 6
(c) greater than 9 (d) between 15 and 30
[ESE : 1996]

4.4 Effect of impact on the design of rigid pavements is accounted for by
(a) increasing the thickness as would be calculated with static wheel load
(b) providing a base course
(c) adopting a reduced flexural strength of concrete through a factor of safety
(d) adopting an increased stress relative to that produced by static wheel load
[ESE : 1996]

4.5 Consider the following statements with reference to pavements:

1. Flexible pavements are more suitable than rigid pavements in regions where subgrade strength is uneven.
2. Load carrying capacity of rigid pavements depends more on the properties of concrete than the strength of subgrade.
3. Compared to flexible pavements, rigid pavements are more affected by temperature variations.

Which of these statements is/are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 alone

[ESE : 1996]

4.6 If the CBR value obtained at 5 mm penetration is higher than that at 2.5 mm, then the test is repeated for checking; and if the check test reveals a similar trend, then the CBR value is to be reported as the

(a) mean of the values for 5 mm and 2.5 mm penetration
(b) higher value minus the lower value
(c) lower value corresponding to 2.5 mm penetration
(d) higher value obtained at 5 mm penetration

[ESE : 1997]

4.7 The number of load cycles (N_f) to cause the failure of a pavement is proportional to (P is the respective applied load)

(a) P^4 (b) P^{-4}
(c) P^2 (d) P^{-1}

[ESE : 1997]

4.8 **Assertion (A):** Load stresses added to warping stresses are considered while determining the thickness of pavement.

Reason (R): Joints and sealing devices are used to relieve and/or take care of warping stresses, and the design for thickness is accordingly based upon load alone.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

4.9 The general requirement in constructing a reinforced concrete road is to place a single layer of reinforcement

(a) near the bottom of the slab
(b) near the top of the slab
(c) at the middle
(d) equally distributed at the top and bottom

[ESE : 1998]

4.10 The corrected characteristic rebound deflection on a pavement, using Bankelman beam study is 2 mm. The equivalent granular overlay thickness required for an allowable deflection of 1 mm as per original IRC guidelines is

(a) 33 mm (b) 66 mm
(c) 133 mm (d) 166 mm

[ESE : 1999]

4.11 Consider the following:

1. *LL* of soil
2. *PL* of soil
3. *SL* of soil
4. Annual average rainfall
5. Temperature of the soil

As per the latest IRC guidelines, the set of essential data required to determine moisture correction factor of clayey subgrade soil in Bankelman beam study would include

(a) 1, 2 and 4 (b) 1, 2, 3 and 4
(c) 2, 3 and 4 (d) 4 and 5

[ESE : 1999]

4.12 As per latest IRC guidelines for designing flexible pavement of CBR method, the load parameter required is

(a) number of commercial vehicles per day
(b) cumulative standard axles in msa
(c) equivalent single axle load
(d) number of vehicles (all types) during design life

[ESE : 1999]

4.13 If the load, warping and frictional stresses in a cement concrete slab are 210 N/mm^2, 290 N/mm^2 and 10 N/mm^2 respectively, the critical combination of stresses during summer mid-day is

(a) 290 N/mm^2 (b) 390 N/mm^2
(c) 490 N/mm^2 (d) 590 N/mm^2

[ESE : 1999]

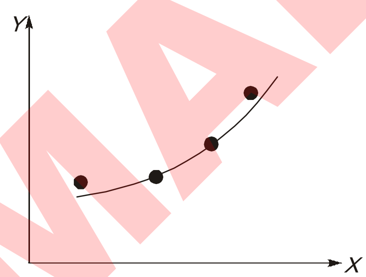
4.14 In cement concrete pavements, tie bars are installed in
(a) expansion joints (b) contraction joints
(c) warping joints (d) longitudinal joints
[ESE : 1999]

5. Highway Materials, Maintenance and Properties

5.1 In the Los Angeles Abrasion Test on aggregate, if the speed of the drum is increased to 50 rpm, then the abrasion value will
(a) increase
(b) decrease
(c) remain unchanged
(d) be unpredictable
[ESE : 1995]

5.2 Which one of the following causes ravelling in bituminous pavement?
(a) Use of soft bitumen
(b) Excessive bitumen content
(c) Low bitumen content
(d) Use of open-graded aggregates
[ESE : 1995]

5.3 A typical Marshall test graph is shown in the given figure. The variable on the *X*-axis is % binder content by weight of total mix. The variable on the *Y*-axis for the given graph will be



(a) stability value
(b) flow value
(c) percentage of voids
(d) unit weight
[ESE : 1995]

5.4 Which one of the following items of hill road construction does not help in the prevention of landslides in the monsoon season?
(a) Retaining walls
(b) Catch water drains
(c) Breast walls
(d) Hair-pin bends
[ESE : 1995]

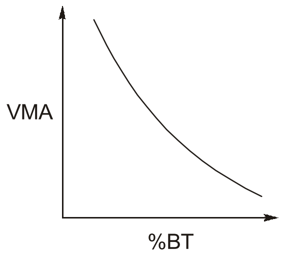
5.5 Consider the following types of roads in the same rainfall region:
1. Water Bound Macadam roads
2. Cement Concrete roads
3. Bituminous high-speed roads
4. Gravel roads
The correct sequence of the descending order of steepness of camber of these roads is
(a) 4, 1, 2, 3 (b) 4, 1, 3, 2
(c) 1, 4, 3, 2 (d) 1, 4, 2, 3
[ESE : 1995]

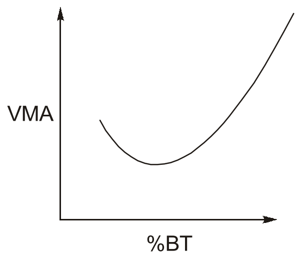
5.6 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:
List-I
A. Disintegration of aggregates due to weathering
B. The removal of material from the surface of the road by grinding action
C. Mutual rubbing or grinding within the mass under the action of traffic
D. Breaking up of road surface layer through cracking into irregular shaped areas
List-II
1. Attrition
2. Crazing
3. Soundness
4. Abrasion
5. Disintegration
Codes:

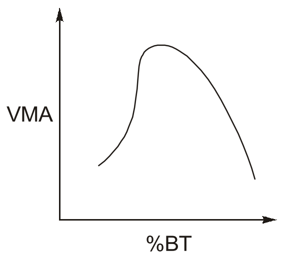
	A	B	C	D
(a)	3	1	5	2
(b)	2	5	1	4
(c)	3	4	1	2
(d)	1	4	3	5

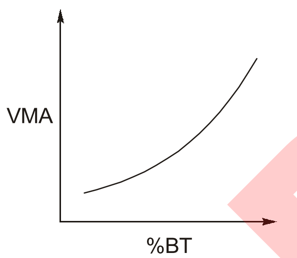
[ESE : 1996]

5.7 Which one of the following diagrams illustrates the relationship between VMA and % bitumen content (BT) in Marshall test?

(a) 

(b) 

(c) 

(d) 

[ESE : 1996]

5.8 In which one of the following bituminous constructions, compaction by pneumatic roller also is specified?
(a) Premix carpet
(b) Bituminous macadam
(c) Bituminous concrete
(d) Surface dressing

[ESE : 1996]

5.9 For an aggregate-soil mixture with maximum size of aggregate as 60 mm, the percentage of material between 6 mm and 75 micron sizes for obtaining Fuller's maximum density criterion shall be nearly
(a) 37 (b) 35
(c) 28 (d) 15

[ESE : 1997]

5.10 **Assertion (A):** Bituminous roads disintegrate even with light traffic, but such road failures are not due to any wrong use of surface treatment.
Reason (R): Improper preparation of the subgrade and the foundation are responsible for this disintegration.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

5.11 The amount of mechanical energy imposed on the aggregate during the aggregate impact test is of the order of
(a) 5320 kg-cm (b) 6750 kg-cm
(c) 7980 kg-cm (d) 11400 kg-cm

[ESE : 1998]

5.12 Which one of the following binders is recommended for a wet and cold climate?
(a) 80/100 penetration asphalt
(b) Tar
(c) Cutback
(d) Emulsion

[ESE : 1998]

5.13 With reference to the Marshall mix design criteria for highways, which one of the following parts is NOT correctly matched?
(a) Stability value : 340 (minimum)
(b) Flow value : 8-16
(c) VFB : 50-75
(d) % Air voids : 3-5

[ESE : 1998]

5.14 Match **List-I** (Pavement deficiency) with **List-II** (Explanation) and select the correct answer using the codes given below the lists:

List-I
A. Bird baths
B. Pot holes
C. Ravelling
D. Subsidence

List-II
1. A step-sided, bowl shaped cavity caused by loss of surfacing as well as base course erosion

2. Deformation which may be caused by localized or variable subgrade failure
3. Irregular deformations which may be the result of differential settlement
4. Removal of larger surface aggregates leaving craters
5. Abrupt lowering of the road surface due to poor drainage

Codes:

	A	B	C	D
(a)	1	4	5	3
(b)	2	1	3	5
(c)	5	2	4	3
(d)	2	1	4	5

[ESE : 1998]

5.15 Which one of the following pairs is NOT correctly matched?
(a) Horizontal curves – Superelevation
(b) *O* and *D* studies – Desire lines
(c) Los Angeles test – Hardness of aggregates
(d) Soundness test – Purity of bitumen

[ESE : 1999]

5.16 For carrying out bituminous patch work during the rainy season, the most suitable binder is
(a) road tar
(b) hot bitumen
(c) cutback bitumen
(d) bituminous emulsion

[ESE : 1999]

5.17 **Assertion (A):** In bituminous mixes, the minimum voids requirement provides space for densification under traffic movements and expansion of bitumen at high temperature.
Reason (R): Insufficient voids in the bituminous mix causes bleeding of the bituminous surface and skidding.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

■■■■

Answers Highway Engineering

1.1 (a)	1.2 (b)	2.1 (c)	2.2 (b)	2.3 (d)	2.4 (a)	2.5 (c)	2.6 (c)	2.7 (d)
2.8 (c)	2.9 (b)	2.10 (a)	2.11 (c)	2.12 (c)	2.13 (b)	2.14 (b)	2.15 (a)	2.16 (c)
3.1 (c)	3.2 (a)	3.3 (c)	3.4 (a)	3.5 (b)	3.6 (c)	3.7 (b)	3.8 (a)	3.9 (b)
3.10 (b)	3.11 (c)	3.12 (b)	4.1 (c)	4.2 (d)	4.3 (a)	4.4 (a)	4.5 (c)	4.6 (d)
4.7 (d)	4.8 (a)	4.9 (c)	4.10 (d)	4.11 (a)	4.12 (b)	4.13 (c)	4.14 (d)	5.1 (a)
5.2 (d)	5.3 (b)	5.4 (d)	5.5 (b)	5.6 (c)	5.7 (b)	5.8 (a)	5.9 (c)	5.10 (a)
5.11 (c)	5.12 (c)	5.13 (c)	5.14 (d)	5.15 (d)	5.16 (d)	5.17 (a)		

Explanations Highway Engineering

1. Highway Development & Planning

1.1 (a)

The main concern in surface drainage is the fast disposal of precipitation on road surface so as to minimize danger to moving vehicles. This is achieved by proper geometric design of the road, i.e. by crowning the carriageway or side cross fall, giving proper cross slope to the shoulders and verges, providing requisite longitudinal gradient.

1.2 (b)

Tresaguet construction was started in 1764 AD in France. Telford construction was started in 1803 AD in London (England). Macadam construction was started in 1815 AD in England. CBR construction was started in 1928 AD in USA

2. Highway Geometric Design

2.1 (c)

Length of transition curve,

$$L = eWN$$

Given,
$$e = \frac{1}{15};\ \frac{1}{N} = \frac{1}{120};$$
$$W = 10\text{ m}$$

$$\therefore \quad L = \frac{1}{15} \times 10 \times 120 = 80\text{ m}$$

2.2 (b)

Deviation angle,

$$N = n_1 - (-n_2) = n_1 + n_2$$
$$= 3\% + 5\% = 8\%$$

For $L > SSD$,

$$L = \frac{NS^2}{4.4} = \frac{8}{100} \times \frac{(128)^2}{4.4}$$
$$= 298\text{ m}$$

2.3 (d)

Design of superelevation for mixed traffic conditions:

To superelevate the pavement up to the maximum limit so that it can counteract the centrifugal force fully neglecting the lateral friction is safer for fast moving vehicles. But for low moving vehicles this may be quite inconvenient. On the contrary to provide low value of superelevation thus relying more on lateral friction would be unsafe for fast moving vehicles.

As a compromise, the superelevation should be provided to fully counteract the centrifugal force due to 75% of the design speed (by neglecting the friction developed) and limited the maximum superelevation to 0.07.

2.4 (a)

To attain the superelevation (i) crown of the cambered section is eliminated first and

(ii) pavement is rotated to attain full superelevation.

Rotation of the pavement section to attain full superelevation is carried out in two ways as follows :

(i) Rotating about centre line (crown) has the advantage in balancing earth work. However the disadvantage of this method is the drainage problem due to depression of the inner edge below the general level. Therefore it is not preferred in high rainfall areas.

(ii) Rotating about the inner edge is preferable in very flat terrain in high rainfall area, when the road is not taken on the embankment, in order to avoid the drainage problem.

2.5 (c)

The criteria for sag vertical curve are:

(i) Comfort condition

(ii) Head light sight distance

(iii) Drainage at lowest point

(iv) Aesthetic consideration

2.6 (c)

When $L_C > S$, the formula for set back distance is

$$M = R-(R-d)\cos\left(\frac{\alpha}{2}\right)$$

Where $$\alpha = \frac{180S}{\pi(R-d)}$$

S is stopping sight distance (SSD)

d is distance between centre line of road and the centre line of the inside lane

L_c is length of the curve

However, this formula is difficult in calculation so approximate equation can be formulated by assuming that the length of chord is equal to SSD.

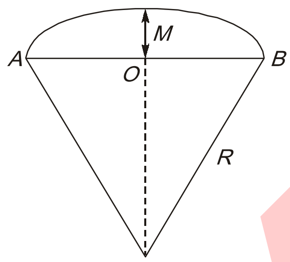
Given, $M = 10$ m $S = 80$ m

$$\therefore \quad R = \frac{M}{2}+\frac{S^2}{8M}$$

$$= \frac{10}{2}+\frac{(80)^2}{8\times 10} = 85 \text{ m}$$

The most close option is (c) i.e. 80 m

Alternate Method



Assuming length of are AB

= Length of chord AB = SSD

From property of circle $AO \times OB = M \times (2R - M)$

$$AO = OB = \frac{SSD}{2} = 40 \text{ m}$$

$$M = 10 \text{ m}$$

So $40 \times 40 = 10\,(2R - 10)$

$\Rightarrow$ $R = 85$ m

So the most close option is (c) i.e. 80 m.

2.8 (c)

Change of grade = 1 – 0.6 = 0.4%

$$\text{Length of the curve} = \frac{0.4}{0.06}\times 30 = 200 \text{ m}$$

2.9 (b)

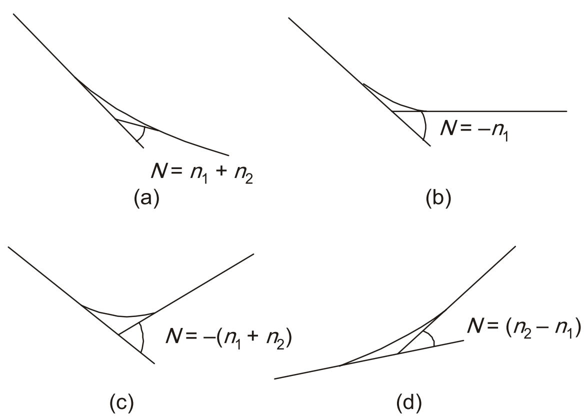
Initial speed of vehicle

$$v = fgt$$

$$s = \frac{v^2}{2fg} = \frac{f^2g^2t^2}{2fg}$$

$$\therefore \quad f = \frac{2s}{gt^2} = \frac{2\times 9.8}{9.8\times 2^2} = 0.5$$

2.10 (a)



1. Impact-free movement of vehicles at design speed
2. Availability of stopping sight distance under headlight of vehicles for night driving as during night sight distance decreases.
3. Comfort of passengers
4. Lowest point in valley curve may be located from consideration of cross drainage
5. Appearance or aesthetics

2.11 (c)

Vertical alignment and centre line change when cant is provided by raising the outer edge of the pavement with inner edge forming the pivot point.

2.12 (c)

Equilibrium superelevation,

$$e = \frac{V^2}{127R} = \frac{40^2}{127 \times 200}$$

$$= 0.0629 \simeq 6.3\%$$

Avoid mistake:

At equilibrium superelevation, $f = 0$.

2.13 (b)

Deviation angle,

$$N = \frac{1}{25} + \frac{1}{40} = 0.065$$

Assuming $L > S$, where S is headlight sight distance,

$$L = \frac{NS^2}{(1.5 + 0.035S)}$$

$$= \frac{0.065 \times 100^2}{1.5 + 0.035 \times 100} = 130 \text{ m}$$

2.14 (b)

Deviation angle,

$$N = \frac{1}{100} + \frac{1}{50} = 0.03$$

Assuming $L > S$;

$S = 500$ m

$$L = \frac{NS^2}{9.6} = \frac{0.03 \times 500^2}{9.6}$$

$$= 781.25 \text{ m}$$

2.15 (a)

As per IRC 66:1976,

Intermediate sight distance = 2 × stopping sight distance.

2.16 (c)

$$V = \sqrt{2gfs} = \sqrt{2 \times 9.8 \times 0.4 \times 16}$$

$$= 11.2 \text{ m/s} = 40.32 \text{ kmph}$$

3. Traffic Engineering

3.1 (c)

Desire lines are graphical representation of Origin and Destination survey. These are straight lines connecting the origin points with destinations, summarized into different area groups. The width of such desire lines is drawn proportional to the number of trips in both directions.

3.2 (a)

Construction of a traffic rotary needs large area which may be available in rural areas at reasonable cost. Other points when traffic rotary is justified are:

(i) Lower limit of traffic volume about 500 vehicles per hour.

(ii) Maximum value of traffic that a rotary can handle efficiently is 3000 vehicles per hour as per IRC.

(iii) If large proportion of traffic is turning right, provision of rotary even beyond these limits is justified.

(iv) IRC further specifies that rotaries may be provided where intersecting traffic is about 50% or more of the total traffic on all intersecting roads or where fast traffic turning right is at least 30% of the total traffic.

3.3 (c)

30° parking require 4.9 m width, while 60° parking require 6.0 m parking width. So ratio is given by

$$\frac{4.9}{6.0} = 0.82$$

3.4 (a)

Flow, $q = ku = 55k - 0.44k^2$

For maximum flow,

$$\frac{dq}{dk} = 0$$

$$\Rightarrow \quad 55 - 0.88k = 0$$

$$\Rightarrow \quad k = 62.5 \text{ veh/km}$$

$$\therefore \quad q_{max} = 55 \times 62.5 - 0.44 \times 62.5^2$$
$$= 1718.75 \text{ veh/hour}$$

For $v = A - Bk$ the maximum flow occurs at about half the mean free speed and is equal to $A^2/4B$. So directly

$$q_{max} = (55)^2/(4 \times 0.44)$$
$$= 1718.75 \text{ vph}$$

3.5 (b)

Collision diagrams are diagrams showing approximate paths of vehicles and pedestrians involved in accidents. They are used to:

(i) Compare and study the accident pattern

(ii) Determine the remedial measures.

3.6 (c)

The provision of emergency escape ramp on long, descending grades is appropriate for slowing or stopping out-of-control vehicles away from the main stream of traffic. Loss of breaking ability through overheating or mechanical failure results in the driver loosing the control of vehicles. Four basic types of emergency escape ramps are commonly used. They are:

(i) Sandpile

(ii) Descending grade

(iii) Horizontal grade

(vi) Ascending grade

3.7 (b)

The practical capacity (Q_p) of the rotary is dependent on the minimum capacity of the individual weaving section.

$$Q_p = \frac{280W(1 + e/W)(1 - p/3)}{(1 + W/L)}$$

where,

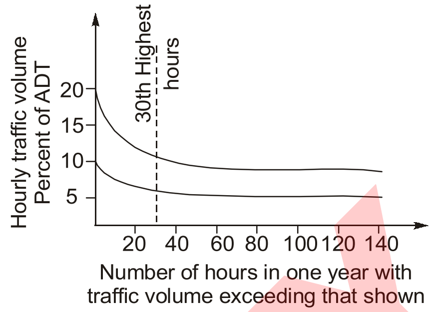
W is width of weaving section

e is average width of entry e_1 and width of nonweaving section e_2 for the range e/W = 0.4 to 1.0

L is length of the weaving section

p is proportion of weaving traffic

3.8 (a)



Highway design to accommodate the traffic volume is according to 30th highest hourly traffic volume from economy point of view as peak hourly traffic is too high and designing facilitates according to it will be too costly.

3.9 (b)

$$\text{Maximum flow} = \frac{\text{Free speed} \times \text{Jam Density}}{4}$$

$$= \frac{80 \times 70}{4} = 1400 \text{ veh/hour}$$

3.10 (b)

Optimum cycle time,

$$C_0 = \frac{1.5L + 5}{1 - Y}$$

L = Total lost time per cycle

= 16 sec

$Y = y_1 + y_2$

$$y_1 = \frac{500}{1600} \text{ and } y_2 = \frac{300}{1600}$$

$$\therefore \quad Y = \frac{500 + 300}{1600} = 0.5$$

$$C_0 = \frac{1.5 \times 16 + 5}{1 - 0.5} = 58 \text{ s}$$

3.11 (c)

For a two lane two way traffic total potential conflict points is 24 outof which 16 are major conflict points and 8 are minor conflict points.

3.12 (b)

As per IRC's suggestion maximum volume of traffic that rotary can handle is 3000 vehicles per hour entering from all legs of rotary intersection.

As per IRC 65:176, traffic rotaries may be provided where intersecting traffic is about 50% of total traffic or fast turning traffic is atleast 30%

of total traffic.

4. Pavement Design

4.1 (c)

Pressure deformation characteristics of rigid pavement are a function of relative stiffness of slab to that of subgrade. The term radius of relative stiffness was coined by Westergaard. It is given by

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4}$$

4.2 (d)

The Benkelman Beam Deflection Method is thus widely used for Evaluation of Structural Capacity of Existing Flexible Pavements and also for Estimation and Design of flexible overlays for Strengthening of any weak pavement for Highways. The Benkelman Beam measures the deflection of a flexible pavement under moving wheel loads.

4.3 (a)

According to **IS:2720** the Plasticity Index (*PI*) of binding material in WBM for base/subbase should be less than 6%.

4.4 (a)

The load carrying capacity of rigid pavement is due to the rigidity and high modulus of elasticity of the slab. The impact load will produce stresses higher than that by the static wheel load. However it is difficult to design for impact. Hence to account for impact load, we increase pavement thickness obtained from static wheel load.

4.5 (c)

In regions where sub-grade strength is uneven, rigid pavements are more suitable than flexible pavements due to

- rigidity of slab
- high modulus of elasticity of the slab

4.6 (d)

The average CBR value of three test specimens is reported to the first decimal place, as the CBR value of the test specimen. If the maximum variation in the CBR values of these specimens exceeds specified limits (3% for CBR up to 10%; 5% for CBR 10 to 30% and 10% for CBR 30-60%), then the design CBR should be the average of at least six specimens.

4.7 (d)

PN_f = Constant as given by McLeod.

where P is wheel load

N_f is number of cycles for failure

4.8 (a)

Combination of load stress and warping stress is recommended (IRC 58:1976) to determine thickness. During summer, frictional stress is subtracted and during winter, frictional stress is added from sum of Load stress and Warping stress while determining critical stress combination in case joints and sealing devices are used.

4.9 (c)

The greater quantity of reinforcement should be placed in the longitudinal direction. Further the reinforcement should either be placed in the mid depth or towards the top of the pavement for better functioning.

4.10 (d)

Corrected rebound deflection,

$$D_c = 2 \text{ mm}$$

Allowable deflection,

$$D_a = 1 \text{ mm}$$

Overlay thickness,

$$h = 550\log_{10}\left(\frac{D_c}{D_a}\right)$$

$$= 550 \log_{10} 2 = 166 \text{ mm}$$

4.11 (a)

The seasonal variations cause variation in subgrade moisture. The plasticity index ($LL - PL$) and annual average rainfall are the data required to determine moisture correction factor. Temperature correction is separately applied.

4.12 (b)

As per the revised guidelines (IRC: 37-1984) design of flexible pavements should be based on the concept of cumulative standard axle loads

(MSA) instead of number of commercial vehicles which was done earlier.

4.13 (c)

Critical combination of stresses

(i) During summer mid-day at bottom of slab (Load stress + warping stress – friction stress), at edge region

$$= 210 + 290 - 10$$
$$= 490 \text{ N/mm}^2$$

(ii) During winter mid-day at bottom of slab (Load stress + warping stress + friction stress), at edge region

$$= 210 + 290 + 10$$
$$= 510 \text{ N/mm}^2$$

(iii) At top of slab during midnights (Load stress + warping stress), at corner region.

$$= 210 + 290$$
$$= 500 \text{ N/mm}^2$$

4.14 (d)

Longitudinal joints in cement concrete pavements are constructed with tie bars. Tie bars are either deformed steel bars or connectors used to hold the faces of slabs in contact. They are designed to withstand tensile stress and ensure that two slabs remain together.

5. Highway Materials, Maintenance and Properties

5.1 (a)

The drum is normally rotated at a speed of 30-33 rpm. By increasing the speed to 50 rpm, there will be greater rubbing between the aggregate and steel balls. So abrasion value $\left(\frac{W_1}{W} \times 100\right)$ will increase.

where

W is weight of aggregate specimen

W_1 is weight of abraded aggregate passing 1.7 mm IS sieve

5.2 (d)

The removal of materials from base course is called ravelling. The loss of base course materials is only possible when either the base course is not covered by a wearing course or the wearing course has completely worn out. Due to the fast moving vehicles plying on road, there is a suction caused between the exposed base course material and pneumatic tyres. This causes removal of binding materials in WBM base and the stone aggregates are left in a loose state. Thus, in such a state if the stone aggregates are open graded, they cause ravelling.

5.3 (b)

Flow value is the deformation of specimen in 0.25 mm units up to the maximum load. It should be between 8 to 16.

Marshall stability value is the maximum load in kg before failure. Its minimum specified value is 340 kg. The stability first increases and then decreases with increase in bitumen content.

Unit weight also increases initially and then decreases.

Percentage of voids in total mix always decrease with increase in bitumen content.

The percentage of voids filled with bitumen increase with increase in bitumen content. But the graph is convex upward.

5.4 (d)

Because of precipitous work, deep valley, steep ascend to obligatory points and presence of innumerable gorges, hair pin bends (sharp 180° bend) are unavoidable on hill roads. It is located on hill sides having the minimum slope and maximum stability. The cutting of slopes for construction of such bends often leaves them prone to land slides during monsoon. The minimum design speed for hair pin bends is 20 kmph.

5.5 (b)

Camber is provided to drain rain water from the surface of pavement. Therefore higher the absorbing capacity of surface, higher will be the camber required to drain water quickly. So correct sequence in order of steepness of camber is :

Cement Concrete roads < Bituminous high speed roads < WBM roads < Gravel roads.

5.7 (b)

Curve (a) → % air voids in total mix (V_v)

Curve (b) → VMA (% voids in mineral agg.)

Curve (c) → unit weight (g/cc)

Curve (d) → Flow value

5.8 (a)

In surface dressing rolling is done with tandem roller of 6 to 8 tonnes weight.

For premix carpet rolling is done by tandem or pneumatic roller of 6 to 9 tonnes. In bituminous concrete and bituminous macadam initial or breakdown rolling shall be done with 8 to 10 tonnes dead weight smooth wheeled rollers. The intermediate rolling shall be done with 8 to 10 tonnes dead weight or vibratory roller or with a pneumatic tyred roller of 12–15 tonnes weight having nine wheels, with a tyre pressure of at least 5.6 kg/cm^2. The finish rolling shall be done with 6-8 tonnes smooth wheeled tandem rollers.

5.9 (c)

The theoretical gradation for maximum density is given by

$$P = 100\left(\frac{d}{D}\right)^n$$

where,

P is percent finer than diameter 'd' (mm) in the material

D is diameter of the largest particle, mm

n is gradation index which depends upon the shape of particles

For spherical particles,

$$n = 0.5$$

Per cent finer than 6 mm

$$= 100\sqrt{\frac{6}{60}} = 100\sqrt{0.1}\% = 31.6\%$$

Percent finer than 0.075 mm

$$= 100\sqrt{\frac{0.075}{60}}\% = 3.5\%$$

Percentage of material between 6 mm and 75 μm = 31.6 – 3.5 = 28.1%

5.10 (a)

Bituminous roads disintegrate even with light traffic when subgrade soil undergoes excessive deformation. It is due to improper preparation of subgrade which results in insufficient bearing capacity or shear failure in subgrade soil.

5.11 (c)

A metal hammer of weight 13.5-14.0 kg having a free fall from a height 38 cm is dropped 15 times in aggregate impact test. So energy imparted = 14 × 38 × 15 = 7980 kg-cm

5.13 (c)

VFB should be between 75 to 85.

5.15 (d)

Los Angeles test is based on abrasion and it measures hardness property of aggregates.

Solubility test is used to measure purity of bitumen. Pure bitumen is completely soluble in solvents like carbon disulphide and carbon tetrachloride.

5.16 (d)

Bituminous emulsion has advantage that it can be used even in rainy weather. It is used in bituminous construction especially in maintenance and patch repair work.

5.17 (a)

The role of voids in compacted mix is to provide reserve space for compaction/densification under traffic movements and expansion of bitumen at high temperature. It also helps to avoid flushing, bleeding of bituminous surface and skidding of vehicles.

UNIT VIII

Railway Engineering

Syllabus

Terminology, Planning, designs and maintenance practices; track modernization.

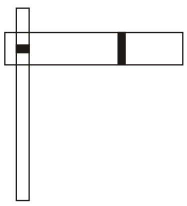
Contents

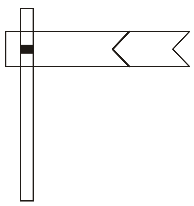
■■■■

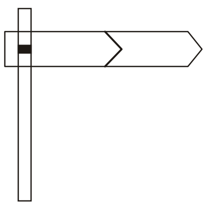
8 Railway Engineering

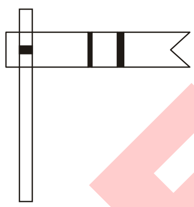
1. Rail Joints, Welding of Rails & Signals

1.1 Which one of the following figures represents a 'Warner signal' in railways?

(a) 

(b) 

(c) 

(d) 

[ESE : 1995]

1.2 A Treadle bar is used for
(a) interlocking points and signals
(b) setting points and crossings
(c) setting marshalling yard signals
(d) track maintenance

[ESE : 1997]

2. Ballast, Formation and Sleepers

2.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Shovel
B. Crow bars
C. Rail tongs
D. Claw bars

List-II
1. To lift rail
2. To remove dog spikes out of sleepers
3. To correct track alignment
4. To handle the ballast

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	4	3	2	1
(d)	3	4	1	2

[ESE : 1995]

2.2 Consider the following statements about concrete sleepers:
1. They improve the track modulus.
2. They have good scrap value.
3. They render transportation easy.
4. They maintain the gauge quite satisfactorily.

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 2 and 4 (d) 1 and 4

[ESE : 1997]

2.3 For a sleeper density of (n + 5), the number of sleepers required for constructing a broad gauge (BG) railway track of length 650 m is
(a) 975 (b) 918
(c) 900 (d) 880

[ESE : 1999]

3. Geometric Design of the Track

3.1 The grade compensation on a 4° curve on a Broad Gauge railway track is
(a) 0.20% (b) 0.16%
(c) 0.12% (d) 0.08%

[ESE : 1995]

3.2 Consider the following situations:
1. Soil is soft.
2. Volume of existing surface traffic on the alignment is heavy.
3. Track is at a deeper level.

4. Water table is high.

In the construction of Metro Railways, "Cut and Cover" method of construction is suitable in situations listed as

(a) 1 and 2 (b) 1 and 3
(c) 1 and 4 (d) 2 and 3

[ESE : 1995]

3.3 Which one of the following types of transition curves is mostly used in Indian Railways?

(a) Euler's spiral (b) Cubic spiral
(c) Lemniscate (d) Cubic parabola

[ESE : 1998]

3.4 Consider the following surveys:

1. Reconnaissance survey
2. Preliminary survey
3. Traffic survey
4. Location survey

The correct sequence in which these surveys are conducted before the alignment of a track is finalized, is

(a) 1, 3, 2, 4 (b) 1, 3, 4, 2
(c) 3, 1, 4, 2 (d) 3, 1, 2, 4

[ESE : 1998]

3.5 In a BG railway track, the specified ruling gradient is 1 in 250. The horizontal curve of 3° on a gradient of 1 in 250 will have the permissible compensated gradient of

(a) 1 in 257 (b) 1 in 357
(c) 1 in 457 (d) 1 in 512

[ESE : 1999]

4. Points and Crossing

4.1 Which of the following pairs are correctly matched?

1. Distance between adjoining face of running rail and check rail — Flangeway clearance
2. Distance through which the tongue rail moves laterally at the toe of switch for the movement of trains — Heel divergence
3. Distance between the gauge faces of the stock rail and tongue rail at the heel — Throw of switch
4. Angle between the gauge face of stock rail and tongue rail — Switch angle

Select the correct answer using the codes given below:

(a) 1 and 4 (b) 2 and 4
(c) 3 and 4 (d) 1, 2, 3 and 4

[ESE : 1995]

4.2 What will be the curve lead for a 1 in $8\frac{1}{2}$ turnout taking off from a straight broad gauge track?

(a) 28.49 m (b) 21.04 m
(c) 14.24 m (d) 7.45 m

[ESE : 1997]

4.3 If 'A' is the angle formed by two gauge faces, the crossing number will be

(a) tan A (b) cot A
(c) sec A (d) A rad

[ESE : 1999]

5. Track Stresses, Traction and Tractive Resistance

5.1 A train is hauled by 2-8-2 locomotive with 22.5 tonnes load on each driving axle. Assuming the coefficient of rail-wheel friction to be 0.25, what would be the hauling capacity of the locomotive?

(a) 15.0 tonnes (b) 22.5 tonnes
(c) 45.0 tonnes (d) 90.0 tonnes

[ESE : 1996]

5.2 The load on each axle of a locomotive is 22 tonnes. If the coefficient of friction is 0.2 then the hauling capacity due to 3 pairs of driving wheels will be

(a) 26.4 t (b) 19.8 t
(c) 13.2 t (d) 6.6 t

[ESE : 1999]

Answers Railway Engineering

1.1	(b)	1.2	(a)	2.1	(b)	2.2	(d)	2.3	(b)	3.1	(b)	3.2	(c)	3.3	(d)	3.4	(d)
3.5	(b)	4.1	(a)	4.2	(a)	4.3	(b)	5.1	(b)	5.2	(c)						

Explanations Railway Engineering

1. Rail Joints, Welding of Rails & Signals

1.1 (b)

Fig (a) $\rightarrow$ Calling on signal

Fig (b) $\rightarrow$ 2-Aspect warner signal

Fig (c) $\rightarrow$ Automatic signal

1.2 (a)

Treadle bar or lock bar is provided for the purpose that the point may not be operated while train is on it i.e., for interlocking points and signals.

2. Ballast, Formation and Sleepers

2.1 (b)

Crow bar is used to raise sleeper to a desired height

2.2 (d)

The scrap value of concrete sleepers is nil.

2.3 (b)

Length of BG rail = 12.8 m

$$\text{Number of BG rails in 650 m} = \frac{650}{12.8} \simeq 51$$

Sleeper density = 13 + 5 = 18 per rail

Number of sleepers = 18 × 51 = 918

3. Geometric Design of the Track

3.1 (b)

For BG track grade compensation is 0.04% per degree of curve. For 4° curve grade compensation will be

$$= 4 \times 0.04 = 0.16\%.$$

3.2 (c)

Cut and Cover Method is a method of shallow tunnel construction wherein a trench is excavated and roofed over with an overhead support system, strong enough to support the load that the tunnel is expected to carry in the future.

Loose Soils with High water table table have very low shear strength. So this method is employed in these cases so that the required depth is cut out and then refilled. Direct tunneling is not preferred as it may lead to collapse of soil.

Also in case track is at a deeper level or in case there is heavy traffic then direct tunneling is preferred over Cut and Cover Method.

3.3 (d)

Cubic parabola (Froude's curve) is the most widely used. Its equation is $y = Cx^3$

$$\text{where} \quad C = \frac{1}{6RL}$$

R is radius of circular curve

L is total length of transition curve

3.4 (d)

Preliminary survey is called initial location survey. Detailed survey is called final location survey.

3.5 (b)

Grade compensation = 0.04 × 3 = 0.12%

$$\text{Permissible gradient} = \frac{1}{250} - \frac{12}{10000} = \frac{1}{357}$$

4. Points and Crossing

4.1 (a)

Heel divergence : Distance between running faces of stock (running) rail and gauge faces of tongue rail measured at the heel of the switch.

Flangeway clearance : Distance between adjacent face of running faces of running rail and check rail.

Switch angle : Angle between the running faces of stock rail and tongue rail.

Throw of switch : Distance through which the toe of the tongue rail moves side ways.

4.2 (a)

Curve lead, $CL = 2\,GN$

$$G = 1.676 \text{ m}$$

$$\therefore \quad CL = 2 \times 1.676 \times 8.5 = 28.49 \text{ m}$$

4.3 (b)

There are three methods of calculating crossing number:

(i) Right Angle or Cole's Method

$N = \cot A$

This method is adopted by Indian railways.

(ii) Centre Line Method

$$N = \frac{1}{2}\cot(A/2)$$

(iii) Isosceles Triangle Method

$$N = \frac{1}{2}\text{cosec}(A/2)$$

This method is important for layouts of tramways. The value of angle of crossing obtained from the right angle method is the least and hence it is the best method.

5. Track Stresses, Traction and Tractive Resistance

5.1 (b)

2-8-2 means 2 bogie carriers, 8 central or driving or coupled wheels and 2 rear or trailing wheels.

$$\text{Thus, number of axles} = \frac{2+8+2}{2} = 6$$

$$\text{Number of driving axles} = \frac{8}{2} = 4$$

Hauling capacity = $0.25 \times 4 \times 22.5 = 22.5$

5.2 (c)

Hauling capacity = $0.2 \times 22 \times 3 = 13.1$ t

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UNIT

IX

Airport, Dock , Harbour & Tunnelling Engineering

Syllabus

Airport : Layout, planning & design.

Harbour : Terminology, layouts and planning.

Tunnelling : Alignment, methods of construction, disposal of muck, drainage, lighting and ventilation.

Contents

9 Airport, Dock , Harbour & Tunnelling Engineering

1. Airport, Dock , Harbour & Tunnelling Engineering

1.1 In "full face" method of constructing tunnel, the first operation relates to
(a) removal of bottom portion
(b) excavation of one drift in the centre
(c) removal of top portion
(d) excavation being done along the perimeter
[ESE : 1996]

1.2 Match **List-I** (Shape of tunnel) with **List-II** (Suitable for) and select the correct answer using the codes given below the lists:
List-I
A. Circular section
B. Horse-shoe section
C. Egg-shaped
D. Segmental-roof section
List-II
1. soft rock
2. hard rock
3. carrying water
4. sewers
5. subways
Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	3	1	4	5
(c)	2	1	4	3
(d)	1	2	3	5

[ESE : 1997]

1.3 Which one of the following is considered to be an advantage of the heading and benching method of tunnel construction?
(a) It is suitable for construction in unstable rocks.
(b) In this method, it is easy to install timber support.
(c) Tunnelling can be continuous and the work can be expedited.
(d) In case of excessive water, it is easy to take corrective steps.
[ESE : 1997]

1.4 A ship is berthed in a chamber and lifted by principles of buoyancy. Such a chamber is called
(a) dry dock (b) wet dock
(c) floating dock (d) refuge dock
[ESE : 1997]

1.5 Maximum gross take-off weight of an aircraft is
(a) equal to the maximum structural landing weight
(b) less than the maximum structural landing weight
(c) more than the maximum structural landing weight
(d) equal to the empty operating weight plus the payload
[ESE : 1997]

1.6 Consider the following statements:
Wind rose diagram is used for the purpose(s) of
1. runway orientation
2. estimating the runway capacity
3. goemetric design of holding apron
Which of these statements is/are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1 alone
[ESE : 1997]

1.7 Which of the following factors are taken into account for estimating the runway length required for aircraft landing?
1. Normal maximum temperature
2. Airport elevation
3. Maximum landing weight
4. Effective runway gradient
Select the correct answer using the codes given below:

(a) 1, 2, 3 and 4 (b) 1, 3 and 4
(c) 2 and 3 (d) 1, 2 and 4

[ESE : 1997]

1.8 **Assertion (A):** Solid fill type of wharf structure provides adequate resistance to the impact of mooring vessels, besides other advantages.

Reason (R): Solid fill structures are stable and inexpensive (except in deep water) and require little maintenance.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

1.9 Match **List-I** (Description) with **List-II** (Structure) and select the correct answer using the codes given below the lists:

List-I

A. Constructed approximately perpendicular to the shore to retard erosion of an existing beach
B. Structures that are placed parallel to the shoreline to separate the land from the water
C. Built roughly perpendicular to the shore for maintaining an entrance channel
D. Built generally parallel to the shoreline to protect a shore area

List-II

1. Jetties **2.** Breakwaters
3. Seawalls **4.** Groynes
5. Wharves

Codes:

	A	B	C	D
(a)	4	3	1	5
(b)	5	2	4	3
(c)	1	4	5	3
(d)	4	3	1	2

[ESE : 1998]

1.10 How many hectares of anchorage area will be required by a 181 m long ship anchored by a single anchor in a harbour of 15 m depth?

(a) 12 (b) 16
(c) 18 (d) 20

[ESE : 1998]

1.11 On which of the following factors will the selection of the type of Groyne depend?

1. Availability of material
2. Foundation condition
3. Presence or absence of marine borers
4. Topography of the beach
5. The height, period and angle of attack of approaching waves

Select the correct answer using the codes given below:

(a) 1, 2, 3 and 4 (b) 2, 3, 4 and 5
(c) 1 and 2 (d) 5 alone

[ESE : 1998]

1.12 Match **List-I** (Shape of tunnel) with **List-II** (Attribute for preference) and select the correct answer using the codes given below the lists:

List-I

A. Horse-shoe section
B. Circular
C. Egg-shaped
D. Segmental roof section

List-II

1. Gives self-cleaning velocity even in dry weather flow
2. Suitable for soft rocks
3. Best suited for non-cohesive soils
4. Suitable for soft materials
5. Suitable for sub-bays

Codes:

	A	B	C	D
(a)	2	3	4	5
(b)	5	4	1	3
(c)	3	2	4	1
(d)	2	3	1	5

[ESE : 1998]

1.13 In an airport, if 4 groups of 5 gates each located well-separated are considered for traffic and the future-to present traffic ratio is 3, then the total requirement of future gates will be

(a) 32 (b) 36
(c) 44 (d) 68

[ESE : 1998]

1.14 Castor angle is defined as the angle

(a) formed by the longitudinal axis of the aircraft and the direction of movement of the nose gear.

(b) between the direction of wind and the longitudinal axis of the runway.
(c) between the true speed of the aircraft and the crosswind component.
(d) between the horizontal and the fuselage axis.

[ESE : 1998]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.15 Assertion (A): The open type of wharf substructure is expensive in deep-water locations where, however, a low-level super-structure is required.

Reason (R): Open type of wharf substructure offers little restriction to water movements; hence it can be used to support piers in rivers and coastal areas alike.

[ESE : 1998]

1.16 Assertion (A): Wind data are reported with the true north as the reference, while the runway orientation is cited relative to the magnetic azimuth.

Reason (R): The true azimuth obtained from the wind rose analysis should be changed to the corresponding magnetic azimuth.

[ESE : 1998]

1.17 Consider the following factors:

1. Size and type of ship served
2. Availability of materials
3. Wharf configuration
4. Mooring procedures

The spaces required alongside a wharf for berthing would depend upon factors

(a) 1, 2 and 4 (b) 2, 3 and 4
(c) 1, 2 and 3 (d) 1, 3 and 4

[ESE : 1999]

1.18 Which one of the following is a component of a shield for tunnelling?

(a) Liner plate (b) Trench jack
(c) Stiffener (d) Cutting edge

[ESE : 1999]

1.19 The runway length after correcting for elevation and temperature is 2845 m. If the effective gradient on runway is 0.5 per cent, the revised runway length will be

(a) 2845 m (b) 2910 m
(c) 3030 m (d) 3130 m

[ESE : 1999]

Answers Airport, Dock , Harbour and Tunnelling Engineering

1.1	(d)	1.2	(b)	1.3	(a)	1.4	(c)	1.5	(c)	1.6	(d)	1.7	(d)	1.8	(b)	1.9	(a)
1.10	(d)	1.11	(a)	1.12	(d)	1.13	(d)	1.14	(a)	1.15	(b)	1.16	(b)	1.17	(c)	1.18	(d)
1.19	(d)																

Explanations Airport, Dock , Harbour and Tunnelling Engineering

1. Airport, Dock , Harbour & Tunnelling Engineering

1.1 (d)

Excavation of small sized heading (drift) is done centrally at top or bottom of the face in the drift method.

In heading and benching method the top portion is driven in advance of the bottom portion.

In full face method the whole section is excavated once for all. It is suitable for tunnels of small cross-sections area say up to 3 m diameter.

1.2 (b)

Circular section can withstand pressure caused by water, water bearing soils or soft grounds. It is best suitable for sewers and water carrying purposes.

Horse-shoe section has a semi circular roof together with arched sides and a curved invert. It also is suitable for carrying water or sewage. The section is found to be most suitable for soft rocks. This shape is commonly used for highways and railway tunnels.

Egg shaped section is commonly used for carrying sewage because it gives self cleansing velocity even in dry weather flow.

D-section or segmental roof section is suitable in hard rock for sub-ways or navigation channels.

1.3 (a)

Heading and benching method is used when the tunnel section is very large and quality of rock is not very satisfactory i.e., the rock is unstable. In self supporting rocks, the top heading advance are round ahead of the bottom heading. In unstable (broken or non self supporting rocks), the bench provides platform for timber supports to the heading.

1.4 (c)

Docks or wet docks or tidal basins are enclosed and are shut off by entrances or locks to maintain a uniform level of water and basins are partially enclosed areas of water.

Dry docks are repair docks. These are long, excavated chamber, having side walls, a semi circular end wall and a floor.

A floating dry clock is a floating vessel which can lift a ship out of water and retain it above water by means of its own buoyancy.

1.5 (c)

Maximum gross take off weight is the maximum load that the aircraft is certified to carry during take off and the airport pavement are designed for this weight.

Maximum structural landing weight is the difference between the gross take off weight and the weight of fuel consumed during the trip. The main gear of an aircraft is designed to support the maximum structural weight because such situations rarely occur. Operating empty weight includes the weight and all necessary gear required for flight.

Payload is the total revenue producing load. Thus it includes the weight of passengers and their baggage, mail and cargo.

Operating empty weight + Aircraft weight

= Payload + Trip fuel + Fuel reserve

The weight of an aircraft on landing

= Operating empty weight + Payload

+ Fuel reserve

This should not exceed maximum structural landing weight.

Take off weight = Landing weight + Trip fuel

This should not exceed the maximum gross take off weight of the aircraft.

1.6 (d)

The runway is usually oriented in the direction of the prevailing winds. During landing it provides breaking effect and the aircraft comes to a stop in a short length of the runway. During take off, it provides greater lift on the wings of the aircraft.

1.7 (d)

The basic runway length is determined from the performance characteristics of the aircraft using the airport. The following cases are usually considered :

(i) Normal landing case requires that aircraft should come to a stop within 60% of the landing distance.

(ii) Normal take-off case requires a clearway

(iii) Engine failure case may require either a clearway or a stopway or both.

The basic length is corrected for (in the same order):

(i) Elevation at the rate of 7% for every 300 m rise in elevation of airport above the MSL.

(ii) Temperature at the rate of 1% for every 1°C rise in airport reference temperature above the standard atmospheric temperature at that elevation.

(iii) Gradient at the rate of 20% for every 1% of the effective gradient.

1.8 (b)

A wharf or quay is a structure on the shore of a harbor or on the bank of a river or canal where ships may dock to load and unload cargo or passengers. Solid fill type provides bearing strength and stability and offers adequate resistance impact mooring vehicles but in deep water construction is difficult as well as expensive.

1.9 (a)

Groynes are structures built to protect beach or retard erosion of an existing or resorted beach by trapping of littoral drift. They are usually made perpendicular to shoreline.

Sea-walls, bulkheads and revetment are the structures constructed parallel to shore-line to develop a demarcating line between land area and water area.

Jetties are piled projection and they are built out from the shore to deep water. They are provided at places where harbour entrance is affected by littoral drift or the sea is shallow for a long distance.

1.10 (d)

Anchorage area is a place where ships may be held for quarantine inspection, await docking space or await favourable weather condition. The water area required for an anchorage depends upon number, type and size of vessels.

The anchorage area is calculated as the area of the circle having radius

$$R = 4 \times \text{depth of water} + \text{length of ship} + \text{safe clearance to adjacent ship}$$

$$= 4 \times 15 + 181 + 12 = 253 \text{ m}$$

So area $= \pi R^2 \simeq 20$ ha

1.11 (a)

Type of groynes does not depend on height, period or angle of attack of approaching wave.

1.12 (d)

Circular section: best suitable for non-cohesive soils and for tunnels driven by shield-method.

Horse shoe section: When lined, this cross section offers good resistance external ground pressure and serves to combine the advantages of both the D-shaped and circular sections. This section is found to be most suitable for soft rocks.

Egg shaped section is used in sewage flow because it gives self cleansing velocity even in dry weather flow.

Segmental roof section is suitable for sub-bays.

1.13 (d)

Gate is the parking space for an aircraft.

Number of Gate positions

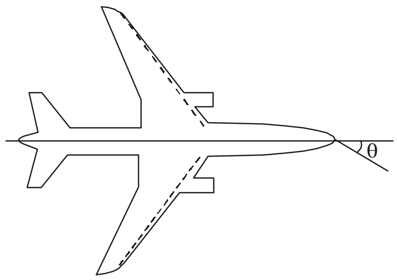
$$= \frac{\text{Capacity of runway}}{60 \times 2} \times \text{average gate occupancy time}$$

For the present traffic $4 \times 5 = 20$ gates are needed.

Therefore for future traffic (three times present traffic) 60 gates will be required. In addition some aircrafts will have higher occupancy time in future as they will be very big compared to the present traffic composition. Therefore 68 gates will be the correct choice.

1.14 (a)

Castor angle is the angle formed between the longitudinal axis of aircraft and direction of movement of nose gear.



1.15 (b)

There are two types of wharf structures:

(i) Vertical face structures or closed on solid structures.
 (a) Block wall
 (b) Caisson
 (c) Cellular bulk head
 (d) Sheet pile walls

(ii) Open structures with decks supported by piles or cylinders.
 (a) High level docks
 (b) Relieving type platforms in which structural slab is below finished deck and space between is filled to provide additional weight for stability.

Solid type structures are quite commonly used where the depth of water does not exceed 16 m and the bottom conditions are suitable for the support of gravity type structures.

Open type wharf structures are used for deep water and the wharf structures are used for deep water and they have more favourable overall stability properties because of the lack of fill near its front.

1.16 (b)

Wind direction is measured with true north as reference and runway orientation is cited relative to magnetic azimuth.

True azimuth should be changed to magnetic azimuth by taking into account magnetic variation for airport location.

1.17 (c)

Mooring procedures involve many complexities and careful consideration will need to be made for safe berthing and unberthing from ports. These are irrelevant while determining spaces required alongside wharf for berthing.

1.18 (d)

The cutting edge grinds the hard rock or slice into soil in the tunnel face by chisel-shaped cutting teeth. Other components of shield are: skin plate, hood, port holes, tail and propelling jack.

1.19 (d)

For every 1% effective gradient, runway length should be increased by 20%. For 0.5% gradient the increase should be 10%.

So runway length = 2845×1.1

$= 3129.5 = 3130$ m.

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