DETAILED SOLUTIONS

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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 2

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

1.	(c)	17.	(a)	33.	(a)	49.	(d)	65.	(c)
2.	(a)	18.	(b)	34.	(b)	50.	(b)	66.	(b)
3.	(c)	19.	(d)	35.	(d)	51.	(a)	67.	(c)
4.	(b)	20.	(c)	36.	(d)	52.	(c)	68.	(d)
5.	(b)	21.	(b)	37.	(b)	53.	(c)	69.	(b)
6.	(a)	22.	(b)	38.	(a)	54.	(c)	70.	(a)
7.	(c)	23.	(d)	39.	(c)	55.	(d)	71.	(d)
8.	(b)	24.	(c)	40.	(d)	56.	(c)	72.	(d)
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11.	(c)	27.	(c)	43.	(c)	59.	(b)	75.	(a)
12.	(c)	28.	(c)	44.	(c)	60.	(c)		
13.	(d)	29.	(c)	45.	(b)	61.	(c)		
14.	(c)	30.	(c)	46.	(b)	62.	(c)		
15.	(c)	31.	(b)	47.	(d)	63.	(d)		
16.	(c)	32.	(c)	48.	(c)	64.	(d)		

***Q.67 [*Answer key has been updated*]**

DETAILED EXPLANATIONS

1. (c)

Soil classification as per plasticity index, I_P is given below.

I_P	Soil description
0	Non plastic
< 7	Low plastic
7 – 17	Medium plastic
> 17	Highly plastic

2. (a)

A soil with a steeper flow curve i.e. having high flow index possesses lower shear strength.

3. (c)

- Sensitivity is measure of loss in strength of soils as a result of remoulding.
- Activity of a clay is defined as ratio of plasticity index and percentage by weight finer than 2μ.

4. (b)

$$\text{Dry density of soil, } \rho_d = \frac{(1-\eta_a)G\rho_w}{1+Gw}$$

where η_a is percentage air voids

$$\rho_d = \frac{\rho}{1+w} = \frac{2}{1+0.2} = \frac{5}{3}\text{g/cc}$$

Hence,
$$\rho_d = \frac{5}{3} = \frac{(1-\eta_a)\times 2.7\times 1}{1+2.7\times 0.2}$$

$$\Rightarrow \quad \frac{5\times 1.54}{3\times 2.7} = 1-\eta_a$$

$$\Rightarrow \quad \eta_a = \left(1-\frac{77}{81}\right)\times 100$$

$$= \frac{400}{81}\%$$

5. (b)

- Alluvial deposit - Soils that have deposited from suspension in running water.
- Marine deposit-Soils that have been deposited from suspension in sea water.
- Aeolin deposit-Soils that have been transported by wind.

6. (a)

- A soil on dry side of optimum has a higher water deficiency and can imbibe more water than wet side of optimum.
- Permeability decreases sharply with increase in water content on dry side of optimum.

7. (c)

Given:

$$e_{\text{in-situ}} = 0.5$$
$$e_{\max} = 0.8$$
$$e_{\min} = 0.4$$

Now, Relative density $= \left(\dfrac{e_{\max} - e_{\text{in-situ}}}{e_{\max} - e_{\min}}\right) \times 100$

$$= \frac{0.8 - 0.5}{0.8 - 0.4} \times 100 = 75\%$$

$$\text{Relative compaction} = \frac{\gamma_{d(\text{in-situ})}}{\gamma_{d(\max)}} = \frac{\left(\dfrac{G\gamma_w}{1 + e_{\text{in-situ}}}\right)}{\left(\dfrac{G\gamma_w}{1 + e_{\min}}\right)} = \frac{1 + e_{\min}}{1 + e_{\text{in-situ}}}$$

$$= \left(\frac{1 + 0.4}{1 + 0.5}\right) \times 100 = \frac{1.4}{1.5} \times 100 = 93.33\%$$

8. (b)

Compression and flow are assumed to be one-dimensional.

9. (b)

Given:

$$\Delta e = e_0 - e = 1.2 - 1.1 = 0.1$$
$$\Delta\bar{\sigma} = 0.75 - 0.5 = 0.25 \text{ kg/cm}^2$$
$$C_V = 10 \text{ m}^2/\text{year} = \frac{10 \times 10^4}{86400 \times 365} \text{cm}^2/\text{sec}$$

Now, coefficient of permeability, $k = C_v m_v \gamma_w$

$$= C_v \times \frac{\Delta e}{\Delta\bar{\sigma}(1 + e_0)} \times \gamma_w$$

$$= \frac{10 \times 10^4}{86400 \times 365} \times \frac{0.1 \times 10^{-3}}{0.25 \times (1 + 1.2)} \times 1$$

$$= 5.7 \times 10^{-7} \text{ cm/sec}$$

10. (c)

- Even though most expansive soils are dark in colour, there are many swelling soils which are lighter in colour and even of brown colour.
- Pounded water will percolate only to a limited depth. The expansive soil at deeper levels will contribute to an enhanced level of swelling after the structure is erected.

11. (c)

- Greater the viscosity, lower is the permeability of soil.
- Dispersion effect causes the permeability to decrease, because of reduction in size of voids which is available for flow.

13. (d)

Given, $n = 50\%, G = 2.65$ and FOS = 3

Now, $e = \frac{n}{1-n} = \frac{0.5}{1-0.5} = 1$

Now permissible hydraulic gradient,

$$i = \frac{i_{cr}}{FOS}$$

$$= \frac{1}{FOS}\left(\frac{G-1}{1+e}\right)$$

$$= \frac{1}{3}\left(\frac{2.65-1}{1+1}\right) = \frac{1.65}{3\times 2} = 0.275$$

15. (c)

Given:

$$\phi = 30°, \gamma = 16 \text{ kN/m}^3, H = 6 \text{ m}$$

Now, $k_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30°}{1-\sin 30°} = \frac{1+(1/2)}{1-(1/2)} = 3$

Total passive earth pressure, $P_p = \frac{1}{2}k_P\gamma H^2$

$$= \frac{1}{2}\times 3\times 16\times 6^2$$

$$= 864 \text{ kN/m}$$

16. (c)

Earth pressure distribution is assumed to be triangular and point of application is taken at lower third point of wall.

17. (a)

ESP is quite different in case of over consolidated and normally consolidated clays.

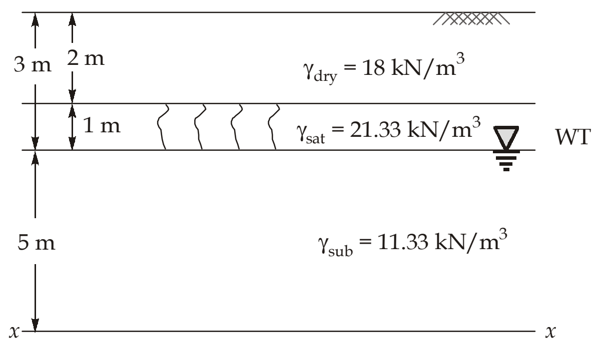
19. (d)

For a given soil 'A' depends upon the strain, anisotropy, sample disturbance and over consolidation ratio.

20. (c)

Given,

$$G = 2.7$$
$$e = 0.5$$
$$\gamma_w = 10 \text{ kN/m}^3$$



Now,
$$\gamma_{dry} = \frac{G\gamma_w}{1+e}$$
$$= \frac{2.7 \times 10}{1+0.5} = 18 \text{ kN/m}^3$$
$$\gamma_{sat} = \frac{(G+e)\gamma_w}{1+e}$$
$$= \frac{(2.7+0.5)\times 10}{1+0.5} = 21.33 \text{ kN/m}^3$$

$\therefore$
$$\gamma_{sub} = \gamma_{sat} - \gamma_w = 21.33 - 10 = 11.33 \text{ kN/m}^3$$

Now, effective stress at depth *x*-*x*, $\bar{\sigma} = 2 \times \gamma_{dry} + 1 \times \gamma_{sat} + 5 \times \gamma_{sub}$
$$= 2 \times 18 + 1 \times 21.33 + 5 \times 11.33$$
$$= 113.98 \text{ kN/m}^3$$
$$\simeq 114 \text{ kN/m}^2$$

21. (b)

As per Terzaghi's theory,

Ultimate bearing capacity, $q_u = CN_C + \gamma D_f N_q + 0.5\gamma B N_\gamma$
$$= 15 \times 30.1 + 18 \times 1 \times 18.4 + 0.5 \times 18 \times 1.2 \times 16.7$$
$$= 451.5 + 331.2 + 180.36$$
$$= 963.06 \text{ kN/m}^2$$
$$= 963 \text{ kN/m}^2$$

22. (b)

$$\text{Factor of safety} = \frac{\text{Ultimate load capacity of pile}}{\text{Working load + Negative skin friction}}$$

Now, Ultimate load capacity of pile = 1382 – 300 + 478

($\because$ In top 3 m of pile, regative skin friction is there).

= 1560 kN

Negative skin friction = 300 kN

So, $$3 = \frac{1560}{\text{Working load} + 300}$$

$\Rightarrow$ Working load = 520 – 300 = 220 kN

23. (d)

As per Cl. 7.1.5 of IS 2911 : Part 4 (2013)

$$\text{Safe vertical load on pile} = \text{Min.}\begin{bmatrix} \frac{2}{3}\times(\text{Load at which settlement is 12 mm}) \\ \text{or} \\ 0.5\times(\text{Load at which displacement} \\ \text{is 10\% of pile diameter}) \end{bmatrix}$$

$$= \text{Min.}\begin{bmatrix} \frac{2}{3}\times 235.7 = 157.1\,\text{kN} \\ 0.5\times 450 = 225\,\text{kN} \end{bmatrix} = 157.1 \text{ kN}$$

24. (c)

$$\text{Allowable pile load, } Q_a = \frac{WH}{F(S+C)}$$

For drop hammer, F = 6, C = 2.5

$\therefore$ $$Q_a = \frac{50\times 150}{6(0.5+2.5)} = 416.67 \text{ kN}$$

25. (b)

$$\text{Area ratio, } A_r = \frac{51^2 - 35^2}{35^2}\times 100$$

$$= \frac{2601-1225}{1225}\times 100 = 112.33\%$$

26. (a)

Contact pressure is uniformly distributed in flexible footing in clayey soil. Hence, a dish shaped pattern of settlement is obtained.

27. (c)

$$\text{Depth of excavation, } H = \frac{c_u}{S_n F_c \gamma}$$

where

$$c_u = 50 \text{ kN/m}^2,$$
$$S_n = 0.261$$
$$F_C = 1$$
$$\gamma = 20 \text{ kN/m}^3$$

$$\therefore \quad H = \frac{50}{0.261 \times 1 \times 20} = 9.578 \text{ m}$$

28. (c)

As we know

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

where

$$\Delta H = 1.5 \text{ mm},$$
$$H = 30 \text{ mm}$$
$$e_0 = 1.12$$

$$\therefore \quad \frac{1.5}{30} = \frac{\Delta e}{1+1.12}$$

$$\Rightarrow \quad \Delta e = \frac{1.5 \times 2.12}{30} = 0.106$$

Now, Final void ratio, $e_f = e_0 - \Delta e$

$$= 1.12 - 0.106 = 1.014$$

29. (c)

As we know

$$G = \frac{1}{\frac{\rho_w}{\rho_d} - \frac{w_s}{100}}$$ where w_s is shrinkage limit in%.

Now,

$$G = 2.7$$

$$\rho_d = \frac{430}{250} = 1.72 \text{ g/cc}, \rho_w = 1 \text{ g/cc}$$

$$\therefore \quad G = 2.7 = \frac{1}{\frac{1}{1.72} - \frac{w_s}{100}}$$

$$\Rightarrow \quad \frac{1}{1.72} - \frac{1}{2.7} = \frac{w_s}{100}$$

$$\Rightarrow \quad w_s = 21.1\% = 0.211$$

Now, weight of water, $W_w = w_s \times 430$

$$= 0.211 \times 430$$
$$= 90.73 \text{ gm}$$
$$\simeq 90.7 \text{ gm}$$

30. **(c)**

As 100% of soil is finer than 4.75 mm sieve, it is not gravel.

As only 6% of soil is finer than 75μ sieve, it is coarse grained soil i.e. sand.

Now, $$C_u = \frac{D_{60}}{D_{10}} = \frac{0.22}{0.16} = 1.375 < 6$$

$$C_C = \frac{D_{30}^2}{D_{10} \times D_{60}} = \frac{0.19^2}{0.22 \times 0.16} = 1.03$$

As $C_u < 6$, so sand is poorly graded i.e. SP.

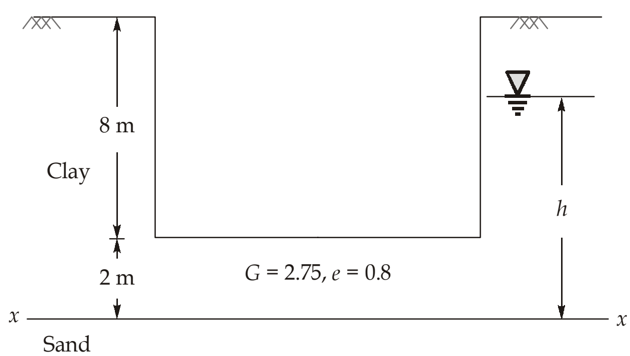
Now, as the soil is non-plastic, sand will contain silt as fines i.e. SM.

Hence its symbol is SP – SM.

32. **(c)**

Let, the height of water table be, 'h'

Now, at x- x Effective stress, $\bar{\sigma} = 0$



$$2\gamma_{sat} = h\gamma_w$$

$$\Rightarrow \quad h = \frac{2\gamma_{sat}}{\gamma_w} = \frac{2 \times (G + e)}{(1 + e)}$$

$$= 2 \times \left(\frac{2.75 + 0.8}{1 + 0.8}\right) = 3.94 \text{ m}$$

Now,depth of water table below ground surface = 10 – 3.94 = 6.06 m

33. **(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

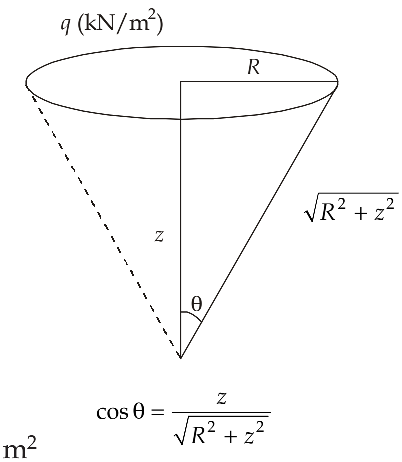
Number of equipotential drops, N_d = Number of equipotential lines – 1 = 11 – 1 = 10

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

34. (b)

Vertical stress at a depth z is given by

$$\sigma_z = q(1 - \cos^3\theta)$$



$$\Rightarrow \quad \sigma_z = q\left(1 - \frac{z^3}{(z^2 + R^2)^{3/2}}\right)$$

$$\cos\theta = \frac{z}{\sqrt{R^2 + z^2}}$$

where $q = 100 \text{ kN/m}^2$

$z = 3 \text{ m}, R = 4 \text{ m}$

$$\therefore \quad \sigma_z = 100\left(1 - \frac{3^3}{(3^2 + 4^2)^{3/2}}\right)$$

$$= 100\left(1 - \frac{27}{125}\right) = 78.4 \text{ kN/m}^2$$

35. (d)

For laboratory sample

$$H_1 = \frac{20}{2} = 10 \text{ mm} \quad \text{(Due to double drainage)}$$

$$t_1 = 10 \text{ minutes}$$

For site

$$H_2 = 10 \text{ m} \quad \text{(Due to single drainage)}$$

$$t_2 = ?$$

For same degree of consolidation

$$\frac{t_1}{H_1^2} = \frac{t_2}{H_2^2}$$

$$\Rightarrow \quad t_2 = t_1 \times \frac{H_2^2}{H_1^2}$$

$$= \frac{10 \times 10000^2}{10^2} = 10^7 \text{ minutes}$$

36. (d)

$$\text{FOS} = \frac{C + \gamma_{sub} Z \cos^2\beta \tan\phi}{\gamma_{sub} Z \cos\beta \sin\beta}$$

For critical, height, $\text{FOS} = 1$ and $Z = H_C$

$$\therefore \quad \gamma_{sub} H_C \cos\beta\sin\beta = C + \gamma_{sub} H_C \cos^2\beta\tan\phi$$

$$\Rightarrow \quad C = (\gamma_{sub} H_C \cos^2\beta(\tan\beta - \tan\phi))$$

$$\Rightarrow \quad H_C = \frac{C}{\gamma_{sub}\cos^2\beta(\tan\beta - \tan\phi)}$$

38. (a)

Because of very high permeability of sand, it does not take much time for pore water to drain out. Due to this reason, any structure on a sandy soil experience very little settlement after it has been constructed.

39. (c)

$$k_0 = \frac{k\mu}{\gamma} = \frac{k\mu}{\rho g} = \frac{k\nu}{g}$$

41. (b)

As we know,

$$N_1 V_1 = N_2 V_2$$

Where $N_1 = 0.01$ N

$V_1 = 60$ mL

Since, 1 mL of 0.02 N H_2SO_4 reacts with 1 mL of alkalinity as $CaCO_3$

$\therefore$ $N_2 = 0.02$

Hence, $$V_2 = \frac{N_1}{N_2} \times V_1 = \frac{0.01}{0.02} \times 60 = 30 \text{ mL}$$

$\therefore$ Total alkalinity of water sample of 200 mL = 30 mg

Total alkalinity of water sample in 1 L = 30 × 5 = 150 mg/l as $CaCO_3$

43. (c)

Volume of sample of sewage = 2.5 ml

Volume of diluted sample = 250 ml

So, dilution factor $= \frac{250}{2.5} = 100$

Now, BOD of raw sewage = (8 – 5) × 100

= 300 mg/l

46. (b)

Mean cell residence time, $\theta_C = \frac{VX}{Q_w X_u}$

where $V = 1600 \text{ m}^3$,

$X = 3000 \text{ mg}/l = 3 \text{ kg/m}^3$

$\theta_C = 10$ days

$Q_w X_u$ = Mass of solids wasted per day

$$\Rightarrow \quad Q_w X_u = \frac{1600 \times 3}{10} = 480 \text{ kg/day}$$

47. (d)

As we know, Power, $P = G^2\mu V$

Where $G = 30\ \text{sec}^{-1}$, $\mu = 1.14 \times 10^{-3}\ \text{Ns/m}^2$, $V = 250\ \text{m}^3$

$\therefore$ $P = 30^2 \times 1.14 \times 10^{-3} \times 250$

$= 256.5$ Watts

48. (c)

$$\text{Settling velocity, } V_t = \sqrt{\frac{4}{3}\frac{gd(G-1)}{C_D}}$$

where $C_D = 1.2$

$d = 0.5\ \text{mm} = 5 \times 10^{-4}\ \text{m}$

$G = 2.62$

$g = 9.81\ \text{m/s}^2$

$$\therefore \quad V_t = \sqrt{\frac{4 \times 9.81 \times 5 \times 10^{-4} \times (2.62 - 1)}{3 \times 1.2}}$$

$$= \left(\sqrt{9 \times 9.81}\right) \times 10^{-2}$$

$= 9.396 \times 10^{-2}\ \text{m/s}$

$\simeq 94\ \text{mm/s}$

51. (a)

- An example of ionic layer compression occurs in nature when a turbid stream flows into ocean. There, the ion content of water increases drastically and coagulation and settling occur.
- The nature, rather than quantity of ions is of importance in theory of adsorption and charge neutralization.

52. (c)

- All forms of carbonate hardness as well as magnesium non-carbonate hardness can be converted to precipitating species by addition of lime.
- Complete removal of hardness cannot be accomplished in this method.
- The optimum pH for $CaCO_3$ precipitation by lime addition is from 9 to 9.5.
- The optimum pH for $Mg(OH)_2$ precipitation requires a pH of about 11.

53. (c)

Hypochrous acid is more effective than hypochlorite ions by approximately two orders of magnitude.

54. (c)

Refer Table 1 and 2 of IS 10500 : 2012.

55. (d)

$$\text{Surface area required, } A_s = \frac{5 \times 10^6 \times 10^{-3}}{40} = 125\ \text{m}^2$$

Now, volume of tank required, $V = A_s \times$ depth of tank

$= 125 \times 3 = 375\ \text{m}^3$

57. (d)

$$\text{Quantity of sewage produced} = 5 \text{ MLD} = 5000 \text{ m}^3/\text{day}$$

$$\text{Area of farmland required for immediate need} = \frac{150}{1.5} = 100 \text{ hectares}$$

(excluding extra provision of rest and rotation)

$$\therefore \quad \text{Consuming capacity of soil} = \frac{5000}{100} = 50 \text{ m}^3/\text{hectares}/\text{day}$$

59. (b)

Nitrogenous organic matter gets oxidised to ammonia, then to nitrites and finally to nitrates, which is then consumed by plants, through photosynthesis to form plant proteins.

60. (c)

$$\text{Relative stability, } S = 100[1 - (0.794)^{t_{20}}] \text{ at } 20°\text{C}$$

and

$$S = 100[1 - (0.794)^{t_{37}}] \text{ at } 37°\text{C}$$

where t_{20} and t_{37} represent the time in days for a sewage sample to decolorize a standard volume of methylene blue solution when incubated at 20°C or 37°C respectively.

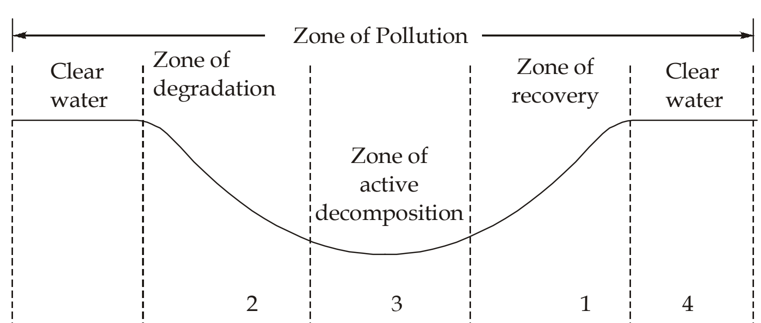
61. (c)

$$\text{Total daily BOD produced by system} = 1000 \times 75 = 75000 \text{ gm}$$

$$\text{Standard per capita BOD} = 50 \text{ gm}$$

$$\text{Now, population equivalent} = \frac{75000}{50} = 1500$$

62. (c)



67. (c)

- **Specific yield:** It is defined as the volume of water released from storage by an unconfined aquifer per unit surface area of aquifer per unit decline of the water table.
- **Specific Capacity:** It is defined as the rate of flow through the well per unit drawdown that has determined for initial first meter fall of water in well.
- **Specific storage:** It is the amount of water that a portion of an aquifer releases from storage, per unit mass or volume of aquifer, per unit change in hydraulic head, while remaining fully saturated.

68. (d)

Given,

$Q = 0.004\ \text{m}^3/\text{s} = 14.4\ \text{m}^3/\text{hr},\ s = 3\ \text{m},\ \dfrac{c'}{A} = 1\ \text{m}^3/\text{hr}/\text{m}^2/\text{m}$

Now, $$Q = \left(\frac{c'}{A}\right) \times A \times s$$ where A is area of well.

$$\Rightarrow \quad 14.4 = 1 \times A \times 3$$

$$\Rightarrow \quad A = 4.8\ \text{m}^2$$

$$\Rightarrow \quad \frac{\pi}{4} d^2 = 4.8$$

$$\Rightarrow \quad d = \sqrt{\frac{4.8 \times 4}{\pi}} = 2.47\ \text{m}$$

70. (a)

- Organic ammonia indicates pollution and presence of undecomposed organic matter.
- Nitrites indicate the partly oxidised organic matter.
- Nitrates indicate the fully oxidised organic matter.

71. (d)

This formula is based on the fact that volume of this type of circular tank used for sedimentation i.e. the one having a cone shaped bottom with 1 : 1 slope, is found to have a volume equal to $d^2(0.011d + 0.785H)$

73. (b)

As per the National Board of Fire Underwriters formula.

$$Q(\text{in lit/min}) = 4637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

$$\Rightarrow \quad Q(\text{in m}^3/\text{day}) = 4637 \times 10^{-3} \times 60 \times 24\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

$$= 6677.28\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

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