DETAILED SOLUTIONS

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ESE 2027 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 2

Section A : Geo-technical & Foundation Engineering
Section B : Environmental Engineering

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15.	(b)	30.	(a)	45.	(c)	60.	(a)	75.	(d)

DETAILED EXPLANATIONS

1. (b)

$$\text{For saturated soil, } \gamma_{sat} = \frac{(G+e)}{(1+e)} \times \gamma_w$$

$$\Rightarrow \quad \gamma_{sat} = \frac{(2.65+0.65)}{(1+0.65)} \times 9.81 = 19.62 \text{ kN/m}^3 \simeq 19.6 \text{ kN/m}^3$$

2. (a)

When the centre-to-centre spacing of piles in clay is less than the critical spacing, approximately twice the pile diameter, the piles act together and the group tends to fail as a single block. At larger spacing, individual pile failure becomes predominant.

3. (d)

In the USCS, a soil is classified as coarse-grained when more than 50% of the soil, by weight, is retained on the 75 μm sieve.

4. (b)

For constant cross-sectional area,

$$\frac{\Delta e}{(1+e_0)} = \frac{\Delta H}{H}$$

$$\Rightarrow \quad \Delta e = \left(\frac{1}{25}\right)(1+1.12) = 0.0848$$

$$\Rightarrow \quad 1.12 - e_f = 0.0848$$

$$\Rightarrow \quad e_f = 1.12 - 0.0848 = 1.0352 \simeq 1.035$$

5. (c)

Compaction is an almost instantaneous process in which densification occurs primarily due to the reduction in air voids. Consolidation is a time-dependent process involving the expulsion of pore water from saturated soil under an applied load.

6. (a)

For the same void ratio, permeability is not determined by void ratio alone. The pore-channel size, which is strongly related to particle size, has a major influence. From Kozeny-Carman equation,

$$k \propto \left[\frac{e^3}{(1+e)}\right] \times D_{10}^2$$

So, for the same void ratio, a soil with larger effective grain size will generally have much higher permeability.

7. (c)

A sudden drawdown produces changes in effective stress before significant consolidation can occur. A Consolidated Undrained (CU) test can reproduce the initial consolidation condition followed by undrained shearing, making it suitable for such cases.

8. (d)

Hydrometer analysis is based on the settling velocity of soil particles in suspension and is primarily used for determining the particle-size distribution of fine-grained soils, particularly particles finer than 75 μm.

9. (c)

Since the water table is at the base of the footing,

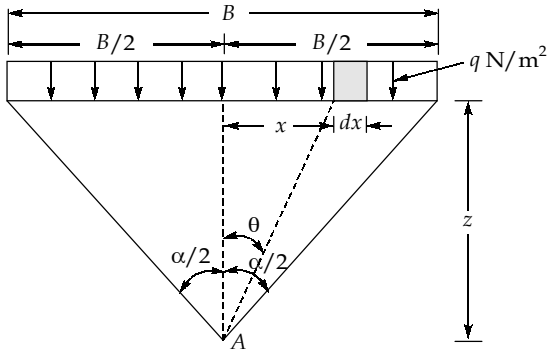
$$\therefore \quad \gamma' = \gamma - \gamma_w$$
$$= 20 - 10 = 10\ \text{kN/m}^3$$

For a square footing, on dense sand,

$$q_f = \gamma D_f N_q + 0.4\gamma' B N_\gamma$$
$$= 20 \times 1.5 \times 48.8 + 0.4 \times 10 \times 2 \times 67.2$$
$$= 1464 + 537.6$$
$$= 2001.6\ \text{kN/m}^2 \simeq 2002\ \text{kN/m}^2$$

10. (c)

Consider a finite strip footing of width B, carrying a uniformly distributed load q kN/m^2. We need the vertical pressure at point A, at depth z, below the centre of the strip.



Consider an elemental strip of width dx at a distance x from the centre. The load on this elemental strip, per unit length, is:

$$Q = q\,dx$$

We know for a line load,

$$\sigma_z = \frac{2Q}{\pi z}\left[\frac{1}{\left(1+\frac{x^2}{z^2}\right)^2}\right]$$

Therefore,

$$d\sigma_z = \frac{2q}{\pi z}\frac{dx}{\left(1+\frac{x^2}{z^2}\right)^2}$$

For the entire strip of width B,

$$\sigma_z = \frac{2q}{\pi z}\int_{-B/2}^{B/2}\frac{dx}{\left(1+\frac{x^2}{z^2}\right)^2}$$

Due to symmetry, $$\sigma_z = \frac{4q}{\pi z}\int_0^{B/2} \frac{dx}{\left(1+\frac{x^2}{z^2}\right)^2}$$

Put $$\frac{x}{z} = \tan\theta$$

$\therefore$ $$x = z\tan\theta$$

and $$dx = z\sec^2\theta\, d\theta$$

Also, $$1+\frac{x^2}{z^2} = 1+\tan^2\theta = \sec^2\theta$$

Hence, $$\sigma_z = \frac{4q}{\pi}\int_0^{\alpha/2} \cos^2\theta\, d\theta$$

Using $$\cos^2\theta = \frac{1+\cos 2\theta}{2}$$

we get $$\sigma_z = \frac{4q}{\pi}\left[\frac{\theta}{2}+\frac{\sin 2\theta}{4}\right]_0^{\alpha/2}$$

$\Rightarrow$ $$\sigma_z = \frac{q}{\pi}(\alpha+\sin\alpha)$$

11. (c)

For transformation of an anisotropic soil section,

$$x_t = x\sqrt{\left(\frac{k_z}{k_x}\right)}$$

$\Rightarrow$ $$\frac{x_t}{x} = \sqrt{\frac{4\times10^{-4}}{9\times10^{-4}}} = 0.67$$

12. (a)

Rankine's theory considers the state of plastic equilibrium and gives a lower bound to the true collapse load. Coulomb's theory considers a possible mechanism of plastic collapse and gives an upper bound to the true collapse load.

13. (d)

Cohesive strength of soil,

$$c_u = \frac{q_u}{2} = \frac{40}{2} = 20\text{kN/m}^2$$

Ultimate load-carrying capacity of pile is

$$Q_u = c_u N_c A_b + \alpha c_u A_s \qquad \text{where } N_c = 9 \text{ for clay}$$
$$= 20(9)(0.5\times0.5) + 0.8\,(20)(4\times0.5\times10)$$
$$= 45 + 320 = 365\text{ kN}$$

14. (c)

The root time method uses a plot of compression against the square root of time.

The log time method requires readings over a longer period, including the range of secondary compression.

A straight-line portion is not always obtained in the root time plot.

For 50% consolidation, the theoretical time factor, $T_v = \frac{\pi}{4}(0.5)^2 = 0.196$.

15. (b)

Weight of pycnometer + dry soil = 500 + 212 = 712 g

Using the pycnometer method,

$$w = \left[\frac{(W_2 - W_1)}{(W_3 - W_4)} \times \left(\frac{G_s - 1}{G_s}\right) - 1\right] \times 100$$

$$= \left[\frac{(712 - 500)}{(900 - 790)} \times \left(\frac{2.65 - 1}{2.65}\right) - 1\right] \times 100 = 20\%$$

16 (c)

For clayey soils,

$$S_F = S_P\left(\frac{B_F}{B_P}\right)$$

$$\Rightarrow \quad S_F = 12\left(\frac{2}{0.5}\right) = 48\,\text{mm}$$

17. (a)

In a direct shear test, maintaining a small spacing between the upper and lower halves of the shear box is a critical procedural requirement designed to prevent extraneous friction from corrupting the test results. This gap, typically set slightly larger than the soil's maximum particle size, ensures that the metal halves do not grind against each other and prevents the upper half from catching or riding over protruding soil grains during lateral movement. Without this clearance, the measured resistance would include unwanted metal-to-metal or particle-to-metal friction alongside the soil's actual internal strength, leading to an artificially high shear strength measurement. Crucially, this spacing does not dictate where the specimen fails; the plane of shear is already artificially fixed along the horizontal split boundary of the two box halves.

18. (b)

A layer of cohesive non-swelling (CNS) soil is placed over expansive soil to counteract the detrimental effects of heaving. A greater thickness of CNS material results in lesser swelling and deformation of the overlying layer.

19. (c)

For the given slope angle and angle of internal friction,

$$S_n = 0.116$$

Stability number, $$S_n = \frac{c}{(F_s \gamma H)}$$

$$\Rightarrow \quad 0.116 = \frac{20}{(2.5 \times 20 \times H)}$$

Hence, $$H = \frac{20}{(2.5 \times 20 \times 0.116)}$$

$$H = 3.45 \text{ m}$$

20. (a)

According to Rankine, when the shear stress in a soil mass is progressively increased, the soil reaches a limiting point beyond which plastic flow begins. At this point, the soil is said to be in plastic equilibrium, and the shear stress at every point in the soil mass equals the corresponding failure stress. Thus, yielding and shear failure occur throughout the soil mass at the same state of stress.

21. (d)

On the dry side of optimum, increasing water content causes a sharp reduction in permeability. At relatively low stress levels, wet-of-optimum compacted soil is more compressible due to its more dispersed structure. Dry-of-optimum compacted soil has greater water deficiency and can therefore absorb more water and swell more. Wet-of-optimum compaction produces a more orderly particle arrangement, which allows greater volume reduction upon drying and hence greater shrinkage.

22. (c)

Assumptions made in Terzaghi's one-dimensional consolidation theory:

- The soil is assumed to be fully saturated.
- The soil is homogeneous and isotropic.
- One-dimensional flow of water is assumed.
- One-dimensional compression of the soil layer is considered.
- Darcy's law is assumed to be valid.
- The coefficient of permeability (K) is assumed to remain constant at every point in the soil layer and during consolidation.
- The compressibility of soil is assumed to remain constant.
- Secondary consolidation or plastic lag is neglected.

23. (c)

Under undrained loading of saturated soil, water cannot escape immediately. The applied stress is therefore initially carried predominantly by the pore water, producing an increase in pore water pressure. Hence, the immediate increase in effective stress is negligible.

24. (b)

Liquidity index,

$$LI = \left(\frac{w - w_P}{w_L - w_P}\right) = \left(\frac{40 - 30}{50 - 30}\right) = 0.5$$

Since, $0 < LI < 1$, the soil is in the plastic state.

25. (a)

Geogrids are primarily used as reinforcement elements. Their apertures allow interaction between the geogrid and surrounding soil, thereby improving the load-carrying capacity and stability of the reinforced soil mass.

26. (d)

For $r = 0$, the Boussinesq equation reduces to

$$\sigma_z = 0.4775\frac{Q}{z^2}$$

27. (d)

For a dense sand, the deviator stress initially increases rapidly with axial strain and reaches a distinct peak value at relatively small strain. With further shearing, the deviator stress decreases and eventually approaches the ultimate stress.

In the case of loose sand, the deviator stress increases gradually with axial strain and does not exhibit a distinct peak; it approaches the ultimate stress with continued shearing.

During drained shearing, dense sand initially undergoes a slight decrease in volume, but with further shearing, the specimen starts to increase in volume due to dilation.

28. (d)

The Standard Penetration Test (SPT) is particularly useful for evaluating the in-situ relative density and strength of cohesionless soils, especially sands and gravels.

29. (c)

For remoulded clay, $C_c = 0.007(w_L - 10)$

$= 0.007(46 - 10) = 0.252$

Total consolidation settlement, $\Delta H = \left[\frac{C_c H_0}{1 + e_0}\right]\log_{10}\left(\frac{\sigma_2}{\sigma_1}\right)$

$$\Rightarrow \quad \Delta H = \left[\frac{0.252 \times 5}{1 + 0.43}\right] \times \log_{10}\left(\frac{600}{400}\right)$$

$$\Rightarrow \quad \Delta H = \left[\frac{0.252 \times 5}{1.43}\right] \times 0.176 = 0.155 \text{ m}$$

30. (a)

An octahedral sheet may contain aluminium or magnesium as the central cation. With aluminium as the central cation, it is called a gibbsite sheet, whereas with magnesium, it is called a brucite sheet.

31. (a)

As we know

$$\text{Quantity of seepage, } q = \frac{kHN_f}{N_d}$$

where, $k = 5 \times 10^{-3}$ cm/s

$= 5 \times 10^{-3} \times 86400 \times 10^{-2} = 4.32$ m/day

$H = 2$ m

Number of flow channels, N_f = Number of flow lines – 1 = 5 – 1 = 4

Number of equipotential drops, N_d = Number of equipotential lines – 1 = 11 – 1 = 10

$$\therefore \quad q = 4.320 \times 2 \times \frac{4}{10} = 3.456 \text{ m}^3/\text{day/m length of pile}$$

32. (d)

Typical values of coefficient of earth pressure at rest (K_0) are:

Loose sand	– 0.4 to 0.5
Dense sand	– 0.6 to 0.8
Normally consolidated clay	– 0.5 to 0.6
Over-consolidated clay with OCR (= 3.5)	– 1.0

33. (c)

Net ultimate bearing capacity is given by

$$q_{nu} = q_u - \gamma D_f$$

where γD_f is the surcharge at the foundation level.

34. (c)

Capillary rise is inversely proportional to the effective particle size,

$$\because \quad h_c = \frac{C}{eD_{10}}$$

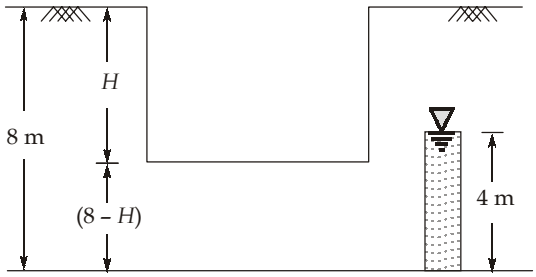
$$\therefore \quad h_c \propto \frac{1}{D_{10}}$$

Hence, $$\frac{h_{c1}}{h_{c2}} = \frac{D_{10,2}}{D_{10,1}}$$

Substituting the given values, $$\frac{60}{h_{c2}} = \frac{0.05}{0.025} = 2$$

$$\Rightarrow \quad h_{c2} = 30 \text{ cm}$$

35. (d)



At the limiting condition of heave, the effective stress at the base of the excavation becomes zero.
Artesian pressure is

$$u = 4\gamma_w$$

The remaining thickness of clay below the excavation is $(8 - H)$ meter.

Hence, $(8 - H)\,\gamma_{sat} = 4\gamma_w$

$\Rightarrow$ $(8 - H)(20) = 4(10)$

$\Rightarrow$ $8 - H = 2$

$\Rightarrow$ $H = 6$ m

36. (d)

A consolidometer consists of two main components:

1. Consolidation cell
2. Loading machine

The consolidation cell contains a circular metal ring in which the soil specimen is placed. The ring prevents horizontal (lateral) deformation of the specimen. Porous filter stones are placed at the top and bottom of the specimen. These permit two-way drainage of water into or out of the specimen during the test.

An axial vertical load is applied to the specimen through the loading machine. Since lateral deformation is prevented, the applied load causes vertical compression and reduction in specimen volume. The resulting vertical deformation is measured using a dial gauge attached to the apparatus.

Two types of consolidation cells are commonly used:

1. Fixed-ring consolidation cell
   - The specimen is laterally confined by the metal ring.
   - Only the top porous stone is allowed to move downward as the specimen compresses.
   - The bottom porous stone remains fixed.
   - Direct measurement of permeability at any stage of loading can be carried out using this arrangement.
   - Therefore, the fixed-ring cell is the more widely adopted arrangement.
2. Floating-ring consolidation cell
   - Both the top and bottom porous stones are free to move.
   - They compress the specimen towards the centre as the specimen consolidates.
   - Direct measurement of permeability at different stages of loading cannot be made using this arrangement.

37. (a)

The top flow line in an unconfined seepage condition represents the phreatic surface. Along this surface, the soil is saturated but the pore-water pressure is equal to atmospheric pressure. Since the pressure is atmospheric, the gauge pressure is zero, and consequently the pressure head is zero.

38. (a)

For a submerged cohesionless slope,

$$F_s = \frac{\gamma_{sub}}{\gamma_{sat}}\left(\frac{\tan\phi}{\tan\beta}\right)$$

Thus, F_s is directly proportional to $\gamma_{sub}/\gamma_{sat}$. Since the submerged unit weight is less than the saturated unit weight, this ratio is less than unity. Therefore, submergence reduces the factor of safety of a cohesionless slope.

39. (a)

The recommended design periods are:

Storage by dams - 50 years
Water treatment units - 15 years
Distribution system - 30 years

40. (b)

Losses due to leakages, damaged meters, unauthorized water connections and other wastages should be accounted for while estimating the total water requirement. Although these losses can be reduced by careful maintenance and universal metering, but even in a well-managed water works they may be as high as 15% of the total water consumption.

41. (b)

The water table is the upper surface of the zone of saturation. It separates the zone of aeration above from the zone of saturation below.

42. (a)

The design period of a water supply scheme should be selected after considering the following factors:

- Useful life of the component structure. The design period should not exceed its useful life.
- Ease or difficulty of future expansion. Components that are difficult to expand may be assigned a higher design period.
- Availability of funds for future expansion and additional provisions.
- Rate of interest on borrowed capital and additional investments.
- Anticipated population growth, including possible shifts in residential, industrial and commercial developments.
- Different components of a water supply scheme have different recommended design periods depending on their function, service life and economic considerations.

43. (b)

Chloride in water is commonly estimated by argentometric titration, in which the sample is titrated with a standard silver nitrate ($AgNO_3$) solution using potassium chromate ($K_2C_rO_4$) as the indicator. For drinking water supplies, the chloride concentration should generally not exceed 250 ppm, as higher concentrations impart a noticeable salty taste and are considered objectionable.

44. (a)

The organic strength of wastewater is assessed using parameters that indicate the amount of organic matter present or its oxygen demand. BOD and COD directly represent the oxygen requirement associated with organic matter, while volatile solids provide an indication of the organic fraction of suspended solids. Dissolved oxygen represents the oxygen present in water and is not a direct measure of wastewater organic strength.

45. (c)

Circular sections are preferred because

- they provide the maximum cross-sectional area for a given wetted perimeter, resulting in a hydraulically efficient section.
- they are easy to manufacture.
- they utilize the minimum quantities of materials.
- they offer less opportunities for deposits, being of uniform curvature all around.

However, a circular section does not maintain the maximum hydraulic mean depth at all flow depths. Its hydraulic characteristics vary with the depth of flow, and other sewer sections can provide greater hydraulic mean depth under particular partial-flow conditions.

46. (a)

During backwashing, the normal filtration flow path is isolated. The influent valve and filtered-water outlet valve are closed, while backwash water is admitted through the backwash-water inlet valve and the dirty wash water is discharged through the wash-water drain valve.

47. (c)

The geotextile filter membrane is placed above the sand drainage layer to protect the drainage layer from clogging by the overlying soil. The cap system itself prevents rainwater from reaching the solid waste and thereby helps avoid leachate formation.

48. (d)

Baffled mixing basins create repeated changes in the direction of flow, producing the disturbances necessary for flocculation. They are generally designed for a detention period of 20-50 minutes, with a clear spacing of about 45 cm or more between successive baffles to facilitate cleaning.
The hydraulic arrangement of the baffles also produces near plug-flow conditions with low short-circuiting, which is one of the advantages of baffled mixing basins.

49. (b)

The littoral zone is the shallow water near the shore in which rooted plants grow. Its extent depends on the slope of the lake bottom and the depth of the euphotic zone. It cannot extend deeper than the euphotic zone.

50. (b)

For a circular tank, $V = d^2(0.011d + 0.785H)$

where

d = 10 m and H = 2 m.

$$V = 10^2 (0.011 \times 10 + 0.785 \times 2)$$
$$= 100(0.11 + 1.57) = 168\ m^3$$

Therefore,

$$t = \frac{V}{Q} = \frac{168}{2016}\ \text{day} = \frac{1}{12}\ \text{day}$$
$$= \frac{1}{12} \times 24\,\text{hrs} = 2\,\text{hrs}$$

51. (d)

Given, $[OH^-] = 10^{-6.5}\ mol/L$

Therefore, $pOH = -\log(10^{-6.5}) = 6.5$

At 25°C, $pH + pOH = 14$

$\Rightarrow$ $pH = 14 - 6.5 = 7.5$

Since the pH is greater than 7, the water sample is alkaline.

52. (d)

The total storage capacity of a distribution reservoir is determined by the requirements for balancing fluctuations in demand, meeting interruptions in normal supply, and providing water for firefighting. These are accounted for through balancing storage, breakdown storage and fire storage, respectively. Service storage is not separately considered as a component in this classification.

53. (c)

$$\text{BOD load of industrial wastewater} = \frac{5000 \times 240}{1000} = 1200\ kg/day$$

$$\text{Population equivalent,} = \frac{\text{Total BOD load}}{\text{Standard BOD contribution per person}}$$
$$= \frac{1200}{0.08} = 15000$$

Therefore, the population equivalent is 15,000.

54. (d)

In a continuous-flow sedimentation tank, particle removal depends on the relationship between the settling velocity of particles and the surface overflow rate. Particles with settling velocities equal to or greater than the surface overflow rate can be removed theoretically.

Settling particles have both horizontal and vertical components of motion because they are carried forward by the flow while settling under gravity.

During coagulation, coagulants such as alum react with the alkalinity of water and form insoluble hydroxide precipitates, which provide a surface for the enmeshment of impurities. Flocculation subsequently uses gentle mixing to bring destabilised particles together and promote the formation and growth of larger flocs.

55. (a)

The tree system consists of a main pipe with several branch pipes and dead ends, making flow calculations relatively simple. In the grid-iron system, interconnected pipes provide multiple flow paths, but it generally requires a larger number of valves and greater pipe length. In the circular system, the mains are arranged along the periphery of the area, whereas in the radial system, water is supplied from a central point towards the periphery.

56. (d)

For a tube well penetrating fully into an artesian aquifer,

$$Q = \frac{2.72bks}{\log_{10}(R/r)}$$

Given,

$b = 16$ m, $k = 55$ m/day, $s = 3.2$ m

Radius of the well, $r = \frac{32}{2}$ cm $= 16$ cm $= 0.16$ m

and radius of influence, $R = 160$ m

Therefore,

$$Q = \frac{2.72 \times 16 \times 55 \times 3.2}{\log_{10}(160/0.16)} = \frac{7659.52}{\log_{10}(1000)}$$

$\Rightarrow$ $Q = 2553.17\ \text{m}^3/\text{day}$

57. (b)

Dissolved oxygen consumed in the diluted sample in 5 days,

$= 4.5$ mg/L

Dilution factor, $= \frac{50}{5} = 10$

Therefore, the 5-day BOD of the wastewater is

$\text{BOD}_5 = 4.5 \times 10 = 45$ mg/L

Using the BOD equation, $Y_t = L_o[1 - 10^{-K_D t}]$

For t = 5 days and $K_D = 0.2$ per day,

$\therefore$ $45 = L_o[1 - 10^{-(0.2)(5)}]$

$\Rightarrow$ $45 = L_o(1 - 0.1) = 0.9\, L_o$

$\Rightarrow$ $L_o = \frac{45}{0.9} = 50$ mg/L

58. (b)

In vacuum flotation, aerated sewage is subjected to reduced pressure, causing dissolved air to come out as fine bubbles. These bubbles get attached to grease and other lighter suspended solids and carry them towards the surface, where they are removed by skimming. The process therefore depends on air bubbles attaching to the particles, rather than on changing their specific gravity, viscosity or inherent buoyancy.

59. (b)

To provide adequate ventilation and free space above the wastewater, the depth of flow at ultimate peak flow is limited according to the sewer diameter:

- Sewers up to 400 mm diameter: 1/2 of the sewer depth
- Sewers between 400 mm and 900 mm diameter: 2/3 of the sewer depth
- Sewers larger than 900 mm diameter: 3/4 of the sewer depth

Therefore, for a sewer diameter between 400 and 900 mm, the permissible flow depth is $\frac{2}{3}$ of the sewer depth.

60. (a)

For cooling purposes, water may require treatment to control bacteria and other organisms that cause fouling of equipment.

Hard water is unsuitable for boiler feed because it causes scale formation on the heating surfaces. The scale increases resistance to heat transfer and consequently reduces boiler efficiency. Boiler feed water should also contain only a very small amount of dissolved oxygen, preferably less than 0.05 mg/L, to minimise corrosion.

The quality requirements of process water are not uniform; they depend on the specific industrial process. Industries such as food, paper, textile and steel manufacturing may require water with different quality characteristics.

61. (c)

A radiation inversion develops due to unequal cooling of the Earth and the air above it. It is characteristically a nocturnal phenomenon and is likely to break up with the rays of the morning sun.

A subsidence inversion is generally associated with a high-pressure system, where air undergoes sinking motion. As the air sinks, it is compressed and heated, forming a warm layer over the cooler air below.

62. (b)

The dimensions of a sedimentation tank are selected so as to obtain a favourable and uniform flow pattern, thereby reducing turbulence and short-circuiting and providing adequate opportunity for suspended particles to settle.

63. (c)

Well development is the process of removing fine material from the aquifer formation surrounding the strainer pipe to improve the performance and efficiency of the well.

The recognized methods of well development are:

1. Development by pumping
2. Development by surging
3. Development by compressed air
4. Development by back washing
5. Development by dry ice

64. (b)

For first-stage BOD exertion,

$$BOD_t = L_0 (1 - e^{-kt})$$

where L_0 is the ultimate BOD.

$$\text{For } t = 5 \text{ days and } k = 0.2 \text{ day}^{-1}$$

$$150 = L_0(1 - e^{-0.2 \times 5})$$

$$\Rightarrow \quad 150 = L_0(1 - e^{-1})$$

Goven $e^{-1} \simeq 0.3679$,

$$L_0 = \frac{150}{1 - 0.3679} \approx 237.3 \text{ mg/L}$$

65. (c)

A detention period of about 3-4 minutes is generally provided in a detritus tank. This relatively longer detention period, along with a lower flow velocity of about 0.09 m/s, helps in separating finer sand and grit particles.

66. (c)

A rapid sand filter is used after coagulation and sedimentation to remove fine suspended and colloidal matter that remains in the water. The filtration process provides a final physical separation of these residual impurities before further treatment or distribution.

67. (b)

Quantity of water supplied per day = $10{,}000 \times 120 = 1{,}200{,}000$ L/day = 1200 m^3/day

Quantity of sewage produced = $0.75 \times 1200 = 900$ m^3/day

Since the farm area includes 50% additional area for rest and rotation,

$$\text{Area required for immediate use} = \frac{150}{1.5} = 100 \text{ ha}$$

$$\text{Therefore, consuming capacity of soil} = \frac{900}{100} = 9 \text{ m}^3/\text{ha/day}$$

68. (b)

A boning rod or traveller is an adjustable-length rod used to measure vertically from the string line. Since the string line is maintained at a known height above the proposed sewer invert, the rod can be adjusted to the required length to determine the depth of excavation, level of foundation concrete, and line and level of the sewer pipe.

69. (a)

The permissible ambient noise levels for different area categories are:

Area category	Day time dB(A)	Night time dB(A)
Industrial area	75	70
Commercial area	65	55
Residential area	55	45
Silence zone	50	40

70. (b)

At 0°C and 1 atm, the molar volume of a gas is 22.4 L/mol. At 20°C and 1 atm, using the gas law,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\Rightarrow \quad V_2 = \frac{22.4 \times (273+20)}{273} = \frac{22.4 \times 293}{273} = 24.04 \text{ L/mol}$$

For SO_2, molecular mass = 64 g/mol.

Using the relation,

$$1\ \mu g/m^3 = \frac{1\ ppm \times \text{molecular mass of polutant}}{\text{L/mol of pollutant at the given temperature and pressure}} \times 10^3\ \text{L/m}^3$$

For a concentration of 64 $\mu g/m^3$,

$$64 = \frac{C_{ppm} \times 64 \times 10^3}{24.04}$$

$$\Rightarrow \quad C_{ppm} = \frac{64 \times 24.04}{64 \times 10^3}$$

$$\Rightarrow \quad C_{ppm} \simeq 0.024 \text{ ppm}$$

71. (c)

For two independent sound sources, the resultant RMS sound pressure is

$$p_{rms} = \sqrt{p_1^2 + p_2^2}$$

Since

$$p_1 = p_2 = 2000\ \mu Pa$$

$$p_{rms} = \sqrt{2000^2 + 2000^2} = 2000\sqrt{2}\ \mu Pa$$

Sound pressure level is

$$\therefore \quad L_p = 20\log_{10}\left(\frac{p_{rms}}{20\ \mu Pa}\right)$$

$$= 20\log_{10}\left(\frac{2000\sqrt{2}}{20}\right) = 20\log_{10}(100\sqrt{2})$$

Using the logarithm property,

$$\log_{10}(100\sqrt{2}) = \log_{10}(100) + \log_{10}(\sqrt{2})$$

$$= 2 + \frac{1}{2}\log_{10}(2)$$

Since

$$\log_{10}(2) \simeq 0.301$$

$$L_p = 20\left[2+\frac{1}{2}(0.301)\right]$$
$$= 20(2 + 0.1505) = 20\ (2.1505) = 43.01\ \text{dB} \simeq 43\ \text{dB}$$

72. (a)

Sludge contains 1% solids. Therefore, for 300 kg of dry solids, the corresponding mass of water is

$$M_w = 300\left(\frac{0.99}{0.01}\right) = 29700\ \text{kg/day}$$

$$\text{Volume of water, } V_w = \frac{29700}{1000} = 29.7\ \text{m}^3/\text{day}$$

Volume occupied by the solids is

$$V_s = \frac{300}{3\times 1000} = 0.1\ \text{m}^3/\text{day}$$

Hence, the total sludge volume is

$$V = V_w + V_s$$
$$\Rightarrow \quad V = 29.7 + 0.1$$
$$\Rightarrow \quad V = 29.8\ \text{m}^3/\text{day}$$

73. (c)

Suspended solids removed in the primary clarifier are

$$S_s = 0.55(280)$$
$$\Rightarrow \quad S_s = 154\ \text{mg/L}$$

BOD reaching the trickling filter is

$$\text{BOD} = (1 - 0.25)(240)$$
$$\Rightarrow \quad \text{BOD} = 180\ \text{mg/L}$$

Solids produced in the trickling filter are

$$S_f = 0.45(180)$$
$$\Rightarrow \quad S_f = 81\ \text{mg/L}$$

Hence, the total solids production is

$$S = 154 + 81 = 235\ \text{mg/L}$$

For a flow of 1400 m^3/day ,

$$\text{Solids production} = \frac{235\times 1400\times 10^3}{10^6} = 329\ \text{kg/day}$$

74. (d)

A trickling filter is an attached-growth biological treatment process, in which microorganisms grow as a biofilm on the filter media.

75. (d)

The BOD/COD ratio cannot exceed 1, but it can be equal to 1 when the oxidisable organic matter is completely biodegradable.

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