DETAILED SOLUTIONS

MADE EASY

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 4

Section A : Solid Mechanics [All Topics]
Section B : Geo-technical & Foundation Engineering-I [Part Syllabus]
Section C : Environmental Engineering-I [Part Syllabus]

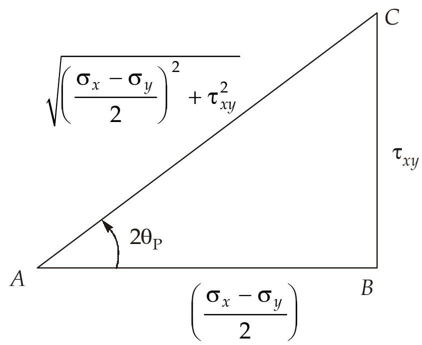
1.	(d)	16.	(b)	31.	(b)	46.	(b)	61.	(b)
2.	(b)	17.	(b)	32.	(a)	47.	(b)	62.	(a)
3.	(a)	18.	(c)	33.	(d)	48.	(d)	63.	(a)
4.	(d)	19.	(d)	34.	(c)	49.	(b)	64.	(c)
5.	(d)	20.	(b)	35.	(d)	50.	(a)	65.	(a)
6.	(c)	21.	(c)	36.	(b)	51.	(a)	66.	(b)
7.	(d)	22.	(d)	37.	(b)	52.	(a)	67.	(d)
8.	(d)	23.	(a)	38.	(a)	53.	(c)	68.	(d)
9.	(d)	24.	(b)	39.	(d)	54.	(b)	69.	(b)
10.	(a)	25.	(d)	40.	(d)	55.	(c)	70.	(c)
11.	(c)	26.	(c)	41.	(d)	56.	(a)	71.	(b)
12.	(b)	27.	(b)	42.	(a)	57.	(b)	72.	(d)
13.	(b)	28.	(c)	43.	(c)	58.	(d)	73.	(d)
14.	(c)	29.	(c)	44.	(c)	59.	(c)	74.	(b)
15.	(c)	30.	(c)	45.	(d)	60.	(c)	75.	(c)

* Q. No. 30 & 41 (Answer key and explanation has been updated)

DETAILED EXPLANATIONS
Section A : Solid Mechanics

1. (d)

$\because$
$$\tan(2\theta_p) = \frac{\tau_{xy}}{\left(\frac{\sigma_x - \sigma_y}{2}\right)}$$



In ΔABC,

$$\cos 2\theta_p = \frac{\left(\frac{\sigma_x - \sigma_y}{2}\right)}{\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}}$$

$\Rightarrow$
$$\cos 2\theta_p = \frac{\pm(\sigma_x - \sigma_y)}{\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}}$$

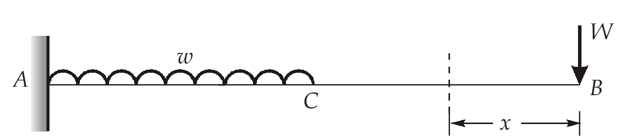
2. (b)

Modulus of toughness is the strain energy per unit volume required to cause the material to rupture.

3. (a)

The bending stress is directly proportional to the distance of the beam fibres from the neutral axis. Maximum stress occurs on the outermost fibres of the beam.

4. (d)

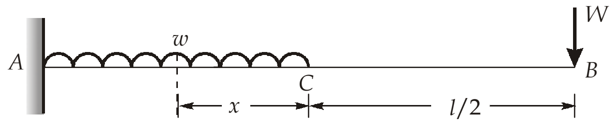


For BC portion:

$$M_x = -Wx \quad \text{(linear)}$$

At $x = 0$, $M_B = 0$

At $x = \frac{l}{2}$ $\quad M_C = -\frac{Wl}{2}$

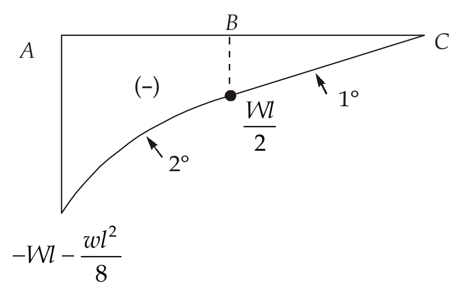


$$M_x = -W\left(\frac{l}{2}+x\right)-\frac{wx^2}{2} \text{ (Parabolic)}$$

For CA portion:

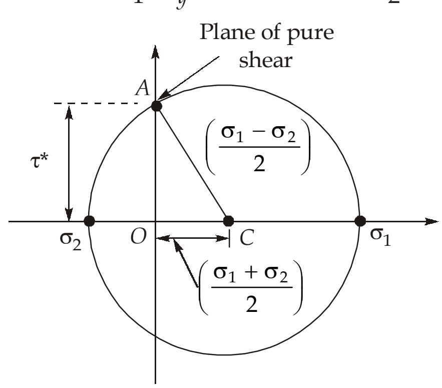
At $x = 0$, $\quad M_C = -\frac{Wl}{2}$

At $x = \frac{l}{2}$ $\quad M_A = -Wl - \frac{wl^2}{8}$



5. (d)

Given: $\quad \sigma_x = 288 \text{ MPa} = \sigma_1, \sigma_y = -18 \text{ MPa} = \sigma_2$



Radius of circle, $\quad AC = \left(\frac{\sigma_1-\sigma_2}{2}\right)$

$$OC = \left(\frac{\sigma_1+\sigma_2}{2}\right)$$

Magnitude of shear stress at the plane of pure shear is,

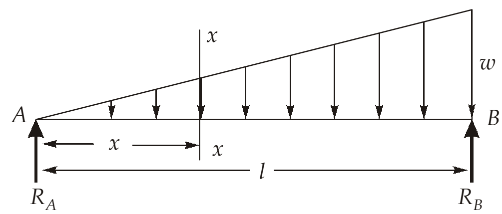
$$\tau^* = OA = \sqrt{AC^2 - OC^2}$$

$$\Rightarrow \quad \tau^* = \sqrt{\left(\frac{\sigma_1-\sigma_2}{2}\right)^2 - \left(\frac{\sigma_1+\sigma_2}{2}\right)^2}$$

$$\Rightarrow \quad \tau^* = \sqrt{\frac{1}{4}(-4\,\sigma_1\sigma_2)}$$

$$\Rightarrow \quad \tau^* = \sqrt{-288 \times (-18)} = 72 \text{ MPa}$$

6. (c)



$$R_A = \frac{wl}{2} \times \frac{1}{3} = \frac{wl}{6}$$

$$R_B = \frac{wl}{2} - \frac{wl}{6} = \frac{wl}{3}$$

Shear force at section x-x,

$$V_x = R_A - \frac{1}{2}\frac{wx}{l}x = \frac{wl}{6} - \frac{wx^2}{2l}$$

For, $V_x = 0$,

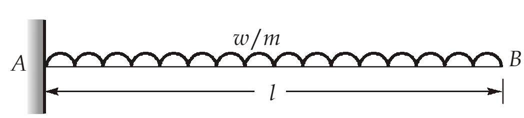
$$\frac{wl}{6} = \frac{wx^2}{2l}$$

$$\Rightarrow \quad \frac{l}{6} = \frac{x^2}{2l}$$

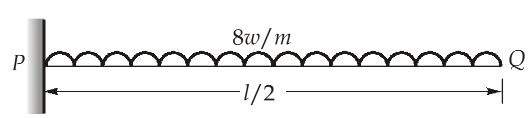
$$\Rightarrow \quad x = \frac{l}{\sqrt{3}}$$

Distance from end B $= l - x = l - \dfrac{l}{\sqrt{3}} = l\left(\dfrac{3-\sqrt{3}}{3}\right)$

7. (d)

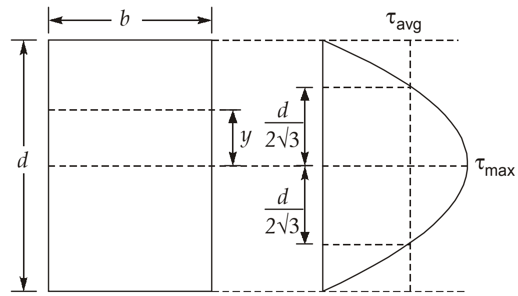


Slope at free end, $\theta_B = \dfrac{wl^3}{6EI} = \theta$



Slope at free end, $\theta_Q = \dfrac{(8w)(l/2)^3}{6EI} = \dfrac{wl^3}{6EI} = \theta$

8. (d)



Shear stress at any point in rectangular section is given by

$$\tau_y = \frac{V}{2I}\left(\frac{d^2}{4} - y^2\right)$$

Average shear stress, $\tau_{avg} = \frac{V}{bd}$

Now, $\frac{V}{2I}\left(\frac{d^2}{4} - y^2\right) = \frac{V}{bd}$

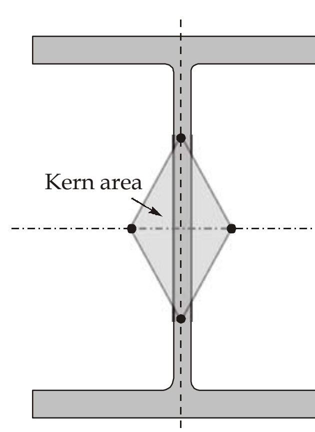
$\Rightarrow$ $\frac{6}{bd^3}\left(\frac{d^2}{4} - y^2\right) = \frac{1}{bd}$

$\Rightarrow$ $\frac{d^2}{4} - y^2 = \frac{d^2}{6}$

$\Rightarrow$ $y^2 = d^2\left(\frac{1}{4} - \frac{1}{6}\right) = \frac{d^2}{12}$

$\therefore$ $y = \pm\frac{d}{2\sqrt{3}}$

9. (d)



Kern is that area through which if load passes then there will be no resultant tension anywhere in the cross section.

Shape of Cross-Section	Shape of kern
Rectangle	Rhombus
I section	Rhombus
Square	Square
Solid circular	Circular
Hollow circular	Circular

10. (a)

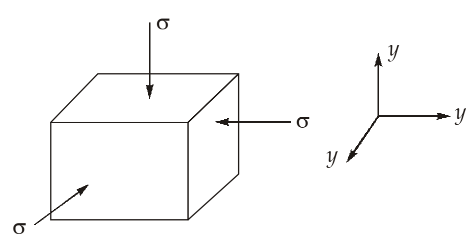
Longitudinal strain, $$\in_l = \frac{Pd}{4tE}(1-2\mu)$$

Hoop strain, $$\in_h = \frac{Pd}{4tE}(2-\mu)$$

$$\text{Ratio} = \frac{\in_l}{\in_h} = \frac{1-2\mu}{2-\mu} = \frac{1-2\times 0.3}{2-0.3} = \frac{4}{17}$$

11. (c)

As the object is confined in all directions, so compressive stress will develop in all sides on increasing the temperature.



Let 'σ' be the stress produced and since object is confined in all directions, hence net deflection is zero in every direction.

$$\Delta x = \Delta y = \Delta z = 0$$

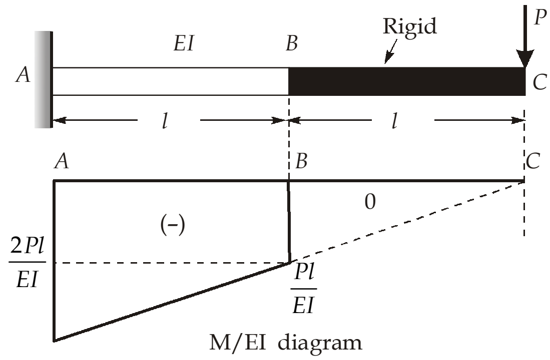
Now, $$\Delta x = 0$$

$$\Rightarrow \quad L\alpha T - \left[\frac{\sigma}{E}L - \mu\frac{\sigma}{E}L - \mu\frac{\sigma}{E}L\right] = 0$$

$$\Rightarrow \quad L\alpha T = \frac{L\sigma}{E}(1-2\mu)$$

$$\Rightarrow \quad \sigma = \frac{E\alpha T}{1-2\mu}$$

12. (b)



M/EI diagram

By moment area method,

Deflection at C with respect to tangent at A

$$\delta_{C/A} = \text{Moment of area between } C \text{ and } A \text{ about } C$$

$$\Rightarrow \quad \delta_C = -\frac{Pl}{EI}l\left(\frac{3l}{2}\right) - \frac{1}{2}\times\frac{Pl}{EI}\times l\left(\frac{2l}{3}+l\right)$$

$$\Rightarrow \quad \delta_C = -\frac{Pl^3}{EI}\left(\frac{3}{2}+\frac{5}{6}\right)$$

$$\Rightarrow \quad \delta_C = \frac{7}{3}\left(\frac{Pl^3}{EI}\right)(\downarrow)$$

13. (b)

The maximum shear stress is zero, while the principal stress is the value of the normal stress, which is constant but not necessarily zero.

14. (c)

$$\frac{\tau}{r} = \frac{T}{j}$$

$$\Rightarrow \quad \tau = \frac{T}{j}r$$

Shear stress is zero at $r = 0$ and maximum at $r = R$.

15. (c)

Volumetric strain, $\in_v = \in_x + \in_y + \in_z$

$\Rightarrow \quad \in_v = 0.001 + 0.002 + 0.003$

$\Rightarrow \quad \in_v = 0.006$

Bulk modulus, $K = \dfrac{p}{\in_v} = \dfrac{120\ MPa}{0.006}$

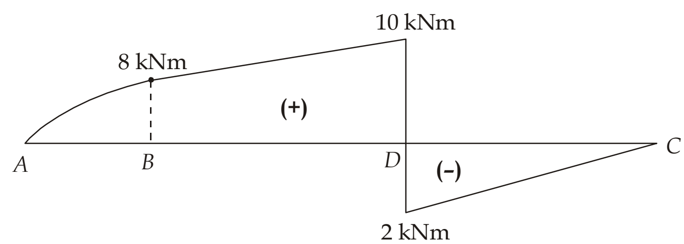
$= 20 \times 10^3$ MPa = 20 GPa

16. (b)

$$V_A = 4 \times 1 = 4 \text{ kN}$$
$$\Sigma M_B = 0$$
$$\Rightarrow V_C \times 16 + 12 + 4 \times 1 \times 2 - V_A \times 4 = 0$$
$$\Rightarrow V_C = -\frac{4}{16} = -\frac{1}{4} = -0.25 \text{ kN} = 0.25 \text{ kN}(\downarrow)$$
$$V_B = +0.25 \text{ kN } (\uparrow)$$

BM at *B*,
$$M_B = V_A \times 4 - 4 \times 1 \times 2$$
$$= 4 \times 4 - 8 = 8 \text{ kNm } (\circlearrowright)$$

BMD of beam is shown below



$\therefore$ Maximum bending moment in beam *ABC* = 10 kNm

17. (b)

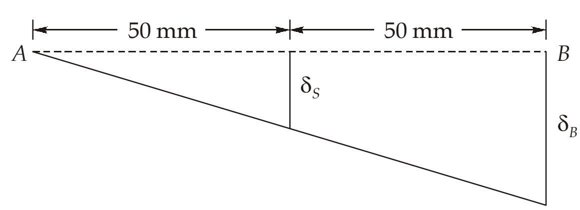
18. (c)

True strain for finite increment of loading such that length changes from L_0 to L is given by

$$\in_t = \int_{l_0}^{L} \frac{dL}{L} = \ln\left(\frac{L}{L_0}\right)$$
$$\Rightarrow \in_t = \ln\left(\frac{L_0 + \delta}{L}\right) = \ln\left[1 + \frac{\delta}{L_0}\right]$$
$$\Rightarrow \in_t = \ln(1 + \in)$$

19. (d)

Force in the spring,
$$F = \frac{500 \times 100}{50} = 1000 \text{ N}$$



Deflection in the spring, $\delta_S = \frac{F}{k} = \frac{1000}{100} = 10 \text{ mm}$

So, deflection at point *B*, $\delta_B = \frac{10 \times 100}{50} = 2 \times 2 = 20 \text{ mm}$

20. (b)

The fatigue-propogation life is defined as "the period of fatigue-crack growth from initiation to failure".

21. (c)

22. (d)

23. (a)

$$\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$$

$$R = \frac{1000}{2} = 500 \text{ mm}$$

$$y = \frac{0.5}{2} = 0.25 \text{ mm}$$

$$f = \frac{E}{R}y = \frac{200 \times 10^3 \times 0.25}{500} = 100 \text{ N/mm}^2 = 100 \text{ MPa}$$

24. (b)

$\therefore$ $$T_x = T\frac{x^3}{L^3}$$

So elongation of length dx due to change in temperature is given as

$$dL = \alpha\,(dx)\,T_x$$

$\Rightarrow$ $$dL = \alpha\frac{T\,x^3}{L^3}dx$$

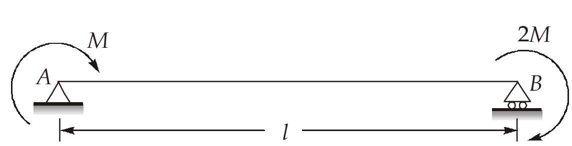
So, $$\Delta L = \int_0^L dL = \int_0^L \frac{\alpha T x^3}{L^3}dx$$

$\Rightarrow$ $$\Delta L = \left[\frac{\alpha T x^4}{4L^3}\right]_0^L = \frac{\alpha T L}{4}$$

$\therefore$ $$\in = \frac{\Delta L}{L} = \frac{\alpha T}{4}$$

So, $$\text{Stress} = \in E = \frac{E\alpha T}{4}$$

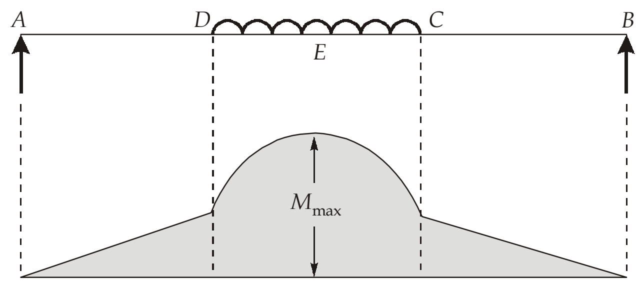
25. (d)



Using superposition theorem,

Slope at A, $$\theta_A = \frac{Ml}{3EI} - \frac{2Ml}{6EI} = 0$$

26. (c)



BMD

For pure bending condition, shear force must be zero.

27. (b)

Maximum shear strain.

$$\frac{\gamma_{max}}{2} = \sqrt{\left(\frac{\epsilon_x - \epsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$\Rightarrow \quad \frac{\gamma_{max}}{2} = \left[\frac{1200-(-600)}{2}\right] \times 10^{-6}$$

$$\Rightarrow \quad \gamma_{max} = 1800 \times 10^{-6}$$

28. (c)

29. (c)

Beam of uniform strength refers to a condition when extreme fibers of the beam are stressed to uniform stress along throughout length of beam.

30. (c)

Bending moment at point C = 0

∴ Taking moments about C on RHS,

$$V_B \times 2 = 0$$

$$\Rightarrow \quad V_B = 0 \text{ kN}$$

$$\because \quad V_A + V_B = 50$$

$$\Rightarrow \quad V_A = 50 \text{ kN} (\uparrow)$$

31. (b)

Springs having helix angle less than 10° are termed as close-coiled springs; springs having helix angle greater than 10° are termed as open-coiled springs.

32. (a)

$$\text{Torsional stiffness} = \frac{GJ}{L}$$
$$\text{Flexural stiffness} = \frac{EI}{L}$$
$$\text{Axial stiffness} = \frac{AE}{L}$$
$$\text{Torsional rigidity} = GJ$$
$$\text{Flexural rigidity} = EI$$
$$\text{Axial rigidity} = AE$$

33. (d)

34. (c)

Given:
$$\varepsilon_1 = 515 \times 10^{-6}$$
$$\varepsilon_2 = -200 \times 10^{-6}$$
$$E = 200 \text{ GPa} = 2 \times 10^5 \text{ N/mm}^2$$
$$\nu = 0.3$$

Principal stresses are given by,

$$\sigma_1 = \frac{E(\varepsilon_1 + \mu\varepsilon_2)}{1-\mu^2}$$

$\Rightarrow$
$$\sigma_1 = \frac{2\times10^5\left(515+0.3(-200)\right)10^{-6}}{1-0.3^2}$$

$\Rightarrow$
$$\sigma_1 = \frac{0.2(455)}{0.91} = 100 \text{ MPa}$$

and
$$\sigma_2 = \frac{E(\varepsilon_2 + \mu\varepsilon_1)}{1-\mu^2}$$

$\Rightarrow$
$$\sigma_2 = \frac{2\times10^5\left(-200+0.3(515)\right)10^{-6}}{1-0.3^2}$$

$\Rightarrow$
$$\sigma_2 = \frac{0.2(-45.5)}{0.91} = -10 \text{ MPa}$$

35. (d)

36. (b)

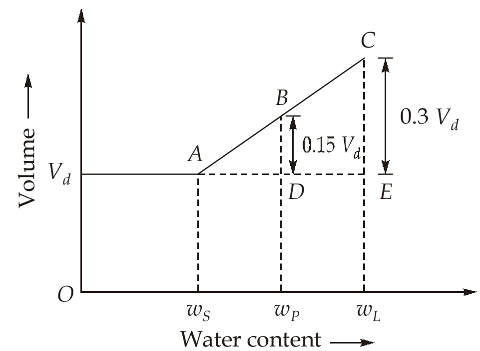
$$P_{cr} = \frac{\pi^2 EI}{l_{eff}^2}$$

The critical load of a column is proportional to the flexural rigidity and inversely proportional to the square of the length. However, the strength of material itself does not appear in the equation for the critical load. Thus, the critical load is not increased by using a stronger material.

37. (b)

Section B : Geo-technical & Foundation Engineering-I

38. (a)



Given:
$$I_P = 18\%$$
$$w_L = 45\%$$

Now,
$$I_P = w_L - w_p$$
$$\Rightarrow \quad w_p = w_L - I_P$$
$$\Rightarrow \quad w_p = 45 - 18 = 27\%$$

In ΔABD and ΔACE,
$$\frac{AD}{AE} = \frac{BD}{CE}$$
$$\Rightarrow \quad \frac{w_p - w_s}{w_L - w_s} = \frac{0.15\,V_d}{0.3\,V_d}$$
$$\Rightarrow \quad \frac{27 - w_s}{45 - w_s} = \frac{1}{2}$$
$$\Rightarrow \quad 2(27 - w_s) = 45 - w_s$$
$$\Rightarrow \quad 54 - 2w_s = 45 - w_s$$
$$\Rightarrow \quad w_s = 54 - 45 = 9\%$$

39. (d)

40. (d)

Stress at center of circular loaded area using Boussinesq's theory is given by,
$$\sigma_z = q\left[1 - \frac{1}{\left(1 + \frac{r^2}{z^2}\right)^{3/2}}\right]$$
$$\Rightarrow \quad \sigma_z = 60\left[1 - \frac{1}{\left(1 + \left(\sqrt{3}\right)^2\right)^{3/2}}\right]$$

$$\Rightarrow \quad \sigma_z = 60\left[1-\frac{1}{(4)^{3/2}}\right] = 60\left(1-\frac{1}{8}\right)$$

$$\Rightarrow \quad \sigma_z = 60\times\frac{7}{8} = 52.5 \text{ kN/m}^2$$

41. (d)

Flow index, $$I_F = \frac{w_1 - w_2}{\log\left(\frac{N_2}{N_1}\right)}$$

$$\Rightarrow \quad I_F = \frac{64-36}{\log\left(\frac{100}{10}\right)} = 28\%$$

$$I_P = w_L - w_P = 50\% - 37\% = 13\%$$

Toughness index, $$I_T = \frac{I_P}{I_F}$$

$$\Rightarrow \quad I_T = \frac{13}{28} = 0.47 \quad \text{(Nearest option is (d))}$$

42. (a)

Given: $D_{10} = 0.002$ cm

Effective pore diameter,

$$d = 0.2 \times D_{10}$$

$$\Rightarrow \quad d = 0.2 \times 0.002 = 0.0004 \text{ cm}$$

Maximum height of capillary rise at 20°C,

$$h_{c\,\max} = \frac{0.2968}{d} \text{cm} \qquad [d \text{ in cm}]$$

$$\Rightarrow \quad h_{c\,\max} = \frac{0.2968}{0.0004} = 742 \text{ cm}$$

$$= 74.2 \text{ m}$$

43. (c)

In Rankine's theory, with an inclined backfill or inclined surcharge, the vertical and lateral stresses are assumed to be conjugate and inclined by the same angle as the slope of the backfill. Wall friction is neglected in this assumption.

44. (c)

$$G_s = \frac{W_s}{V_1\gamma_w - W_1 + W_3} = \frac{22}{20\times1-34+22} = \frac{22}{8} = 2.75$$

45. (d)

For over consolidated soils,

$$k_o = k_{o(NCC)}\sqrt{OCR}$$

$$\Rightarrow \quad k_o = 0.54\sqrt{4} = 0.54 \times 2 = 1.08$$

46. (b)

Effective stress,

$$\bar{\sigma} = \sigma - u$$

$$\Rightarrow \quad \bar{\sigma} = 240 - 100$$

$$\Rightarrow \quad \bar{\sigma} = 140 \text{ kN/m}^2$$

Shear strength,

$$\tau = c' + \bar{\sigma}\tan\phi'$$

$$\Rightarrow \quad \tau = 20 + 140 \tan 30°$$

$$\Rightarrow \quad \tau = 20 + \frac{140}{\sqrt{3}}$$

$$\Rightarrow \quad \tau = 20 + \frac{140}{1.732}$$

$$\Rightarrow \quad \tau = 20 + 80.83 = 100.83 \text{ kN/m}^2$$

$$\Rightarrow \quad \tau \approx 101 \text{ kN/m}^2$$

47. (b)

For one-way drainage: H = Thickness of clay layer

For two-way drainage: H = Half of thickness of clay layer.

48. (d)

Isomorphous substitution: In a clay mineral lattice, metallic ions of one kind may be substituted by other metallic ions of a lower valency, but of the same physical size.

In montmorillonite, the interlayer space can hold moisture and exchangeable cations, causing swelling of clay.

49. (b)

$$C_v = \frac{k_z}{m_v \gamma_w}$$

Also,

$$m_v = \frac{a_v}{1+e_o}$$

$$\therefore \quad C_v = \frac{k_z(1+e_o)}{a_v \gamma_w}$$

50. (a)

At any stage during a triaxial test, either the pore-water line is kept open and the drainage line closed, or the drainage line is kept open and the pore-water line closed. In other words, the measurement of pore-water pressure is carried out under undrained conditions, whereas the measurement of volume change is made under drained conditions. Hence, both parameters cannot be measured simultaneously during the same stage of the test.

51. (a)

We know, $T_v = C_v \dfrac{t}{d^2}$

For a soil, T_v and C_v are constants.

$$\therefore \quad \frac{t_l}{d_l^2} = \frac{t_f}{d_f^2}$$

$$\Rightarrow \quad \frac{4}{\left(\frac{40}{2}\right)^2} = \frac{t_f}{(4000)^2}$$

$$\Rightarrow \quad t_f = \frac{4000^2 \times 4}{400}$$

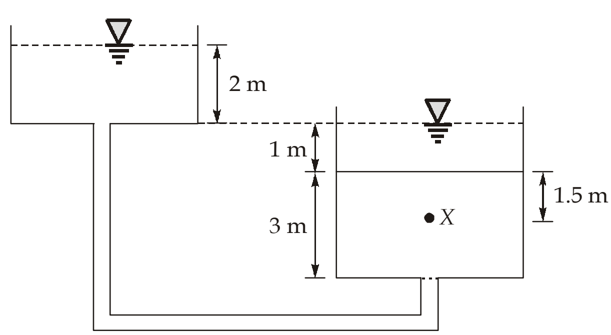
$$\Rightarrow \quad t_f = 160000 \text{ hours}$$

$$\Rightarrow \quad t_f \simeq 6667 \text{ days}$$

52. (a)

Adding coarser fractions such as sand or silt to a clayey soil generally causes both the liquid limit and the plasticity index of the soil to decrease. This occurs because the inclusion of non-plastic coarse particles dilutes the clay fraction, thereby reducing the soil's specific surface area and its capacity to adsorb and retain water. As a result, both the water-holding ability and the plasticity range of the soil decrease.

53. (c)



Total head loss = 2 m

Length of soil = 3 m

Hydraulic gradient, $i = \dfrac{2}{3}$

Effective stress at X, $\bar{\sigma}_x = \gamma' z - iz\gamma_w$

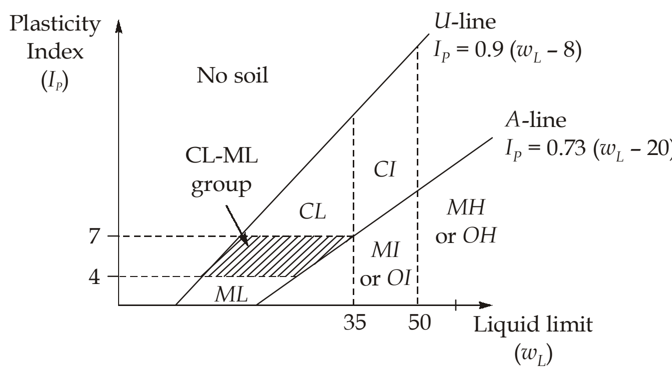
$$\Rightarrow \quad \bar{\sigma}_x = (18 - 10)\, 1.5 - \frac{2}{3} \times 1.5 \times 10$$

$$\Rightarrow \quad \bar{\sigma}_x = 2 \text{ kN/m}^2$$

54. (b)

Pore pressure parameters, introduced by Skempton, are dimensionless quantities that define the relationship between changes in total stress and the resulting change in pore-water pressure under undrained loading conditions. The induced pore pressure may be positive or negative, depending on the soil type and stress history.

55. (c)



Casagrande's Chart

56. (a)

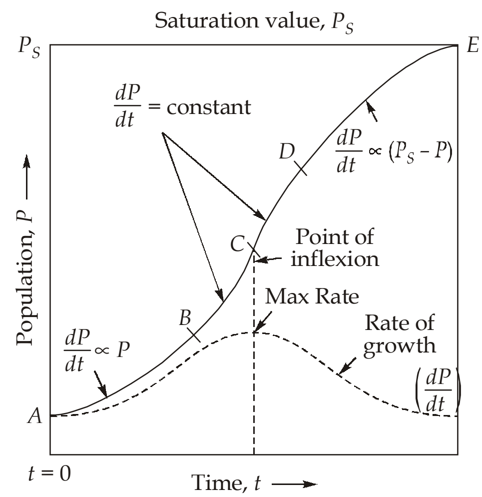
The effective stress in the soil at any point is increased by an amount equal to the seepage force at that point for downward flow. This happens due to the fact that the seepage force is the viscous drag transmitted to the particles while the seeping water is being pushed through the pores.

Section C : Environmental Engineering-I

57. (b)

- **Specific storage:** The volume of water released from unit volume of a saturated aquifer under unit change in head is known as specific storage.
- **Storativity:** The volume of water released from storage per unit surface area of aquifer per unit decline in the component of hydraulic head normal to that surface.
- **Transmissivity:** The ability of movement of water through an aquifer.
- **Hydraulic diffusivity:** The ratio of transmissivity and storativity.

58. (d)



Ideal population growth curve or logistic curve

59. (c)

Ozone, formaldehydes and PANs are formed by the photochemical reactions caused by sunlight between two primary pollutants.

60. (c)

While small concentrations of silver ions help control microbial growth, excessive or prolonged exposure through drinking water can lead to Argyria. It is a condition in which silver accumulates in body tissues, producing bluish-grey pigmentation of the skin, eyes and mucous membranes. Silver is also toxic to aquatic organisms. Acceptable limit and cause for rejection limit in drinking water for silver is 0.1 mg/*l*. (Table 2 of IS 10500 : 2012)

61. (b)

To prevent the spread of water-borne diseases, the following preventive or precautionary measures are recommended:

- **Water Supply Inspection:** All town or city water sources, including wells and hand pumps, must be regularly checked and disinfected to ensure a safe and wholesome supply.
- **Pipe Network Maintenance:** Water pipelines should be frequently tested for leakage and contamination; all leaking joints must be properly sealed.
- **Proper System Design:** While designing the distribution network, sewer lines and water lines must be laid as far apart as possible to prevent cross-contamination.
- **Emergency Disinfection:** During floods or low-flow periods, when surface sources are likely to be contaminated, public warning must be issued to use water after-boiling and extra chlorination applied.
- **Public Food Hygiene:** People should be advised to eat freshly cooked, hot food, avoid raw foods, and use personal utensils, especially while travelling.
- **Cleanliness and Sanitation:** General cleanliness should be inculcated; open urination and defecation must be prevented by providing adequate public urinals and latrines.

- **Fly Control:** The fly nuisance should be minimized through cleanliness and the use of insecticides, as flies act as disease vectors.
- **Immunization and Personal Hygiene:** On disease outbreaks, prompt inoculation of the public and strict personal hygiene (especially hand-washing after patient contact) must be enforced.

62. (a)

- **Ecotone:** An ecotone is a transitional zone between two ecosystems, where the communities of both meet and integrate. This zone often exhibits the edge effect, leading to higher species diversity due to the presence of species from both adjoining communities as well as unique species confined to the ecotone.
- **Ecological Amplitude:** Ecological amplitude of a species refers to the range of environmental conditions within which it can survive, grow, and reproduce successfully. It includes tolerance to parameters such as temperature, humidity, soil type, and light intensity. Species with a broad ecological amplitude can adapt to a wide range of environments (e.g., eurythermal species), while those with a narrow amplitude are stenothermal.
- **Climax Community:** In ecological succession, the climax community represents a stable and self-sustaining state with maximum biomass and productivity attainable under existing climatic conditions. It marks the final, equilibrium stage of succession, in harmony with local environmental factors.

63. (a)

In grit chambers, particles like sand and silt settle individually without mutual interference or flocculation. Hence, settling is discrete i.e. type I settling.

64. (c)

We know that,

$$n \text{ dB} + n \text{ dB} + n \text{ dB} = (n + 4.8) \text{ dB}$$

$$\therefore \quad 60 \text{ dB} + 60 \text{ dB} + 60 \text{ dB} = (60 + 4.8) \text{ dB} = 64.8 \text{ dB}$$

65. (a)

We know,

1 mg/l of alum reacts with 0.45 mg/l of alkalinity as $CaCO_3$.

$\therefore$ For 9 mg/l of alkalinity as $CaCO_3$,

$$\text{Filter alum required} = \frac{9}{0.45} mg/l = 20 \text{ mg}/l$$

$$\text{Water treated per day} = 20 \times 10^6 \, l$$

$$\text{Alum required per day} = 20 \times 10^6 \times 20 \text{ mg} = 400 \times 10^6 \text{ mg}$$

$$\text{Alum required per year} = 400 \times 365 = 146000 \text{ kg} = 146 \text{ tonnes}$$

66. (b)

Pulp and paper industries require water free from iron and manganese.

67. (d)

68. (d)

We know,

$$\frac{D_e}{D} = \frac{1-n}{1-n_e}$$

$$\Rightarrow \quad \frac{1.2}{1} = \frac{1-0.55}{1-n_e}$$

$$\Rightarrow \quad 1 - n_e = \frac{0.45}{1.2}$$

$$\Rightarrow \quad n_e = \frac{5}{8}$$

Now, head loss through expanded bed,

$$H_L = D_e (1 - n_e) (G - 1)$$

$$\Rightarrow \quad H_L = 1.2 \left(1-\frac{5}{8}\right) (2.65 - 1)$$

$$\Rightarrow \quad H_L = 1.2 \times \frac{3}{8} \times 1.65$$

$$\Rightarrow \quad H_L = 0.74 \text{ m}$$

69. (b)

- When excess lime is added to water, it raises the pH of water to such levels of alkalinity that are detrimental to bacteria. When the lime raises the pH of water to about 9.5, 99.9% to 100% bacteria are removed.
- Treatments like recarbonation are used after disinfection for removal of excess lime from water before it is supplied to the general public.

70. (c)

$$T_a = 273 + 13 = 286\ K$$
$$T_s = 273 + 156 = 429\ K$$
$$\Delta T = 429 - 286 = 143\ K$$

By Holland's equation, rise of plume above the stack,

$$\Delta h = \frac{v_s D}{u}\left[1.5+\left(2.68\times10^{-3}\times\frac{pD\Delta T}{T_s}\right)\right]$$

$$\Rightarrow \quad \Delta h = \frac{9\times1}{3}\left[1.5+\left(2.68\times10^{-3}\times\frac{1000\times1\times143}{429}\right)\right]$$

$$\Rightarrow \quad \Delta h = 3\left[1.5+\left(2.68\times\frac{1}{3}\right)\right]$$

$$\Rightarrow \quad \Delta h = 4.5 + 2.68 = 7.18 \text{ m}$$

Effective height of stack,

$$H = h + \Delta h = 210 + 7.18 = 217.18 \text{ m}$$

71. (b)

Electrodialysis is primarily implemented for the desalination of brackish water.

72. (d)

- The membrane filter technique detects coliforms by filtration and incubation on selective media. Visible colonies thus formed are then counted.
- Coliform bacteria ferment lactose with formation of gas within a maximum of 48 hours at 35°C. This property of coliform organisms is used in multiple tube fermentation technique.
- The MPN index is a statistical estimation of coliform density per 100 mL, based on the number of positive tubes in different dilutions.

73. (d)

Highly turbid waters are difficult to treat by zeolite process as the suspended impurities deposited around the zeolite particles obstruct the working of the zeolite.

74. (b)

- The distribution system is designed for maximum hourly draft or the maximum daily demand or coincident draft with fire, whichever is more.
- Coincident draft is taken as the sum of maximum daily draft and fire draft.

75. (c)

As the grain size increases, the interstitial surface area reduces, and therefore, specific retention also reduces while specific yield increases.

■■■■