PRE-GATE-2020
Civil Engineering
(Questions with Detailed Solutions)

The GA section consists of 10 questions. Questions 1 to 5 are of 1 mark each, and Questions 6 to 10 are of 2 marks each.

Q. 1 – Q. 5 carry one mark each.

01. Fill in the blank with an appropriate phrase
Jobs are hard to _____ these days
(A) Come by (B) Come down
(C) Come of (D) Come from

01. Ans: (A)

Sol: 'Come by' means to manage to get something.

02. The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.
MONKEY : TROOP:
(A) sheep : hard
(B) elephant : Parliament
(C) bacteria : Colony
(D) wolves : School

02. Ans: (C)

Sol: Troop consists of monkeys just as a colony consists of bacteria.

03. ***Choose the most appropriate word from the options given below to complete the following sentence:***
If you had gone to see him, he _______ delighted.
(A) Would have been (B) Will have been
(C) Had been (D) Would be

03. Ans: (A)

Ans: 'A" conditional tense type 3 grammatical code is
If +had+V3, would +have+V3

04. Which of the following options is closest in meaning to the underlined word?
European intellectuals have long debated the consequences of the **hegemony** of American popular culture around the world.
(A) regimen (B) vastness
(C) dominance (D) popularity

04. Ans: (C)

Sol: Dominance means influence or control over another country, a group of people etc.

05. How many one-rupee coins, 50 paise coins 25 paise coins in total of which the numbers are proportional to 5, 7 and 12 are together work ₹115?
(A) 50, 70, 120 (B) 60, 70, 110
(C) 70, 80, 90 (D) None of these

05. Ans: (A)

Sol: $(5 \times 1+7\times0.5+12\times0.25)\ x = 115$
$(5+3.5+3)\ x = 115$
$11.5x = 115$
$x = 10$
$\therefore$ Number of one rupee coin = $5x = 5\times10 = 50$
Number of 5-paise coin = $7x = 7\times10 = 70$
Number of 25-paise coin = $12x = 12\times10 = 120$

Q. 6 – Q. 10 carry Two marks each.

06. Critical reading is a demanding process. To read critically, you must slow down your reading and, with pencil in hand, perform specific operations on the text mark up the text with your reactions, conclusions, and questions, then you read, become an active participant.

This passage best supports the statement that

(A) Critical reading is a slow, dull but essential process.

(B) The best critical reading happens at critical times in a person's life.

(C) Readers should get in the habit of questioning the truth of what they read.

(D) Critical reading requires thoughtful and careful attention.

06. Ans: (D)

Sol: Choice (A) is incorrect because the author never says that reading is dull.

Choice (B) and (C) are not support by the paragraph.

Choice (D) is correct as it is implied in the entire passage.

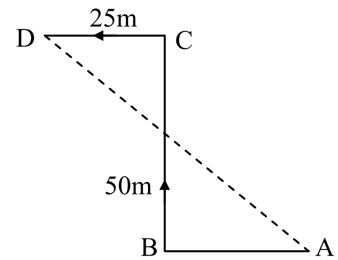
07. Anil's house faces east from the back-side of the house, he walks straight 50 metres, then turns to the right and walks 50m again finally, he turns towards left and stops after walking 25 m Now Anil is in which direction from the starting point?

(A) South-east (B) South-west

(C) North-east (D) North- west

07. Ans: (D)

Sol: The movement of Anil are shown in the adjoining figure



He starts walking from back of his house (i.e) towards west now, the final position is D, which is to the north west of his starting point A.

08. A and B enter into a partnership, A puts in ₹50 and B puts in ₹45. At the end of 4 months, A withdraws half his capital and at the end of 5 months B withdraws $\frac{1}{2}$ of his, C then enters with a capital of ₹70 at the end of 12 months, the profit of concern is ₹254, how can the profit be divided among A, B and C ?

(A) ₹76, ₹80 and ₹98 (B) ₹80, ₹76 and ₹98

(C) ₹76, ₹98 and ₹80 (D) None of these

08. Ans: (B)

Sol: A's share : B's share : C's share

$(50\times4+25\times8) : (45\times5+22.5\times7) : (70\times7)$

400 : 382.5 : 490

800 : 765 : 980

160 : 153 : 196

Total profit = ₹254

Profit of A

$= \frac{160}{160+153+196} \times 254 = \frac{160}{509} \times 254 = ₹80$

Profit of B = $\frac{153}{509} \times 254 = ₹76$

Profit of C = $\frac{196}{509} \times 254 = ₹98$

∵ Hence option 'B' is correct.

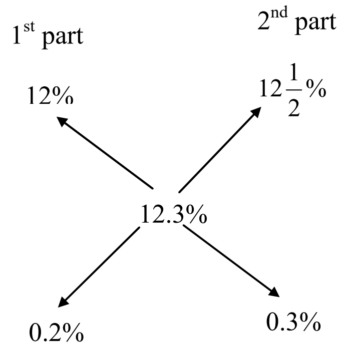
09. A sum of ₹25400 was lent out in two parts, one of 12% and the other at $12\frac{1}{2}$%. If the total annual income is ₹3124.2, the money lent at 12% is ____.

(A) ₹15240 (B) ₹25400

(C) ₹10160 (D) ₹31242

09. Ans: (C)

Sol: Overall rate of interest $\frac{3124.2}{25400} \times 100 = 12.3\%$



∴ The sum will be divided in the ratio 0.2:0.3 (or) 2:3

∴ The sum lent at 12%

$= 25400 \times \frac{2}{5} = ₹10160.$

10. The following question is to be answered on the basis of the table given below.

Category of personnel	**Number of staff in the year-1990**	**Number of staff in the year-1995**
Data preparation	18	25
Data control	5	8
Operators	18	32
Programmers	21	26
Analysts	15	31
Managers	3	3
Total	80	135

What is the increase in the sector angle for operators in the year 1995 over the sector angle for operators in the year 1990?

(A) 4° (B) 3° (C) 2° (D) 1°

10. Ans: (A)

Sol: Sector angle for operators in the year 1990

$= \frac{18}{80} \times 360° = 81°$

Sector angle for operator in the year 1995 $= \frac{32}{135} \times 360° = 85.33 \simeq 85\%$

∴ Required difference = 85°– 81°= 4°

Q. 11 – Q. 35 carry one mark each.

11. For the function $f(x, y) = x^2 - y^2$, the point (0, 0) is

(A) a local minimum

(B) a saddle point

(C) a local maximum

(D) not a stationary point

11. Ans: (B)

Sol: Given $f(x,y) = x^2 - y^2$

$\Rightarrow f_x = 2x,\ f_y = -2y$ and

$f_{xx} = 2,\ f_{xy} = 0,\ f_{yy} = -2$

Consider $f_x = 0$ and $f_y = 0$

$\Rightarrow 2x = 0$ and $-2y = 0$

$\Rightarrow (0,0)$ is a stationary point

At (0, 0), $f_{xx}\,f_{yy} - (f_{xy})^2 = -4 < 0$

$\therefore$ f(x, y) has neither a maximum nor minimum at (0, 0).

12. A continuous random variable X has a probability density function $f(x) = e^{-x}$, $0 < x < \infty$. Then $P(X > 2)$ is

(A) 0.1353 (B) 0.2354

(C) 0.2343 (D) 1.1353

12. Ans: (A)

Sol: $P(X > 2) = \int_2^\infty f(x)\cdot dx$

$= \int_2^\infty e^{-x} dx$

$= \left.\frac{e^{-x}}{-1}\right|_2^\infty$

$= e^{-2} = 0.1353$

13. The solution to $x^2y^{11} + xy^1 - y = 0$ is

(A) $y = C_1x^2 + C_2\,x^{-3}$ (B) $y = C_1 + C_2x^{-2}$

(C) $y = C_1\,x + \frac{C_2}{x}$ (D) $y = C_1\,x + C_2\,x^4$

13. Ans: (C)

Sol: Put $ln\,x = t$ so that $x = e^t$ and

let $x\frac{dy}{dx} = Dy$, $x^2\frac{d^2y}{dx^2} = D(D-1)\,y$

where $D = \frac{d}{dt}$

Given differential equation is

$x^2y^{11} + xy^1 - y = 0$

$\Rightarrow D(D-1)y + Dy - y = 0$

$\Rightarrow (D^2 - 1)\,y = 0$

Consider Auxiliary equation f(D) = 0

$\Rightarrow D^2 - 1 = 0$

$\Rightarrow D = 1, -1$ are different real roots

$\therefore$ The general solution of given equation is

$y = c_1e^t + c_2e^{-t}$

$= c_1\,x + \frac{c_2}{x}$

14. A numerical solution of the equation $f(x) = x + \sqrt{x} - 3 = 0$ can be obtained using Newton – Raphson method. If the starting value is $x = 2$ for the iteration then the value of x that is to be used in the next step is

(A) 1.306 (B) 2.739

(C) 1.694 (D) 2.306

14. Ans: (C)

Sol: Given $f(x) = x + \sqrt{x} - 3 = 0$ and $x_0 = 2$

$f^1(x) = 1 + \frac{1}{2\sqrt{x}}$

Newton – Raphson formula is

$$x_{n+1} = x_n - \frac{f(x_n)}{f^1(x_n)}$$

$$\Rightarrow x_1 = x_0 - \frac{f(x_0)}{f^1(x_0)}$$

$$= 2 - \frac{(2+\sqrt{2}-3)}{\left(1+\frac{1}{2\sqrt{2}}\right)} = 1.6939$$

$x_1 = 1.6939$

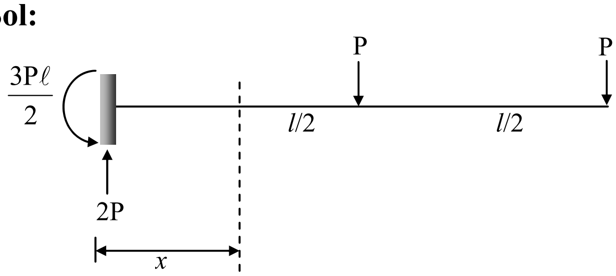
15. Which of the following statements are correct?
    P. Modulus of sub-grade reaction can be estimated by CBR test
    Q. Emulsion is used for wet and cold climatic conditions
    R. Los Angeles test is a hardness cum impact test on aggregates.
    (A) P and Q (B) P and R
    (C) Q and R (D) P, Q and R

15. Ans: (C)

16. A cantilever of length l carries two concentrated loads each of magnitude P placed at distances $l/2$ and l from the fixed end .The strain energy stored by the cantilever is
    (A) $\left(\frac{13P^2\ell^3}{24EI}\right)$ (B) $\left(\frac{P^2\ell^3}{8EI}\right)$
    (C) $\left(\frac{7P^2\ell^3}{24EI}\right)$ (D) $\left(\frac{P^2\ell^3}{12EI}\right)$

16. Ans: (C)

Sol:



$$M_x = 2Px - \frac{3P\ell}{2}$$

$$U = \int_0^\ell \frac{M_x^2}{2EI}.dx = \int_0^\ell \left(\frac{4Px - 3P\ell}{2EI}\right)$$

$$= \frac{1}{8EI}\int_0^\ell (16P^2x^2 + 9P^2\ell^2 - 24P^2x\ell)dx$$

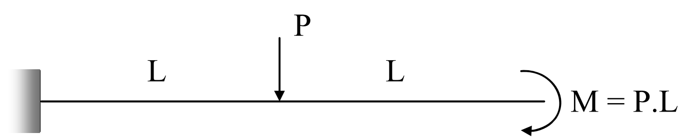
$$= \frac{1}{8EI}\times\left[\frac{16P^2x^3}{3} + 9P^2\ell^2.x - \frac{24P^2\ell.x^2}{2}\right]_0^\ell$$

$$= \frac{1}{8EI}\times\left[\frac{16P^2\ell^3}{3} + 9P^2\ell^3 - 12P^2\ell^3\right]$$

$$= \frac{P^2\ell^3}{8EI}\times\left[\frac{16+27-36}{3}\right]$$

$$= \frac{7P^2\ell^3}{24EI}$$

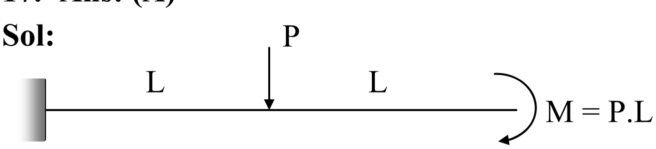
17. A cantilever beam is subjected to the loads as shown in figure. The deflection under the point load is ______.



(A) $\frac{5PL^3}{6EI}$ (B) $\frac{3PL^3}{8EI}$
(C) $\frac{6PL^3}{32EI}$ (D) $\frac{PL^3}{3EI}$

17. Ans: (A)

Sol:



Deflection under point load

$$= \frac{PL^3}{3EI} + \frac{ML}{EI}\left(\frac{L}{2}\right)$$

$$= \frac{PL^3}{3EI} + \frac{(PL)L^2}{2EI} = \frac{PL^3}{EI}\left(\frac{1}{3}+\frac{1}{2}\right) = \frac{5PL^3}{6EI}$$

18. A 300 mm diameter well penetrates fully a confined aquifer of thickness 30 m. When the well is pumped at a rate of 900 litres/min, the steady state draw downs in the two observation wells located at 10 m and 75 m radial distance from the pumping well are found to be 2.8 m and 1.2 m respectively. The coefficient of transmissibility would be ____ m^2/day.
(A) 180.38 (B) 112.81
(C) 259.75 (D) 78.34

18. Ans: (C)

Sol: Q = 900 *l*/min, B = 30 m, d_w = 300 mm
$r_1 = 10\text{ m} \rightarrow S_1 = 2.8\text{ m}$, $r_2 = 75\text{ m} \rightarrow S_2 = 1.2\text{ m}$
T = ? m^2/day

$$Q = \frac{2\pi T(S_1 - S_2)}{\ell n\left(\frac{r_2}{r_1}\right)}$$

$$\frac{900\times10^{-3}}{\left(\frac{1}{24}\times\frac{1}{60}\right)} = \frac{2\times\pi\times T(2.8-1.2)}{\ln\left(\frac{75}{10}\right)}$$

T = 259.75 m^2/day

Q = 900 μ min used then answer will be 180.38 conversion required

If log is used answer will be 112.809

19. A well with a radius of 0.5 m completely penetrates in an unconfined aquifer of thickness 50 m and K = 9.772 m/day. The water level in the well remians at 40 m up on pumping. Assuming that pumping has essentially no effect on water at R = 500 m, what is the steady stage discharge ?
(A) 4886 m^3/day (B) 4000 m^3/day
(C) 5333.07 m^3/day (D) 241.857 m^3/day

19. Ans: (B)

Sol:

$$Q = \frac{\pi K[H_2^2 - H_1^2]}{\ell n\left[\frac{r_2}{r_1}\right]} = \frac{\pi K[H^2 - h^2]}{\ell n\left[\frac{R}{r_w}\right]} = \frac{\pi\times 9.772[50^2 - 40^2]}{\ell n\left[\frac{500}{0.5}\right]}$$

3999.8 ≃ 4000 m^3/day

20. Criteria for satisfactory performance of footings are
1. Soil supporting the footing must be safe against shear failure
2. Footing must be rigid
3. Footing must not settle beyond permissible value
4. Footing should be above water table

Which of the following statements are correct?
(A) 3 and 4 only (B) 1 and 2 only
(C) 1 and 3 only (D) 2 and 4 only

20. Ans: (C)

Sol: For satisfactory performance, footing need not be rigid, it can be flexible too and water table can be anywhere

21. Correction for fines in standard penetration test is given by
(A) $N'' = 15 + \frac{1}{2}(N' + 15)$
(B) $N'' = 15 + \frac{1}{2}(N' - 15)$
(C) $N'' = 50 + \frac{1}{2}(N' - 15)$
(D) $N'' = 50 + \frac{1}{2}(N' + 15)$

21. Ans: (B)

22. The Design criteria for an Inverted filter to prevent piping failure due to upward seepage as given by Terzaghi is

(A) $\frac{D_{15}\text{ of filter}}{D_{85}\text{ of foundation}} < 4 \text{ to } 5 < \frac{D_{10}\text{ of filter}}{D_{15}\text{ of foundation}}$

(B) $\frac{D_{85}\text{ of foundation}}{D_{15}\text{ of filter}} < 4 \text{ to } 5 < \frac{D_{15}\text{ of filter}}{D_{15}\text{ of foundation}}$

(C) $\frac{D_{15}\text{ of filter}}{D_{85}\text{ of foundation}} < 20 \text{ to } 25 < \frac{D_{15}\text{ of filter}}{D_{15}\text{ of foundation}}$

(D) $\frac{D_{15}\text{ of filter}}{D_{85}\text{ of foundation}} < 4 \text{ to } 5 < \frac{D_{15}\text{ of filter}}{D_{15}\text{ of foundation}}$

22. Ans: (D)

23. In PERT analysis the time estimate of activities correspond to

(A) Normal distribution

(B) Poisson's distribution

(C) β-distribution

(D) Binomial distribution

23. Ans: (C)

Sol: In PERT, for an activity β-distribution is used but for entire project normal distribution is used.

24. If $\tau = \left(\frac{du}{dy}\right)^3$ and $\vec{V} = y^2\hat{i}$, then the apparent viscosity is

(A) 2y (B) $2y^2$

(C) 0 (D) $4y^2$

24. Ans: (D)

Sol: Given that $\tau = \left(\frac{du}{dy}\right)^3$ and $u = y^2$

$$\tau = \left(\frac{du}{dy}\right)^2 \times \left(\frac{du}{dy}\right)$$

$$= \mu_{app.} \times \left(\frac{du}{dy}\right)$$

Where $\mu_{app} = \left(\frac{du}{dy}\right)^2 = \left[\frac{d}{dy}\left(y^2\right)\right]^2 = [2y]^2$

$$= 4y^2$$

25. A hydraulic turbine operates at the following parameters at its best efficiency point: speed = 90 rpm, discharge = 200 m^3/s, net head = 55 m and brake power = 100 MW. The dimensionless specific speed in radians of this turbine is

(A) 190 (B) 1.13

(C) 3.17 (D) 36.24

25. Ans: (B)

Sol: Given data:

N = 90 rpm, Q = 200 m^3/s, H = 55 m and P = 100 MW

The dimensionless specific speed of a turbine is given as:

$$N_s^* = \frac{\omega\sqrt{P/\rho}}{(gH)^{5/4}}$$

where, ω = speed in rad/s

P = Power in Watt

Thus, $N_s^* = \frac{2\pi \times \frac{90}{60}\sqrt{\frac{100\times 10^6}{10^3}}}{(9.81\times 55)^{5/4}}$

$$= 0.36\,\pi$$

$$= 1.13$$

26. Find carbonaceous and non-carbonaceous hardness in mg/l as $CaCO_3$ from the following ionic substances found in water
Ca = 4 m eq/lit; Mg = 2 m eq/lit;
CO_3 = 1 m eq/lit; HCO_3 = 2 m eq/lit
(A) 150 & 300 (B) 150 & 200
(C) 150 & 150 (D) 150 & 100

26. Ans: (C)

Sol: TH = Ca × 50 + Mg × 50
= 4 × 50 + 2 × 50
= 300 mg/l as $CaCO_3$
TA = CO_3 × 50 + HCO_3 × 50
= 1 × 50 + 2 × 50
= 150 mg/l as $CaCO_3$
∵TH > TA
CH = TA = 150 mg/l as $CaCO_3$
NCH = TH – CH
= 300 – 150
= 150 mg/l as $CaCO_3$

27. A smoke parcel of temperature 40°C released from a industrial stack would rise vertically above ground. If ELR is –0.5°C/100 m and atmospheric temperature on the top of the stack is 39°C
(A) 10 m (B) 50 m
(C) 100 m (D) 200 m

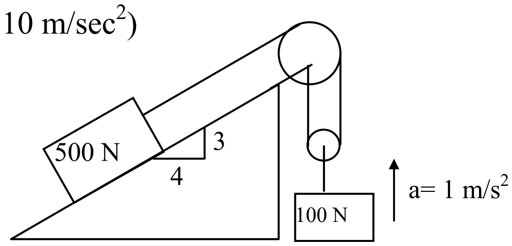
27. Ans: (D)

Sol: Till temperature of smoke parcel is equal to the temperature of ambient atmosphere, smoke parcel will rise.

$$40-\frac{1}{100}\times x = 39-\frac{0.5}{100}\times x$$

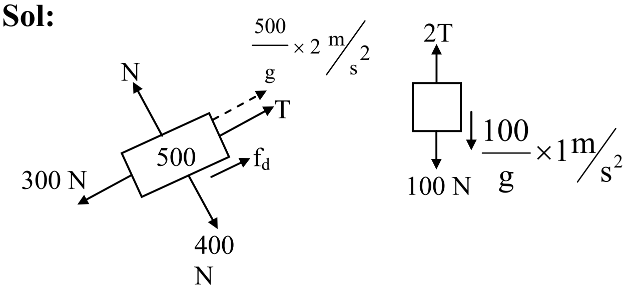
(40 – ALR) = (39 – ELR)
x = 200 m

28. In the figure shown below, the value of co-efficient of dynamic friction between 500 N block and incline is ______ (Assume g = 10 m/sec^2)



28. Ans: 0.36 **Range 0.35 – 0.38**

Sol:



$$T=\frac{100+10}{2}$$

T= 55 N

f_d = 300 – (100 + 55)

f_d = 145 N

$f_d = \mu_d N$

145 = μ_d (400)
μ_d = 0.3625

29. If directional derivative of $\phi = 2xz - y^2$, at the point (1, 3, 2) becomes maximum in the direction of $\bar{a}$, then magnitude of $\bar{a}$ is

29. Ans: 7.48 **Range: 7.4 to 7.5**

Given $\phi = 2xz - y^2$

$$\nabla\phi=\frac{\partial\phi}{\partial x}\bar{i}+\frac{\partial\phi}{\partial y}\bar{j}+\frac{\partial\phi}{\partial z}\bar{k}$$

$= 2z\bar{i} - 2y\bar{j} + 2x\bar{k}$

$\therefore$ Required direction vector

$= \bar{a} = (\nabla\phi)$ at $(1, 3, 2) = (4\bar{i} - 6\bar{j} + 2\bar{k})$

Magnitude of $\bar{a} = \sqrt{16+36+4}$

$= \sqrt{56} = 7.48$

30. A circular area carries an uniformly load of 15 t/m^2 with a radius of 4 m. The intensity of vertical stress at a point 5 m below the centre of circular area will be _____(in t/m^2) (Rounded upto two decimal places)

30. Ans: 7.86 Range: 7.80 – 7.90

$q = 15$ t/m^2

$r = 4$ m

$z = 5$ m

For circular loaded area :

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

$$= 15\left\{1 - \left(\frac{1}{1+\left(\frac{4}{5}\right)^2}\right)^{3/2}\right\}$$

$\therefore \sigma_z = 7.857 \simeq 7.86$ t/m^2

31. During chain survey, sloping ground makes an angle of 60° with horizontal with 30 m chain, the hypotneusal allowance (in m) is ______.

31. Ans: 30 m Range: 29.5 to 30.5

Sol: $\therefore$ Hypotneusal allowance = L (secθ – 1)

= 30 (sec 60° – 1)

= 30 m

32. A RC canopy has an effective span is 6 m. Width of flange is 1000 mm, width of rib is 300 mm and thickness of slab is 100 mm. The beam is monolithically cast with their columns at the ends. The effective width of flange (in m, up to two decimals places) as per IS:456-2000 is (in m) _________.

32. Ans: 0.56 Range: 0.50 to 0.60

RC Canopy is treated as an Isolated L beam

Since it is monolithically constructed, will be options of data the l_o value taken as 0.7 times the effective span

Effective width of flange

$$b_f = \frac{0.5 \times \ell_o}{\frac{\ell_o}{b} + 4} + b_w \not> b$$

(b = width of the flange, b_w = Width of web)

$$= \frac{0.5 \times 0.7 \times 6}{\frac{0.7 \times 6}{1} + 4} + 0.3$$

$= 0.56$ m $< b \quad \therefore$ O.K

33. A mechanical mixing device imparts a power of 1960 watts to water in a rapid mixing tank of size 4 m^3 induce a velocity gradient of ________ S^{-1}. If dynamic viscosity of water is 1×10^{-3} N-sec/m^2.

33. Ans: 700 Range: No Range

Power P = 1960 watts

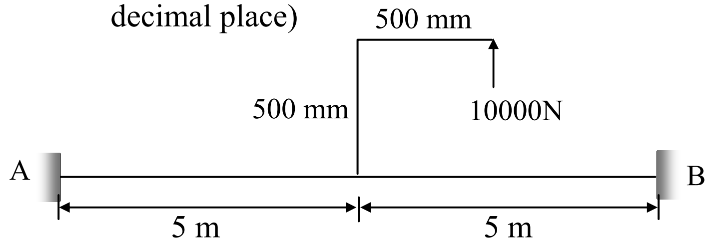
Volume V = 4 m^3

$\mu = 1 \times 10^{-3}$ N sec/m^2

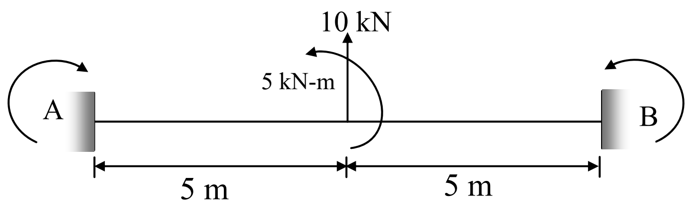
Velocity gradient $G = \sqrt{\frac{P}{v\mu}} = \sqrt{\frac{1960}{4 \times 1 \times 10^{-3}}}$

$= 700$ s^{-1}

34. The fixed end moment at 'A' for the beam shown below is (in kN-m) _____. (up to two decimal place)



34. Ans: 11.25 kN-m **Range: No Range**

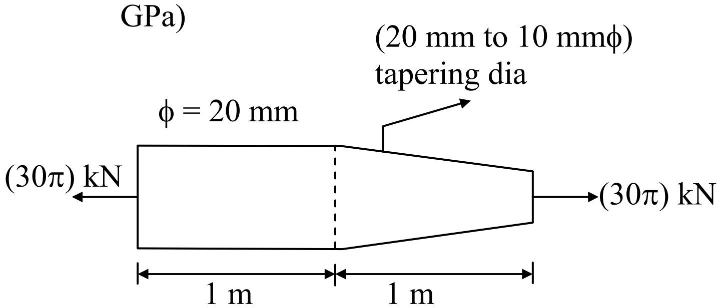


$$@\ A = -\frac{M}{4} + \frac{w\ell}{8}$$

$$= -\frac{5}{4} + \frac{10\times10}{8}$$

$$= 11.25 \text{ kN-m}$$

35. The change in length of bar subjected to axial force of (30π) kN is______ mm (E = 200 GPa)



35. Ans: 4.5 mm **Range: No Range**

Sol: $\delta\ell = \delta\ell_{(1)} + \delta\ell_{(2)}$

$$= \frac{[(30\pi)\times10^3][1000]}{\frac{\pi}{4}(20^2)(200\times10^3)} + \frac{[30\pi\times10^3][1000]}{\frac{\pi}{4}(20\times10)(200\times10^3)}$$

$$= \frac{4\times30\times1000}{(20^2)(200)} + \frac{4\times30\times1000}{(20\times10)(200)} = 1.5 + 3 = 4.5 \text{ mm}$$

Q. 36 – Q. 65 carry Two marks each.

36. Given matrix [A] = $\begin{bmatrix} 4 & 2 & 1 & 3 \\ 6 & 3 & 4 & 7 \\ 2 & 1 & 0 & 1 \end{bmatrix}$, then the system AX = O, where X = $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$ has

(A) no solution
(B) a unique solution
(C) only one independent solution
(D) two linearly independent solutions

36. Ans: (D)

Sol: Given A = $\begin{bmatrix} 4 & 2 & 1 & 3 \\ 6 & 3 & 4 & 7 \\ 2 & 1 & 0 & 1 \end{bmatrix}$

$R_2 \to 4R_2 - 6R_1$;

$R_3 \to 2R_3 - R_1$

$$\sim \begin{bmatrix} 4 & 2 & 1 & 3 \\ 0 & 0 & 10 & 10 \\ 0 & 0 & -1 & -1 \end{bmatrix}$$

$R_3 \to (10)R_3 + R_2$

$$\sim \begin{bmatrix} 4 & 2 & 1 & 3 \\ 0 & 0 & 10 & 10 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$\therefore\ \rho(A) = 2$

$\therefore$ Number of linearly independent solutions
= Number of variables – Rank of A
= 4 – 2 = 2

37. The annual precipitation data of a city is normally distributed with mean and standard deviation as 1000 mm and 200 mm, respectively. The probability that the annual precipitation will be more than 1200 mm is

(A) 0.1587 (B) 0.3174
(C) 0.3456 (D) 0.2345

37. Ans: (A)

Sol: Let X = annual precipitation

We know area under normal curve in the interval $(\mu - \sigma, \mu + \sigma) = 0.6826$

where μ is mean and σ is standard deviation

$\Rightarrow P(800 < X < 1200) = 0.6826$

Required probability = $P(X > 1200)$

$$= \frac{1-0.6826}{2} = 0.1587$$

38. The normal flows on two approach roads at an intersection are respectively 500 pcu/hr, and 300 pcu/hr. The corresponding saturation flow is 1600 pcu/hr, on each road. The lost time per signal cycle is 16 sec. The optimum cycle time as per Webster is _______ sec.

(A) 72.5 sec (B) 58 sec
(C) 48 sec (D) 19.3 sec

38. Ans: (B)

Sol: Websters optimum cycle time,

$$C_o = \frac{1.5L+5}{1-y}$$

Two phase signal $y = y_1 + y_2$

$$= \frac{500}{1600} + \frac{300}{1600} = 0.5$$

Lost time per cycle L = 16 sec

$$\therefore C_o = \frac{1.5\times16+5}{1-0.5} = \frac{29}{0.5} = 58 \text{ sec}$$

39. What will be non-passing sight distance on a highway for a design speed of 100 kmph when its ascending gradient is 2%? Use coefficient of longitudinal friction as 0.7 and lateral coefficient of friction as 0.15. The brake efficiency is 0.5. Perception reaction time of driver is 2.5 sec.

(A) 176 m (B) 200 m
(C) 185 m (D) 150 m

39. Ans: (A)

Sol: Design speed, υ = 27.77 m/s

$$SSD = \upsilon t + \frac{\upsilon^2}{2g(\eta f + G)}$$

$$= 27.77\times2.5 + \frac{27.77^2}{2\times9.81(0.5\times0.7+0.02)}$$

= 69.425 + 771.17 / 7.2594 = 175.65 m

40. Which of the following statements is corresponding to temperature stresses on a rigid pavement.

P. During mid day the warping stress is compressive on the top face of the rigid pavement

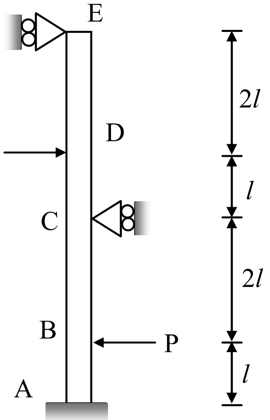
Q. During peak winter pavement will be under compression due to frictional stress

R. Warping stress is zero at the corner of the pavement during mid night.

(A) P, Q and R (B) P only
(C) P and Q (D) Q and R

40. Ans: (B)

41. The plastic moment capacity for the column shown in the figure is M_p. The value of P at collapse is:



(A) $\dfrac{5M_P}{2\ell}$

(B) $\dfrac{3M_P}{\ell}$

(C) $\dfrac{13M_P}{6\ell}$

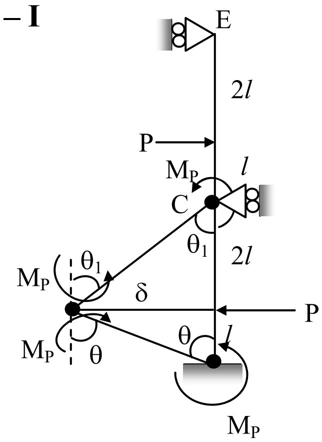
(D) $\dfrac{12M_P}{7\ell}$

41. Ans: (C)

Sol: $r = 4$; $D_s = (r - 2) = 2$; NOP = $D_s + 1 = 3$

There are 3 possible alternate mechanisms as shown below:

ALT – I

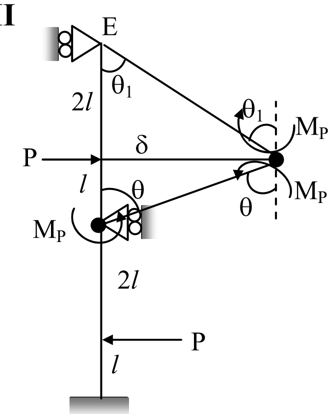


$$P_C \times \delta = M_P\,\theta + M_P\,\theta + M_P\,\theta_1 + M_P\,\theta_1$$

$$P_C \times l \times \theta = 2\,M_P\,\theta + M_P\,\frac{\theta}{2} \times 2$$

$$P_C = \frac{3M_P}{\ell}$$

ALT – II

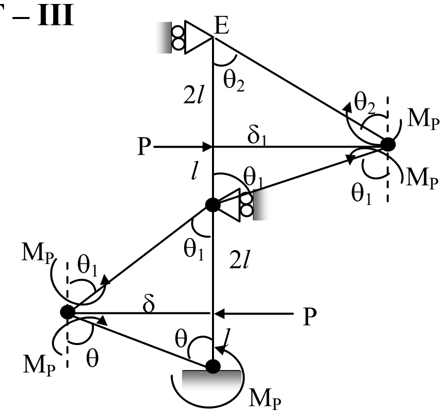


$$P_C \times \delta = M_P\,\theta + M_P\,\theta + M_P\,\theta_1$$

$$P_C \times l \times \theta = 2\,M_P\,\theta + M_P\,\frac{\theta}{2}$$

$$P_C = \frac{5M_P}{2\ell}$$

ALT – III



$$\delta = l\,\theta = 2\,l\,\theta_1$$

$$\theta_1 = \frac{\theta}{2}$$

$$\delta_1 = \ell \times \theta_1 = \frac{\ell\theta}{2} = 2\ell\theta_2$$

$$\theta_2 = \frac{\theta}{4}$$

$$P_C \times \delta + P_C + \delta_1$$

$$= M_P\,\theta + M_P\,\theta + M_P\,\theta_1 + M_P\,\theta_1 + M_P\,\theta_2$$

$$P_C \times \ell\theta + P_C \times \frac{\ell\theta}{2} = 2M_P\theta + 2M_P\frac{\theta}{2} + M_P\frac{\theta}{4}$$

$$P_C = \frac{13M_P}{6\ell}$$

Design collapse load P_C as per upper bound theorem = minimum value obtained from various alternatives $= \frac{13M_P}{6\ell}$

42. A cylindrical rod of diameter 10 mm and 1.0 m length is fixed at one end. The other end is twisted by an angle of 10^o by applying a torque. The maximum shear strain in the rod is _____.
(A) 4.32×10^{-6} radians
(B) 8.72×10^{-4} radians
(C) 1.74×10^{-3} radians
(D) 2.36×10^{-3} radians

42. Ans: (B)

Sol: $\frac{\tau}{r} = \frac{G\theta}{\ell}$

Shear strain, $\phi = \frac{\tau}{G} = \frac{\theta . r}{\ell}$

$$= \frac{\left(10 \times \frac{\pi}{180}\right)(5)}{1000} = 8.72 \times 10^{-4} \text{radian}$$

43. A wide rectangular channel has a Manning's co-efficient of 0.015 carries a discharge of 2 $m^3/s/m$. The possible types of gradually varied flow (GVF) produced in following break in the grade of channel.
S_{01} = 0.0008 and S_{02} = 0.016 respectively are
(A) M_2 only (B) S_2 only
(C) M_2, S_2 (D) M_3, S_1

43. Ans: (C)

Sol: Given : $q = 2\ m^3/s/m$
$n = 0.015$
$S_{01} = 0.0008$
$S_{02} = 0.016$

$\therefore$ Critical depth, $y_c = \left(\frac{q^2}{g}\right)^{1/2}$

$$y_c = \left(\frac{2^2}{9.81}\right)^{1/3} = 0.74 \text{ m}$$

Normal depth, y_n : for wide rectangle

$(P = y,\ R = y)$

$Q = \frac{1}{n}.A.R^{2/3}.S^{1/2}$;

$Q = \frac{1}{n}.By_n.y_n^{2/3}.S_o^{1/2}$

$\therefore\ y_n^{5/3} = \frac{q.n}{\sqrt{S_o}}$

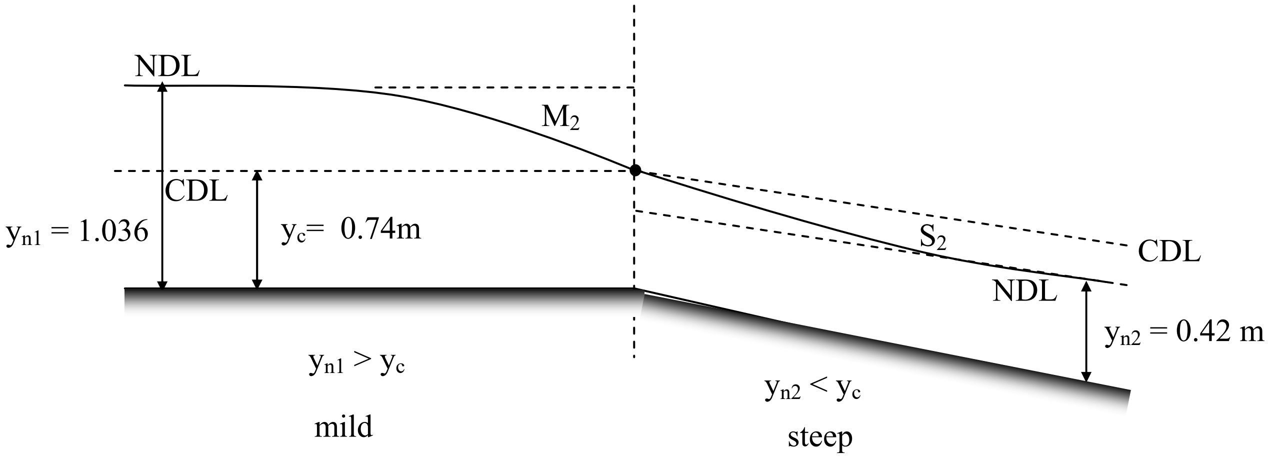
$$S_{01} = 0.0008 \Rightarrow y_{n1} = \left(\frac{2 \times 0.015}{\sqrt{0.0008}}\right)^{3/5} = 1.036\text{m}$$

$$S_{02} = 0.016 \Rightarrow y_{n2} = \left(\frac{2 \times 0.015}{\sqrt{0.016}}\right)^{3/5} = 0.42 \text{ m}$$

$y_{n_1} > y_c \Rightarrow$ mild

$y_{n_2} < y_n \Rightarrow$ steep

Mild slope followed by steep slope



Resulting water surface profiles are M_2 curve on mild slope & S_2 curve on steep slope.

44. Match the following List-I to List-II Based on observation made from Atterberg limit test

Liquid limit, w_L = 60%

Plastic limit, w_p = 40%

Shrinkage limit, w_s = 15%

Natural moisture content, w = 30%

List-I	List-II
P. Consistency Index I_c	1. 25%
Q. Plasticity Index, I_P	2. – 0.5
R. Liquidity Index, I_L	3. 1.5
S. Shrinkage Index, I_S	4. 20%

Codes:

	P	Q	R	S
(A)	2	4	3	1
(B)	2	1	3	4
(C)	3	4	2	1
(D)	3	1	2	4

44. Ans: (C)

Sol: Plasticity index, $I_P = w_L - w_P$

$= 60 - 40 = 20\%$

Shrinkage index, $I_s = w_p - w_s$

$= 40 - 15\% = 25\%$

Consistency Index ,

$$I_c = \frac{w_L - w}{I_p} = \frac{60-30}{20} = 1.5$$

$I_c + I_L = 1 \Rightarrow I_L = -0.5$

45. Following observations were noted in a field unconfined compression test on clay sample.

Initial length = 12 cm

Diameter of sample = 4 cm

Extension of spring = 2.5 cm

Spring constant = 10.5 kg/cm

Change in length of sample = 2.35 cm

If the clay sample failed at an angle of 50° with respect to horizontal, the unconfined compressive strength of soil is

(A) 1.41 kg/cm^2 (B) 0.705 kg/cm^2

(C) 1.68 kg/cm^2 (D) 0.88 kg/cm^2

45. Ans: (C)

Sol: d = 4 cm, l = 12 cm, δl = 2.35 cm

Unconfined compression test: ($\sigma_c = \sigma_3 = 0$)

$\sigma_1 = q_u$

$\therefore\ q_u = 2C_u \tan \alpha_f$

$\therefore\ q_u = \dfrac{Q_f}{A_f}$

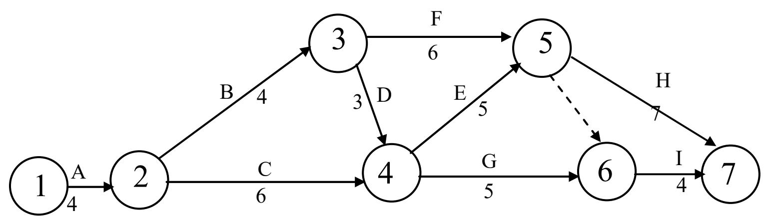
Q_f = Spring constant × Extension of spring

= 10.5 × 2.5 = 26.25 kg

$$A_f = \frac{A}{1-\varepsilon} = \frac{\frac{\pi}{4}d^2}{1-\frac{\delta\ell}{\ell}} = \frac{\frac{\pi}{4}\times 4^2}{1-\frac{2.35}{12}} = 15.62\text{cm}^2$$

$$q_u = \frac{Q_f}{A_f} = \frac{26.25}{15.62} = 1.68\ \text{kg/cm}^2$$

46. The CPM network Diagram of a project by network technique is given below:

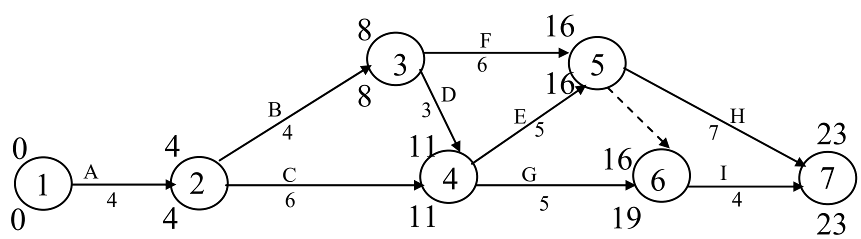


Calculate the sum of Free float of activity 2-4, Independent float of activity 4-6 and Total float of activity 6-7 .

(A) 4 (B) 6 (C) 5 (D) 3

46. Ans: (A)

Sol: (i) The CPM network Diagram:



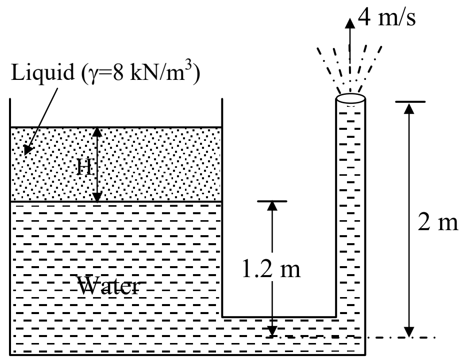
Free float (F_F) of activity (2-4) = $(T_E^j - T_E^i) - t_{ij} = (11-4) - 6 = 1$

Independent float (I_F) of activity (4-6) = $(T_E^j - T_L^i) - t_{ij} = (16-11) - 5 = 0$

Total float (T_F) of activity (6-7) = $(T_L^j - T_E^j) - t_{ij} = (23-16) - 4 = 3$

Sum of Free float (F_F) of activity (2-4), Independent float (I_F) of activity (4-6) and Total float (T_F) of activity (6-7) =1 + 0 + 3 =4

47. Water (assumed inviscid and incompressible) flows steadily with a speed of 4 m/s from the large tank as shown in the figure. The depth, H of the layer of light liquid (Specific weight = 8 kN/m^3) that covers the water in the tank is _______ m. (Assume g = 10 m/s^2)



(A) 1.6 m (B) 2.02 m
(C) 2 m (D) 1 m

47. Ans: (C)

Sol: Equivalent height (y) of H m of liquid in terms of m of water column is

$\gamma \times H = \gamma_w \times y$

Or, $y = \frac{\gamma}{\gamma_w} H = \frac{8}{10} H = 0.8H$

Applying Bernoulli's equation for points (1) (lying on the imaginary water surface) and (2) (exit of the pipe),

we get

$$\frac{P_1}{\gamma_w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma_w} + \frac{V_2^2}{2g} + Z_2$$

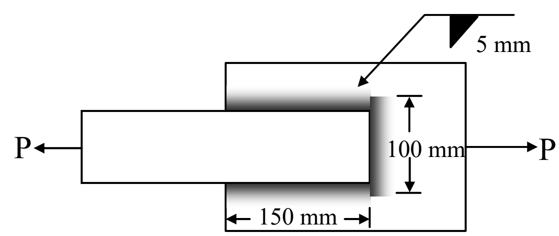
where, $P_1 = P_2 = P_{atm} = 0$; $V_1 = 0$; $V_2 = 4$ m/s; $Z_1 = 1.2 + 0.8$ H and $Z_2 = 2$ m

$$0 + 0 + 1.2 + 0.8H = 0 + \frac{4^2}{2 \times 10} + 2$$

$$0.8H = 0.8 + (2 - 1.2)$$

$$H = \frac{1.6}{0.8} = 2\,m$$

48. An axial loaded steel tie member of 100 mm wide and 12mm thick is fillet welded to a gusset plate using 5mm size of fillet weld as shown in figure. The yield and ultimate tensile stress of steel member are 250 Mpa and 410 Mpa respectively and The yield and ultimate tensile stress of weld are 450 Mpa and 590 Mpa respectively. The partial safety factors against yield stress, ultimate tensile stress and weld strength respectively are γ_{mo}=1.10, γ_{m1}=1.25 and γ_{mw}=1.25. The design axial load carrying capacity of the joint as per LSD of IS800:2007 is



(A) 272.72 kN (B) 381.52 kN
(C) 265.12 kN (D) 354.24 kN

48. Ans: (C)

Sol: Width of member B = 100mm

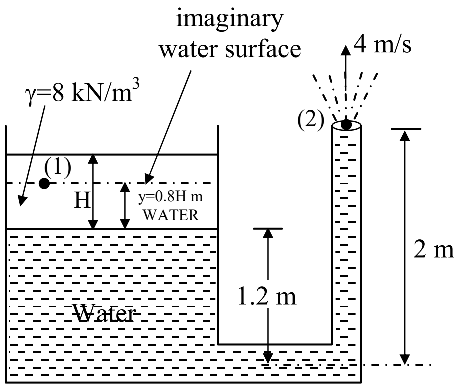
Thickness of member t=10mm

Yield stress of member f_y = 250 Mpa

Ultimate tensile stress of member

f_u = 410 Mpa

Design axial strength of tie member based on gross section yielding



$$T_{dg} = \frac{B \times t \times f_y}{\gamma_{mo}} = \frac{100 \times 12 \times 250}{1.10}$$

$= 272.72 \times 10^3$ N = 272.27 kN

Size of fillet weld (S) = 5mm

Yield stress of weld f_{yw} = 450 Mpa

Ultimate tensile stress of weld

f_{uw} = 590 Mpa

f'_u = Smaller of UTS of member (f_u) and UTS of weld (f_{uw})

= 410 Mpa

Effective throat thickness

$t_t = 0.7 \times 5$ =3.5mm

Effective length of fillet weld

$L_W = 2\times 150 + 100 = 400$mm

Design shear strength of fillet weld P_{dw}

$$P_{dw} = \frac{L_w \times t_t \times f_u^1}{\sqrt{3} \times \gamma_{mw}}$$

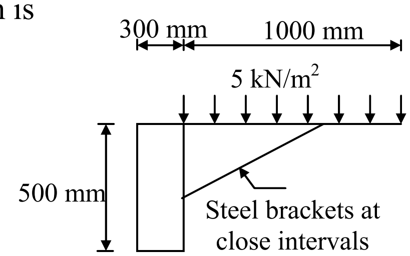
$$= \frac{400 \times 3.5 \times 410}{\sqrt{3} \times 1.25}$$

$= 265.12 \times 10^3$ N = 265.12 kN

Design axial carrying capacity of joint

(P) = Minimum of T_{dg} and P_{dw} =265.12 kN

49. A beam, framing between columns, has an effective span of 5 m and supports a cantilever projection, 1 m wide through out its length a total uniformly distributed load (D.L + L.L) of 5 kN/m² (service load) on the cantilever projection as shown in figure below. As per IS:456-2000 the equivalent maximum nominal shear stress is (in N/mm²) in the beam is

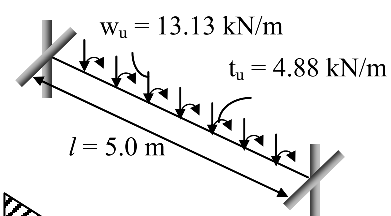


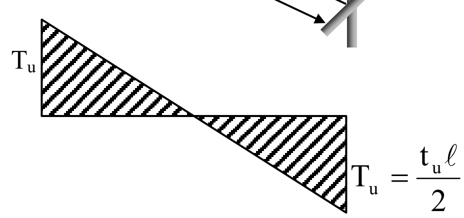
Beam with cantilevered projection

(A) 0.72 MPa (B) 0.24 MPa
(C) 0.54 MPa (D) 0.48 MPa

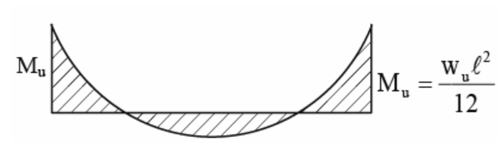
49. Ans: (A)

Sol:

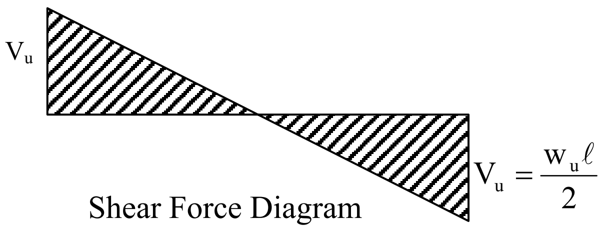




Twisting Moments Diagram



Bending Moments Diagram



Shear Force Diagram

Loads on beam from projection

$= 5 \text{ kN/m}^2 \times 1 \text{ m} = 5 \text{ kN/m}$

From self weight $= 25 \times 0.3 \times 0.5$

$= 3.75$ kN/m

Total load = 8.75 kN/m

Factored distributed load, $w_u = 1.5 \times 8.75$

$= 13.13$ kN/m

Eccentricity of cantilever load from beam centre line $= \frac{1}{2} + \frac{0.3}{2} = 0.65\,\text{m}$

Factored distributed torque,

$t_u = 5 \times 0.65 \times 1.5 = 4.88$ kN-m/m

Maximum twisting moment,

$$T_u = \frac{t_u \ell}{2} = 4.88\left(\frac{5}{2}\right) = 12.2 \text{ kNm}$$

Maximum shear force $V_u = \frac{w_u \ell}{2} = 32.82$ kN

Equivalent nominal shear stress,

$$\tau_v = \frac{V_u + \frac{1.6T_u}{b}}{bd}$$

$$= \frac{32.82 \times 10^3 + 1.6 \times 12.2 \times \frac{10^6}{300}}{300 \times 452}$$

$= 0.72$ MPa

$d = 500 - 30 - 10 - 8 = 452$ mm

50. A rectangular concrete beam 250 mm wide and 300 mm deep is prestressed by a force of 540 kN at a constant eccentricity of 60 mm. The beam is subjected to a concentrated load of 68 kN at the centre of a span of 3 m. The position of the resultant thrust from the top fibre at the quarter span of the beam (Neglect the self weight of the beam) is

(A) 138 mm (B) 162 mm
(C) 200 mm (D) 100 mm

50. Ans: (B)

Sol: Stress due to prestressing force

$$\frac{P}{A} = \frac{540 \times 10^3}{250 \times 300} = 7.2 \text{ N/mm}^2$$

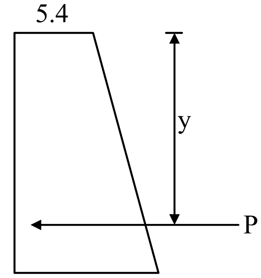
$$\frac{Pe}{Z} = \frac{540 \times 10^3 \times 60}{\frac{1}{6} \times 250 \times 300^2} = 8.6 \text{ N/mm}^2$$

Stress due to external load at the quarter of the span

$$\frac{M_L}{Z} = \frac{\frac{WL}{8}}{Z} = \frac{25.5 \times 10^6}{\frac{1}{6} \times 250 \times 300^2}$$

$= 6.8 \text{ N/mm}^2$

Resultant stress at quarter of the span



Resultant stress diagram at quarter span

Stress at top:

$$f_t = \frac{P}{A} - \frac{Pe}{Z} + \frac{M_L}{Z} = 5.4 \text{ N/mm}^2$$

Stress at bottom:

$$f_b = \frac{P}{A} + \frac{Pe}{Z} - \frac{M_L}{Z} = 9 \text{ N/mm}^2$$

Location of the resultant thrust from top

$$y = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$$

$$= \frac{(5.4\times300)150 + \left(\frac{1}{2}\times300\times3.6\right)200}{(5.4\times300) + \left(\frac{1}{2}\times300\times3.6\right)}$$

= 162 mm

51. A line measures 100 mm on a photograph taken with a camera having focal length of 200 mm. The same line measures 30 mm on a map drawn to a scale of $\frac{1}{40,000}$. If the average altitude is 200 m, the flying height of air craft is

(A) 2200 m (B) 2400 m
(C) 2600 m (D) 3000 m

51. Ans: (C)

Sol: $\frac{\text{Photo scale}}{\text{MapScale}} = \frac{\text{Photo distance}}{\text{Map distance}}$

$$\text{Photo Scale} = \frac{1}{40,000} \times \frac{100}{30} = \frac{1}{12,000}$$

$$S = \frac{f}{(H-h)} = \frac{1}{12,000} = \frac{200\times10^{-3}}{(H-200)}$$

H = 2600 m

52. An ASP operating at a flow rate 10000 m^3/day with influent BOD 300 mg/l and with MLSS concentration 3000 mg/lit designed for $\frac{F}{M}$ ratio 0.2 d^{-1}. Find mean cell residence time in days if the MLSS in return sludge is 10000 mg/lit. Waste sludge flow rate is 200 m^3/d. Take BOD and MLSS of effluent is zero.

(A) 0.15 days (B) 15 days
(C) 10 days (D) 7.5 days

52. Ans: (d)

Sol: Q = 10000 m^3/day $y_i = 300$ mg/l

∵ y_e is not given   ∴ $y_e = 0$

X : 3000 mg/$l$it $\frac{F}{M} = 0.2\,d^{-1}$

$$\frac{F}{M} = \frac{Q(y_i - y_e)}{Vx}$$

$$0.2 = \frac{10000\times(300-0)}{V\times3000}$$

$$V = \frac{10000\times300}{3000\times0.2} = 5000 \text{ m}^3$$

$$\text{MCRT, } \theta_c = \frac{VX}{Q_w X_u + (Q - Q_w)\times X_e}$$

∵ X_e is not given

∴ $X_e = 0$

$$\theta_c = \frac{5000\times3000}{200\times10000} = 7.5 \text{ days}$$

53. In a standard BOD test conducted on 4% sewage sample with no DO mixed with distilled water containing a DO of 8 mg/l. After 5 day incubation at 20°C it's final DO is 1.6 mg/l. To expect same BOD at temperature 35°C how many days it will take.

(A) 1 (B) 2.51
(C) 152 (D) 160

53. Ans: (b)

Sol: $y_5^{20^\circ C} = y_t^{35^\circ C}$

$L_o\left[1-e^{-K_{20}\times 5}\right] = L_o\left[1-e^{-k_{35}\times t}\right]$

$K_{20} \times 5 = K_{20}\,(1.047)^{35-20} \times t$

$t = \frac{5}{(1.047)^{15}} = 2.51$ days

54. Consider the differential equation $\frac{dy}{dx} + 2xy = e^{-x^2}$ with initial condition $y(0) = 1$. The value of $y(1)$ = _____.

54. Ans: 0.7357 Range: 0.73 to 0.74

Sol: Given $\frac{dy}{dx} + 2xy = e^{-x^2}$ …….. (1)

with $y(0) = 1$ …….. (2)

$\therefore$ I. F. = $e^{\int 2x\,dx} = e^{x^2}$

Now, the general solution of (1) is

$\Rightarrow y.\,e^{x^2} = \int e^{x^2}.\,e^{-x^2}\,dx + c$

$\Rightarrow y.\,e^{x^2} = x + c$ …….. (3)

Using (2), (3) becomes

$\Rightarrow 1 = 0 + c \Rightarrow c = 1$

$y = x\,e^{-x^2} + e^{-x^2}$

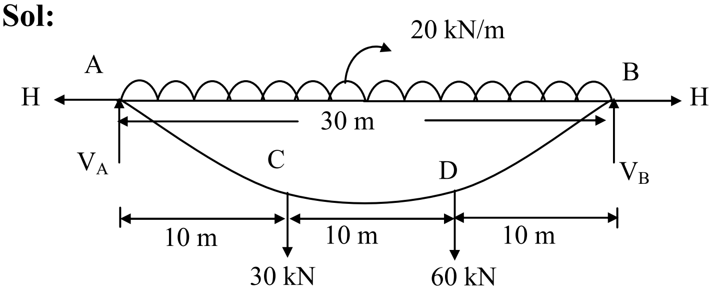
$y = (x+1)\,e^{-x^2}$

$\therefore y(1) = 2 \times e^{-1} = 0.7357$

55. A suspension cable, having supports at same level, has span of 30 m and maximum dip of 5 m. The cable is loaded with uniformly distributed load of 20 kN/m throughout its length and the concentrated load of 30 kN and 60 kN at middle third points. The maximum tension in the cable (in kN) ______.

55. Ans: 638.54 kN Range: 638 to 639

Sol:



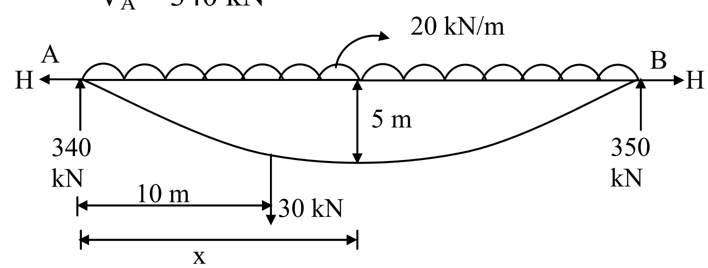
$M_A = 0$

$V_B \times 30 = 30 \times 10 + 60 \times 20 + 20 \times 30 \times 15$

$V_B = 350$ kN

$V_A + V_B = 20 \times 30 + 30 + 60$

$V_A = 340$ kN



Let max dip of 5 m be at a distance 'x' from 'A'. At this section tension in the cable will be horizontal and hence vertical component of tension in cable is zero.

Considering equilibrium of left portion of cable

Equating sum of vertical forces to zero

$340 - 20 \times x - 30 = 0$

$x = 15.5$ m

Taking moment about 'A'

$5 \times H + 15.5 \times 20 \times \frac{15.5}{2} + 30$

$\times 5.5 - 340 \times 15.5 = 0$

H = 540.5 kN

Maximum tension in cable occur at A

$T_{max} = \sqrt{340^2 + 540.5^2}$ m

= 638.54 Kn

56. In a Concrete gravity dam of specific gravity 2.5, limiting height with uplift coefficient (c) is found to be 20% more than that with zero uplift coefficient. Value of c is _________(rounded up to 2 decimal values).

56. Ans: 0.583 Range: 0.58 to 0.59

Sol: $\frac{H_1}{H_2} = \frac{\frac{f}{w(s-c+1)}}{\frac{f}{w(s+1)}} = \frac{120}{100}$

$\frac{2.5+1}{2.5-c+1} = 1.2 = \frac{6}{5}$

12.5 + 5 = 15 – 6 c + 6

6 c = 21 – 17.5 = 3.5

$c = \frac{3.5}{6} = 0.583$

57. The ordinates of 6-hr UH at 3 hours time intervals starting from time t = 0 are 0, 5, 35, 64, 72, 62, 46, 33, 21, 12, 6, 4 & 0 m^3/sec. The peak ordinate of S_6 –curve would be ____ m^3/sec [Upto 1 decimal places].

57. Ans: 180.0144 m^3/sec

Range: 179.9 to 180.1

Sol: Given data:

$\Sigma O'' = 5 + 35 + 64 + 72 + 62 + 46 + 33 + 21 + 12 + 6 + 4 = 360$ m^3/s

$\Delta t\, \Sigma O'' = C.A \times 0.01$

$3 \times 3600 \times 360 = C.A \times 0.01$

C.A = 388.8 km^2

$Q_c = 2.778 \frac{A}{D}$

$Q_e = 2.778 \times \frac{388.8}{6}$

$Q_e = 180.0144$ m^3/sec

58. Water is percolating through a rectangular silty earth fill found on impervious soil length of the earth fill is 30 meters and thickness is 15 metres, U/s water level is 5 metres over the impervious soil. The total seepage loss rate through the earth fill, if its effective grain size is 0.02 mm ____ m^3/day. (Rounded upto two decimal places).

58. Ans: 17.28 Range: 17.27 – 17.30

Sol: Area of flow = 30 × 5 = 150 m^2

Length of flow = Thickness of earth fill

= 15 m

$i = \frac{h}{L} = \frac{5}{15} = \frac{1}{3}$

$\therefore$ Given $D_{10} = 0.02$ mm

= 0.002 cm

$K = 100\ D_{10}^2$

$= 100 \times (0.002)^2$

$= 4 \times 10^{-4}$ cm/sec

$\therefore Q = KiA$

$= 4 \times 10^{-4} \times 10^{-2} \times 60 \times 60 \times 24 \times \frac{1}{3} \times 150$

= 17.28 m^3/day

59. A plate load test is carried out on a 30 cm square plate placed at 1 metre below ground level on a clay deposit load required to cause 25 mm settlement was 7.2 tonnes. A square column footing is to be provided at a depth of 2 m below ground level to take Net load of 100 tonnes, the size of footing, if the settlement of footing is restricted to 15 mm only and factor of safety against shear failure is 3 shall be ___ (in meters) (As per Terzaghi's theory), Given γ = 1.9 gm/cc.

59. Ans : 2.55 Range: 2.50 – 2.60

Sol: Plate load test:

$B_P = 0.3\text{ m} \Rightarrow q_u = \frac{7.2}{0.3\times 0.3} = 80\text{ t/m}^2$

As settlement of footing is different from settlement of plate

Consider bearing capacity for footing settlement

$\therefore q \propto S$

$\frac{q_2}{q_1} = \frac{S_2}{S_1} \Rightarrow q_2 = \frac{15}{25}\times 80$; $q_2 = 48\text{ t/m}^2$

From plate load test:

Square footing:

$q_u = 1.3\, CN_c + \gamma DN_q + 0.4\,\gamma\, B\, N_\gamma$

Given is clay soil : $\phi = 0^o$

$N_c = 5.7$, $N_q = 1$, $N_\gamma = 0$

$\therefore q_u = 1.3 \times C \times 5.7 + \gamma D$ $(1\text{g/cc} = 1\text{t/m}^3)$

$48 = 1.3 \times C \times 5.7 + 1.9 \times 1$

$\therefore C = 6.22\text{ t/m}^2$

Now for actual footing:

Given

$Q_n = 100$ tonnes

$q_n \le q_{ns}$

$q_n = \frac{q_{nu}}{F}$

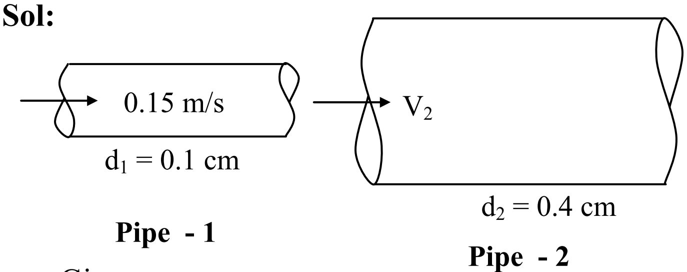
$\frac{Q_n}{B^2} = \frac{1.3CN_c}{F}$

$\frac{100}{B^2} = \frac{1.3\times 6.22\times 5.7}{3}$ $\therefore B = 2.55\text{ m}$

60. The ratio of friction factors (f_1/f_2) in two different pipes with same fluid is 0.5. The average flow velocity in pipe-1 is 0.15 m/s and the pipe diameter is 0.1 cm. The flow in the pipes can be assumed to be laminar. The radius of pipe-2 is 0.2 cm. The average velocity in pipe-2 is _________ m/s. (Rounded off to three decimal places)

60. Ans: 0.019 (Range: 0.018 to 0.020)

Sol:



Given:

$\frac{f_1}{f_2} = 0.5$

Flow is laminar in both pipes.

We know that in laminar flow through a pipe,

$f = \frac{64}{Re} = \frac{64\nu}{Vd}$

Thus,

$\frac{f_1}{f_2} = 0.5 = \frac{64\nu}{0.15\times 0.1\times 10^{-2}} \times \frac{V_2\times 0.4\times 10^{-2}}{64\nu}$

On simplification

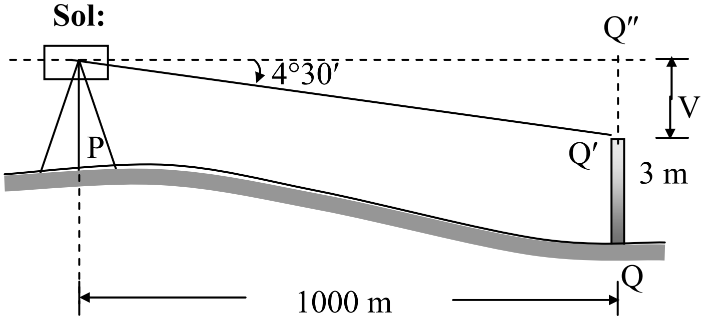
$0.5 = \frac{V_2\times 0.4}{0.15\times 0.1}$

$\Rightarrow V_2 = 0.01875\text{ m/s} \approx 0.019\text{ m/s}$

61. An instrument was set up at P and the angle of depression to a vane 3 m above the foot of the staff held at Q was $4^o 30'$. The horizontal distance between P and Q was known to be 1000 m. If the height of instrument axis is 450.250 m, the R.L of the staff station 'Q' (in m, upto two decimal places) is ______. (Consider the combined correction).

61. Ans: 368.617 m Range: 368.60 to 368.63

Sol:



$V = 1000 \tan 4^o30' = 78.70$ m

Correct value of $V = 78.70 - 0.06735 \times 1^2$

$= 78.633$ m

RL of Q = 450.250 – 78.633 – 3 = 368.617 m

62. A waste water with a flow rate of 10 MLD containing a solids concentration of 200 mg/l applied to sedimentation tank with particle removal efficiency 80%. Find the volume of sludge produced in m^3 in a day from the tank if moisture content of sludge is 98% and specific gravity of solids is 2.7

62. Ans: 79.05 Range: (78.5 - 80)

Sol: Mass of solids wasted /day = $Q \times (\eta_{ST} \times Cin)$

$$= 10 \times \left(\frac{80}{100} \times 200\right)$$

$= 1600$ kg/day

Volume of sludge produced/day

$$= \frac{100}{100-P} \times \frac{M}{\rho_{slu}} \qquad P = 98\%$$

$$\frac{100}{S_{slu}} = \frac{\%Sol}{S_{sol}} + \frac{\%m_c}{S_w} \Rightarrow \frac{100}{S_{slu}} = \frac{2}{2.7} + \frac{98}{1}$$

$S_{slu} = 1.012 \qquad \rho_{slu} = S_{slu} \times \rho_w$

$= 1.012 \times 1000 = 1012$ kg/m^3

Volume of sludge produced /day

$$= \frac{100}{100-P} \times \frac{M}{\rho_{slu}}$$

$$= \frac{100}{(100-98)} \times \frac{1600}{1012} = 79.05 \text{ m}^3$$

63. A rectangular sedimentation tank of length 30 m depth 3 m operating at a flow rate 1 m^3/sec with flow velocity 0.5 cm/sec. Find surface area of sedimentation tank required in m^2 for 100% removal of particles.

63. Ans: 2000 Range: No Range

Sol: L : 30 m H : 3 m

Q : 1 m^3/sec V_H : 0.5 cm/sec = $0.5 \times \frac{1}{100}$ m/s

For 100% removal

$$\frac{H}{V_S} \le \frac{L}{V_H} \Rightarrow V_s . V_H \times \frac{H}{L}$$

$$= 0.5 \times \frac{1}{100} \times \frac{3}{30} \text{ m/sec}$$

And $V_s = V_o = 0.5 \times \frac{1}{100} \times \frac{3}{30}$ m/s

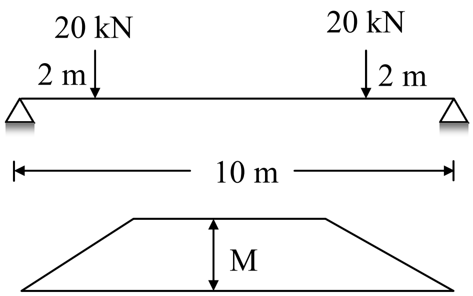
Surface area = $A_s = \frac{Q}{V_o} = \frac{1}{0.5 \times \frac{1}{100} \times \frac{3}{30}} m^2$

$= 2000$ m^2

64. A simply supported beam of 10 m span is subjected to two point loads of 20 kN each placed at a distance of 2 m from each of the free ends. The cross-section of the beam is 200 mm wide and 400 mm deep. The major principal stress at the middle of the beam at the bottom extreme fibre is _____ MPa. (rounded to one decimal place)

64. Ans: 7.5 **Range: No Range**

Sol:



Maximum BM (at mid span), $M = 20 \times 2$

$= 40$ kN-m

At the extreme bottom fibre of the mid span, maximum bending stress is the major principal stress

$$F = \frac{M}{I} \times y_{max} = \frac{40 \times 10^6}{\left[\frac{200 \times 400^2}{6}\right]} = 7.5 \text{ MPa}$$

65. A retaining wall of height 6 m retains a clay soil having unit weight of $\gamma = 20$ kN/m^3, C = 15 kN/m^2 and $\phi = 30^o$. The percentage reduction in depth of tensile crack due to rise in water table from the base of footing to ground surface shall be ___% ($\gamma_w = 10$ kN/m^3)

65. Ans: 50% **Range: No Range**

Sol: H = 6 m

Z_c = tensile crack depth

Initial : No W.T

At $Z = Z_c$: P_a = Active earth pressure

$P_a = 0, \sigma_v = \gamma.Z_c$

$K_a \sigma_v - 2c\sqrt{K_a} = 0$

$$Z_{c_1} = \frac{2C}{\gamma\sqrt{K_a}}$$

Final: WT at G.L

At $Z = Z_c : P_a = 0$

$\sigma_v = \gamma_{sat} Z_c$

Assume $\gamma' = \gamma_{sat}$

$K_a \sigma_v - 2C\sqrt{K_a} = 0$

$K_a . \gamma'. Z_c + \gamma_w Z_c - 2c\sqrt{K_a} = 0$

$$\therefore Z_{c_2} = \frac{2C\sqrt{K_a}}{(K_a\gamma' + \gamma_w)}$$

Given:

C = 15 kN/m^2

$\phi = 30^o \Rightarrow K_a = \frac{1}{3}$

$\gamma = 20$ kN/m^3

$$Z_{C_1} = \frac{2 \times 15}{20 \times \sqrt{1/3}} = 2.6 \text{ m}$$

$$Z_{c_2} = -\frac{2 \times 15 \times \sqrt{1/3}}{\left(\frac{1}{3} \times 10 + 10\right)} = 1.3 \text{ m}$$

% Reduction in crack depth

$$= \frac{2.6 - 1.3}{2.6} \times 100 = 50\%$$