General Aptitude

Q. No. 1 – 5 Carry One Mark Each

1. If I were you, I ________ that laptop. It's much too expensive.

(A) won't buy (B) shan't buy (C) wouldn't buy (D) would buy

Key: (C)

2. He turned a deaf ear to my request.

What does the underlined phrasal verb mean?

(A) ignored (B) appreciated (C) twisted (D) returned

Key: (A)

3. Choose the most appropriate set of words from the options given below to complete the following sentence . __________ , ___________ is a will, _______ is a way.

(A) Wear, there, their (B) Were, their, there

(C) Where, there, there (D) Where, their, their

Key: (C)

4. (*x* % of *y*) + (*y* % of *x*) is equivalent to ______.

(A) 2 % of *xy* (B) 2 % of (*xy*/100) (C) *xy* % of 100 (D) 100 % of *xy*

Key: (A)

Exp:

$$x\%\text{ of } y = \frac{x}{100}y = \frac{xy}{100}$$

$$y\%\text{ of } x = \frac{y}{100}y = \frac{xy}{100}$$

$$(x\%\text{ of } y) + (y\%\text{ of } x) = \frac{2}{100}xy = 2\%\text{ of } xy$$

5. The sum of the digits of a two digit number is 12. If the new number formed by reversing the digits is greater than the original number by 54, find the original number.

(A) 39 (B) 57 (C) 66 (D) 93

Key: (A)

Exp: Let the original number be xy

y---unit digit of xy

x+y=12 -------(1)

10y+x=10x+y+54

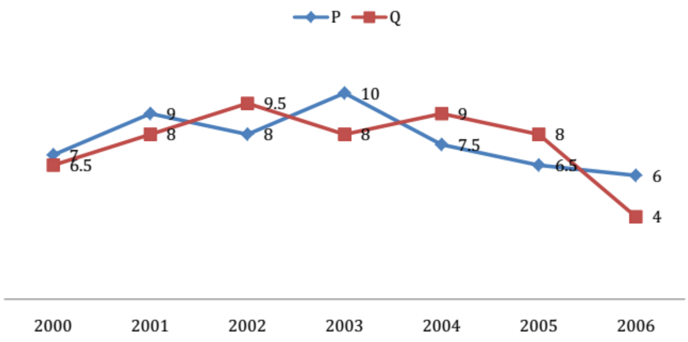
9x-9y=-54-------(2)

Solving (1) & (2) we get, x=3 and y=9

So the number is 39.

Q. No. 6 – 10 Carry Two Marks Each

6. Two finance companies, P and Q, declared fixed annual rates of interest on the amounts invested with them. The rates of interest offered by these companies may differ from year to year. Year-wise annual rates of interest offered by these companies are shown by the line graph provided below



If the amounts invested in the companies, P and Q, in 2006 are in the ratio 8:9, then the amounts received after one year as interests from companies P and Q would be in the ratio:

(A) 2:3 (B) 3:4 (C) 6:7 (D) 4:3

Key: (D)

Exp: let the deposited money in the company P is 8x

And the deposited money in the company Q is 9x

Interest after one year from the company P= $8x\left(\frac{6}{100}\right)$

Interest after one year from the company Q= $9x\left(\frac{4}{100}\right)$

Ratio of Interest= $\dfrac{\frac{8x\times 6}{100}}{\frac{9x\times 4}{100}} = \frac{4}{3}$

7. Today, we consider Ashoka as a great ruler because of the copious evidence he left behind in the form of stone carved edicts. Historians tend to correlate greatness of a king at his time with the availability of evidence today.

Which of the following can be logically inferred from the above sentences?

(A) Emperors who do not leave significant sculpted evidence are completely forgotten.

(B) Ashoka produced stone carved edicts to ensure that later historians will respect him.

(C) Statues of kings are a reminder of their greatness.

(D) A king's greatness, as we know him today, is interpreted by historians

Key: (D)

8. Fact 1: Humans are mammals.

Fact 2: Some humans are engineers.

Fact 3: Engineers build houses.

If the above statements are facts, which of the following can be logically inferred?

I. All mammals build houses.

II. Engineers are mammals.

III. Some humans are not engineers.

(A) II only. (B) III only.

(C) I, II and III. (D) I only.

Key: (B)

9. A square pyramid has a base perimeter x, and the slant height is half of the perimeter. What is the lateral surface area of the pyramid?

(A) x^2 (B) $0.75x^2$ (C) $0.50x^2$ (D) $0.25\,x^2$

Key: (D)

Exp: Lateral surface area of the square pyramid

$A = a\sqrt{a^2 + 4h^2}$

$4a \to$ perimeter

$h \to$ height

$\ell \to$ slanting height

$$\ell^2 = \left(\frac{a}{2}\right)^2 + h^2 \Rightarrow h^2 = \left(\ell^2 - \frac{a^2}{2}\right)$$

$$A = a\sqrt{a^2 + 4\left(\ell^2 - \frac{a^2}{2}\right)} = a2\ell$$

10. Ananth takes 6 hours and Bharath takes 4 hours to read a book. Both started reading copies of the book at the same time. After how many hours is the number of pages **to be** read by Ananth, twice that **to be** read by Bharath? Assume Ananth and Bharath read all the pages with constant pace.

(A) 1 (B) 2 (C) 3 (D) 4

Key: (C)

Exp: Ananth covers 1/6 of the book in 1 hour.

Bharath covers 1/4 of the book in 1 hour

$$\frac{\left(\frac{1}{6}\right)x}{\left(\frac{1}{4}\right)} = 2$$

$$\Rightarrow \frac{x}{6} = \frac{4}{2} = \frac{1}{2}$$

$$\Rightarrow x = \frac{6}{2} = 3\text{hours}$$

Civil Engineering

Q. No. 1 – 25 Carry One Mark Each

1. The spot speeds (expressed in km/hr) observed at a road section are 66, 62, 45, 79, 32, 51, 56, 60, 53, and 49. The median speed (expressed in km/hr) is _______.

   (Note: answer with one decimal accuracy)

Key: (54.5)

Exp: Median speed is the speed at the middle value in series of spot speeds that are arranged in ascending order. 50% of speed values will be greater than the median 50% will be less than the median.

Ascending order of spot speed studies are

32,39,45,51,53,56,60,62,66,79

Median speed $= \frac{53+56}{2} = 54.5 \text{ km / hr}$

2. The optimum value of the function $f(x) = x^2 - 4x + 2$ is

   (A) 2 (maximum) (B) 2 (minimum) (C) −2 (maximum) (D) −2 (minimum)

Key: (D)

Exp: $f'(x) = 0 \Rightarrow 2x - 4 = 0$

$\Rightarrow x = 2 \text{(statinary point)}$

$f''(x) = 2 > 0 \Rightarrow f(x)$ is minimum at x=2

And the minimum value is f(2)

i.e., $(2)^2 - 4(2) + 2 = -2$

$\therefore$ The optimum value of f(x) is -2 (minimum)

3. The Fourier series of the function,

$$f(x) = \quad -\pi < x \le 0$$
$$= \pi - x, 0 < x < \pi$$

in the interval $[-\pi, \pi]$ is

$$f(x) = \frac{\pi}{4} + \frac{2}{\pi}\left[\frac{\cos x}{1^2} + \frac{\cos 3x}{3^2} + ...\right] + \left[\frac{\sin x}{1} + \frac{\sin 2x}{2} + \frac{\sin 3x}{3} + ...\right]$$

The convergence of the above Fourier series at x= 0 gives

(A) $\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}$ (B) $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} = \frac{\pi^2}{12}$

(C) $\sum_{n=1}^{\infty} \frac{1}{(2n-1)^2} = \frac{\pi^2}{8}$ (D) $\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{2n-1} = \frac{\pi^2}{4}$

Key: (C)

Exp: The function is f(x) =0, $-\pi < x \le 0$

$$= \pi - x, 0 < x < \pi$$

And Fourier series is

$$f(x)=\frac{\pi}{4}+\frac{2}{\pi}\left[\frac{\cos x}{1^2}+\frac{\cos 3x}{3^2}+\frac{\cos 5x}{5^2}+...\right]+\left[\frac{\sin x}{1}+\frac{\sin 2x}{2}+\frac{\sin 3x}{3}+...\right] \quad .... (1)$$

At x=0, (a point of discontinuity), the fourier series converges to $\frac{1}{2}\left[f(0^-)+f(0^+)\right]$, where $f(0^-)=\lim_{x\to 0}(0)=0$ and $f(0^+)=\lim_{x\to 0}(\pi-x)=\pi$

Hence, (1) becomes

$$\frac{\pi}{2}=\frac{\pi}{4}+\frac{2}{\pi}\left[\frac{1}{1^2}+\frac{1}{3^2}+...\right]$$

$$\Rightarrow \frac{1}{1}+\frac{1}{3^2}+\frac{1}{5^2}+....\frac{\pi^2}{8}$$

4. *X* and Y are two random independent events. It is known that P(X) = 0.40 and $P\left(X\cup Y^C\right)=0.7$. Which one of the following is the value of *P*(*X* ∪ *Y*)?

(A) 0.7 (B) 0.5 (C) 0.4 (D) 0.3

Key: (A)

Exp: $P\left(X\cup Y^c\right)=0.7 \Rightarrow P(x)+P(y^c)-P(x).P(y^c)=0.7$

(Since, x,y are independent events)

$\Rightarrow P(x)+1-P(y)-P(x)\{1-P(y)\}=0.7$

$\Rightarrow P(y)-P(x\cap y)=0.3---(1)$

$P\left(x\cup y\right)=P(x)+P(y)-P\left(x\cap y\right)=0.4+0.3=0.7\ \ 3$

Second Method:

We know that $\Rightarrow P(x\cup y')=P(x)+P\left[\left(x\cup y\right)'\right]$

$\Rightarrow 0.7=0.4+1-P\left(x\cup y\right)$

$\Rightarrow P(x\cup y)=0.7$

5. What is the value of $\lim_{\substack{x\to 0\\ y\to 0}}\frac{xy}{x^2+y^2}$?

(A) 1 (B) −1 (C) 0 (D) Limit does not exist

Key: (D)

Exp: (i) $\lim_{x\to\infty}\frac{xy}{x^2+y^2}=\lim_{y\to 0}\left(\frac{0}{0^2+y^2}\right)=0$ (i .e., put x=0 and then y=0)

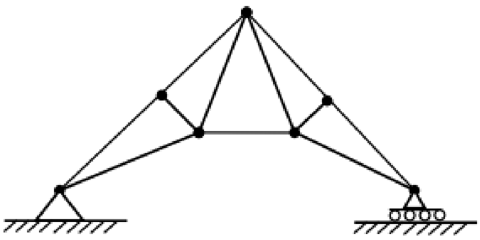
(ii) $\lim_{\substack{x\to 0\\ y\to 0}}\frac{xy}{x^2+y^2}=\lim_{x\to 0}\left(\frac{0}{x^2+0}\right)=0$ (i.e., put y=0 and then x=0)

(iii) $\lim_{\substack{x\to 0\\ y\to 0}}\frac{xy}{x^2+y^2}=\lim_{x\to 0}\frac{x(m.x)}{x^2+m^2x^2}$ (i.e., put y = mx)

$$=\lim_{x\to\infty}\left(\frac{m}{1+m^2}\right)=\frac{m}{1+m^2},$$ which depends on 'm'.

Hence, the limit does not exists.

6. The kinematic indeterminacy of the plane truss shown in the figure is



(A) 11 (B) 8 (C) 3 (D) 0

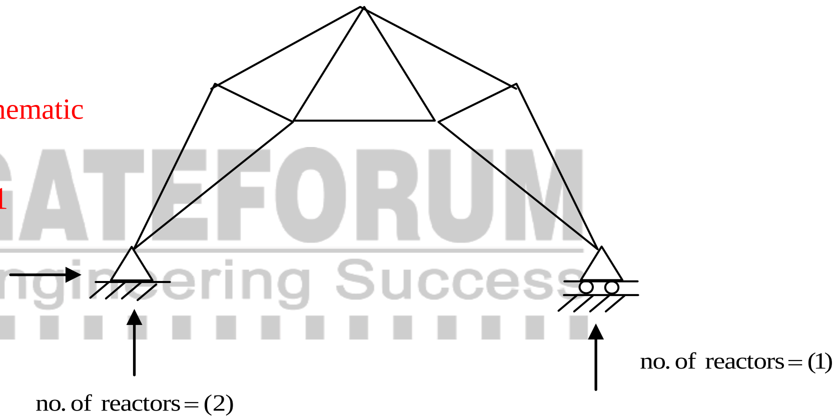
Key: (A)

Exp: Number of joints (J) = 7

For rigid joint plan truss kinematic

Indeterminacy = 2J – R

$=2\times7-(2+1)=14-3=11$



7. As per IS 456-2000 for the design of reinforced concrete beam, the maximum allowable shear stress $(\tau_{c\max})$ depends on the

(A) grade of concrete and grade of steel

(B) grade of concrete only

(C) grade of steel only

(D) grade of concrete and percentage of reinforcement

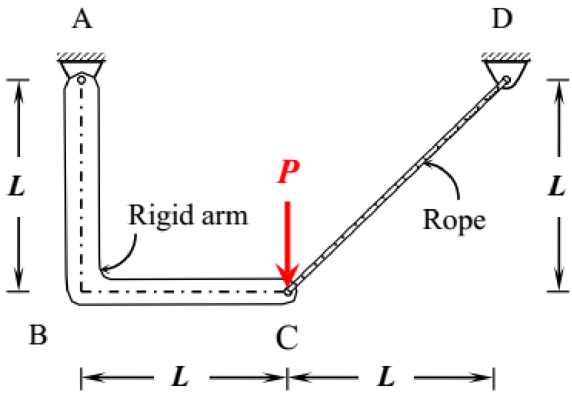
Key: (B)

Exp: By IS 456:2000

$\tau_{c_{max}}=0.62\sqrt{f_{ck}}$

$\tau_{a_{max}}$ depends on grade of concrete only.

8. An assembly made of a rigid arm A-B-C hinged at end A and supported by an elastic rope C-D at end C is shown in the figure. The members may be assumed to be weightless and the lengths of the respective members are as shown in the figure.



Under the action of a concentrated load P at C as shown, the magnitude of tension developed in the rope is

(A) $\frac{3P}{\sqrt{2}}$ (B) $\frac{P}{\sqrt{2}}$ (C) $\frac{3P}{8}$ (D) $\sqrt{2}P$

Key: (B)

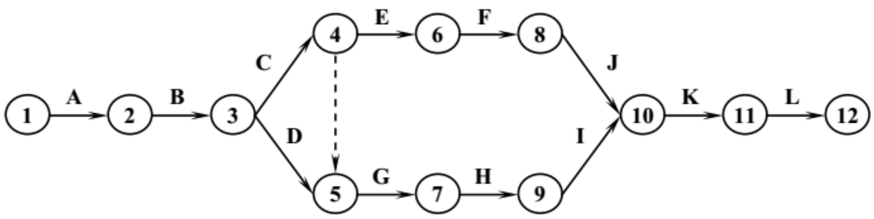
9. As per Indian standards for bricks, minimum acceptable compressive strength of any class of burnt clay bricks in dry state is

(A) 10.0MPa (B) 7.5MPa (C) 5.0MPa (D) 3.5MPa

Key: (D)

10. A construction project consists of twelve activities. The estimated duration (in days) required to complete each of the activities along with the corresponding network diagram is shown below.

Activity		Duration (days)	Activity		Duration (days)
A	Inauguration	1	G	Flooring	25
B	Foundation work	7	H	Electrification	7
C	Structural construction-1	30	I	Plumbing	7
D	Structural construction-2	30	J	Wood work	7
E	Brick masonry work	25	K	Coloring	3
F	Plastering	7	L	Handing over function	1

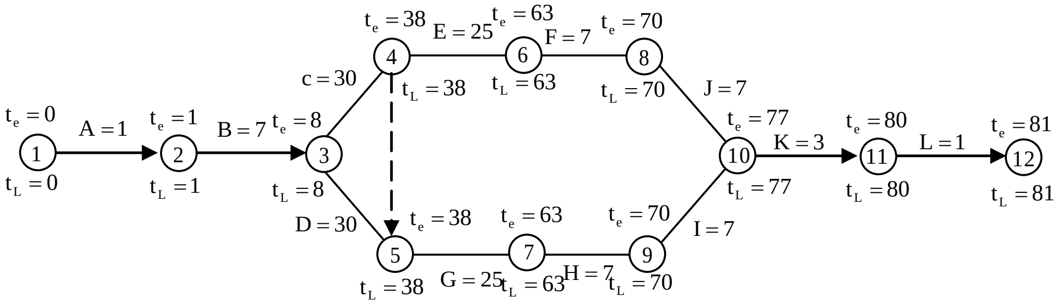


Total floats (in days) for the activities 5-7 and 11-12 for the project are, respectively,

(A) 25 and 1 (B) 1 and 1 (C) 0 and 0 (D) 81 and 0

Key: (C)

Exp:



$(5)-(7) = \text{Total float} = t_e - t_L = 0$

$(11)-(12) = \text{Total float} = t_e - t_L = 0$

11. A strip footing is resting on the surface of a purely clayey soil deposit. If the width of the footing is doubled, the ultimate bearing capacity of the soil

(A) becomes double (B) becomes half (C) becomes four-times (D) remains the same

Key: (D)

12. The relationship between the specific gravity of sand (*G*) and the hydraulic gradient (*i*) to initiate quick condition in the sand layer having porosity of 30% is

(A) $G = 0.7i + 1$ (B) $G = 1.43i - 1$

(C) $G = 1.43i + 1$ (D) $G = 0.7i - 1$

Key: (C)

Exp: For quick sand conditions

$$i = \frac{G-1}{1+e} \Rightarrow G = i(1+e)+1$$

Given porosity $\eta = 30\% = 0.3$

$$e = \frac{n}{1-n} = \frac{0.3}{1-0.3} = \frac{0.3}{0.7} = 0.43$$

$$G = i(1+0.43)+1$$
$$= i(1.43)+1$$
$$= 1.43i+1$$

13. The results of a consolidation test on an undisturbed soil, sampled at a depth of 10 m below the ground level are as follows:

Saturated unit weight : $16 kN/m^3$

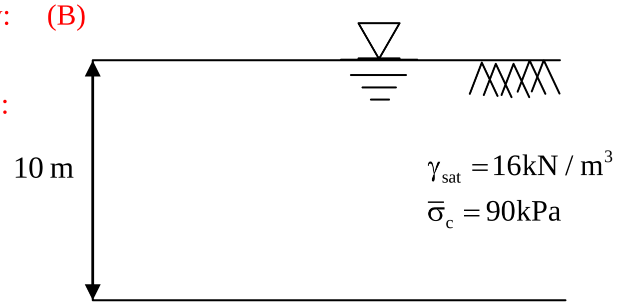
Pre-consolidation pressure : 90kPa

The water table was encountered at the ground level. Assuming the unit weight of water as $10 kN/m^3$, the over-consolidation ratio of the soil is

(A) 0.67 (B) 1.50 (C) 1.77 (D) 2.00

Key: (B)

Exp:



Over consolidation ratio $= \dfrac{\bar{\sigma}_c}{\bar{\sigma}}$

$\bar{\sigma} = 10 \times (16 - 10)$

$= 10 \times 6$

$= 60 kN/m^3$

$O.C.R = \dfrac{90}{60} = \dfrac{9}{6} = 1.5$

14. Profile of a weir on permeable foundation is shown in figure I and an elementary profile of 'upstream pile only case' according to Khosla's theory is shown in figure II. The uplift pressure heads at key points Q, R and S are 3.14 m, 2.75 m and 0 m, respectively (refer figure II).

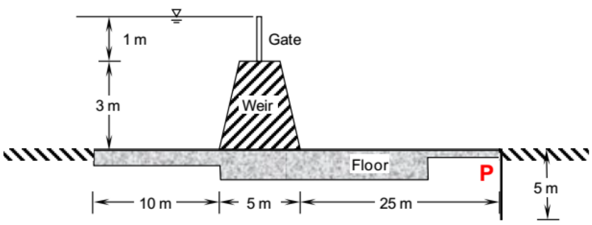


Figure I

.

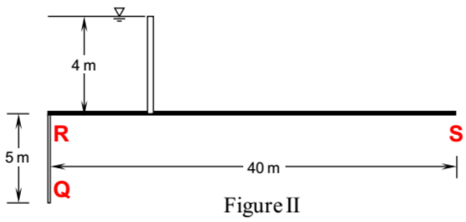


Figure II

What is the uplift pressure head at point P downstream of the weir (junction of floor and pile as shown in the figure I)?

(A) 2.75 m (B) 1.25 m (C) 0.8 m (D) Data not sufficient

Key: (B)

Exp: $\phi_R = \dfrac{2.75}{4} \times 100 = 68.75\%$

$\phi_p = 100 - \phi_R = 31.25\%$

Now, $\phi_p = \dfrac{\text{Pressure head at point}}{\text{Total head}} \times 100$

$\Rightarrow 31.25 = \dfrac{h}{4} \times 100 \Rightarrow h = 1.25\text{m}$

15. Water table of an aquifer drops by 100 cm over an area of 1000 km^2. The porosity and specific retention of the aquifer material are 25% and 5%, respectively. The amount of water (expressed in km^3) drained out from the area is _______.

Key: (0.2)

Exp: $\Delta h = 100\,\text{cm},\ A = 1000\,\text{km}^2$

$n = 0.25,\ r = 0.05$

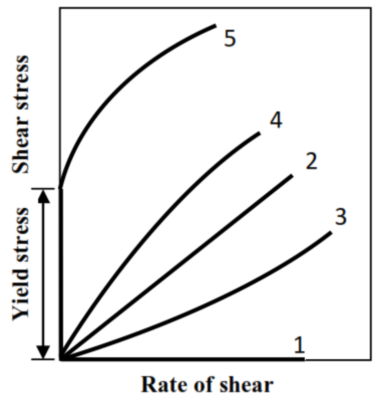
$\because$ Porosity$(\eta) =$ Sp. yield$(y) +$ Sp Retention (r)

$\Rightarrow y = 0.25 - 0.05 = 0.20$

Amount of water drained out $= y \times A \times \Delta h = 0.2 \times 1000 \times 100 \times 10^{-5} = 0.2\text{km}^2$.

16. Group I contains the types of fluids while Group II contains the shear stress - rate of shear relationship of different types of fluids, as shown in the fig

Group I	Group II
P. Newtonian fluid	1. Curve 1
Q. Pseudo plastic fluid	2. Curve 2
R. Plastic fluid	3. Curve 3
S. Dilatant fluid	4. Curve 4
	5. Curve 5



The correct match between Group I and Group II is

(A) P-2, Q-4, R-1, S-5 (B) P-2, Q-5, R-4, S-1

(C) P-2, Q-4, R-5, S-3 (D) P-2, Q-1, R-3, S-4

Key: (C)

17. The atmospheric layer closest to the earth surface is

(A) the mesosphere (B) the stratosphere

(C) the thermosphere (D) the troposphere

Key: (D)

18. A water supply board is responsible for treating 1500 m^3/day of water. A settling column analysis indicates that an overflow rate of 20 m/day will produce satisfactory removal for a depth of 3.1 m. It is decided to have two circular settling tanks in parallel. The required diameter (expressed in m) of the settling tanks is ________________.

Key: (6.9)

Exp: Total area of settling tank required,

$A = \frac{Q}{V} = \frac{1500}{20} = 75m^2$

Since no. of tanks = 2

So, area of each tank $= \frac{75}{2} = 37.5m^2$

$\frac{\pi d^2}{4} = 37.5 \Rightarrow d = 6.91m$

19. The hardness of a ground water sample was found to be 420 mg/L as $CaCO_3$. A softener containing ion exchange resins was installed to reduce the total hardness to 75 mg/L as $CaCO_3$ before supplying to 4 households. Each household gets treated water at a rate of 540 L/day. If the efficiency of the softener is 100%, the bypass flow rate (expressed in L/day) is ____.

Key: (385.7)

Exp: Since each household gets water = 540 L/day

So, total treated water = 540×4=2160 L/day

Let bypass flow rate is QL/day

So,

$$75 = \frac{Q \times 42.0 + (2160 - Q) \times 0}{2160}$$

$$\Rightarrow 2160 \times 75 = Q \times 420$$

$$\Rightarrow Q = 385.71 L/day$$

20. The sound pressure (expressed in µPa) of the faintest sound that a normal healthy individual can hear is

(A) 0.2 (B) 2 (C) 20 (D) 55

Key: (C)

Exp: Faintest sound that a normal healthy individual can hear $20\mu pa$

21. In the context of the IRC 58-2011 guidelines for rigid pavement design, consider the following pair of statements.

I: Radius of relative stiffness is directly related to modulus of elasticity of concrete and inversely related to Poisson's ratio

II: Radius of relative stiffness is directly related to thickness of slab and modulus of subgrade reaction.

Which one of the following combinations is correct?

(A) I: True; II: True (B) I: False; II: False

(C) I: True; II: False (D) I: False; II: True

Key: (C)

22. If the total number of commercial vehicles per day ranges from 3000 to 6000, the minimum percentage of commercial traffic to be surveyed for axle load is

(A) 15 (B) 20 (C) 25 (D) 30

Key: (A)

Exp: If Veh/day ranges from 3000 to 6000, min. 15% of traffic to be surveyed

23. Optimal flight planning for a photogrammetric survey should be carried out considering

(A) only side-lap

(B) only end-lap

(C) either side-lap or end-lap

(D) both side-lap as well as end-lap

Key: (D)

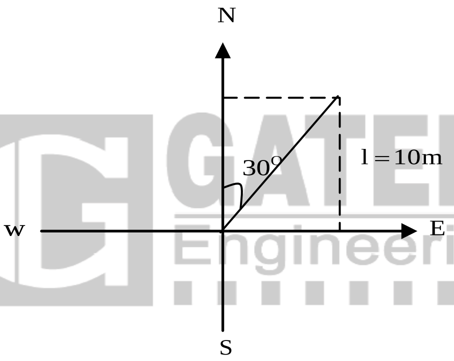
Exp: For optimal flight planning for a photogrammetric survey both side lap and end lap should be considered.

24. The reduced bearing of a 10 m long line is N30°E. The departure of the line is

(A) 10.00 m (B) 8.66 m (C) 7.52 m (D) 5.00 m

Key: (D)

Exp:



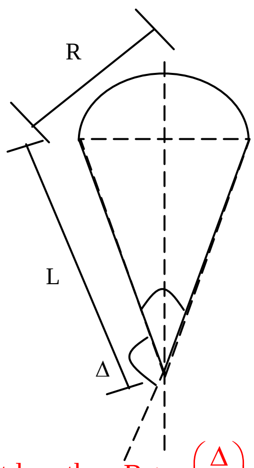
Departure = l. sin 30 = 10 × sin30 $= 10 \times \frac{1}{2} = 5\text{m}$

25. A circular curve of radius R connects two straights with a deflection angle of 60°. The tangent length is

(A) 0.577 R (B) 1.155 R (C) 1.732 R (D) 3.464 R

Key: (A)

Exp:



Tangent length $= \text{R}.\tan\left(\frac{\Delta}{2}\right) = \text{R}.\tan\left(\frac{60}{2}\right) = \text{R}\tan 30^{\circ} = 0.557\text{R}$

Q. No. 26 – 55 carry Two Marks Each

26. Consider the following linear system.

$$x+2y-3z=a$$
$$2x+3y+3z=b$$
$$5x+9y-6z=c$$

This system is consistent if a,b and c satisfy the equation

(A) $7a-b-c=0$ (B) $3a+b-c=0$

(C) $3a-b+c=0$ (D) $7a-b+c=0$

Key: (B)

27. If f(x) and g(x) are two probability density functions,

$$f(x)=\begin{cases}\frac{x}{a}+1: -a\le x<0\\ -\frac{x}{a}+1: 0\le x\le a\\ 0: \text{otherwise}\end{cases}$$

$$g(x)=\begin{cases}-\frac{x}{a}: a\le x<0\\ \frac{x}{a}: 0\le x\le a\\ 0: \text{otherwise}\end{cases}$$

Which one of the following statements is true?

(A) Mean of $f(x)$ and $g(x)$ are same; Variance of $f(x)$ and $g(x)$ are same

(B) Mean of $f(x)$ and $g(x)$ are same; Variance of $f(x)$ and $g(x)$ are different

(C) Mean of $f(x)$ and $g(x)$ are different; Variance of $f(x)$ and $g(x)$ are same

(D) Mean of $f(x)$ and $g(x)$ are different; Variance of $f(x)$ and $g(x)$ are different

Key: (B)

Exp: Mean of f(x) is E(x) $=\int_{-a}^{0}x.\left(\frac{x}{a}+1\right)dx+\int_{0}^{a}x.\left(\frac{-x}{a}+1\right)dx$

$$=\left(\frac{x^3}{3a}+\frac{x^2}{2}\right)_{-a}^{0}+\left(\frac{-x^3}{3a}+\frac{x^2}{2}\right)_{0}^{a}=0$$

Variance of f(x) is $E\left(x^2\right)-\left\{E(x)\right\}^2$ where

$$E(x^2)=\int_{-a}^{0}x^2.\left(\frac{x}{a}+1\right)dx+\int_{0}^{a}x^2.\left(\frac{-x}{a}+1\right)dx$$

$$=\left(\frac{x^4}{4a}+\frac{x^3}{3}\right)_{-a}^{0}+\left(\frac{-x^4}{4a}+\frac{x^3}{3}\right)_{0}^{a}=\frac{a^3}{6}$$

$\Rightarrow$ Variance is $\frac{a^3}{6}$

Next, mean of g(x) is $E(x)=\int_{a}^{0}x.\left(\frac{-x}{a}\right)dx+\int_{0}^{a}x.\left(\frac{x}{a}\right)dx=0$

Variance of g(x) is $E(x^2)-\{E(x)\}^2$, where

$$E(x^2)=\int_{-a}^{0}x^2.\left(\frac{-x}{a}\right)dx+\int_{0}^{a}x^2.\left(\frac{x}{a}\right)dx=\frac{a^3}{2}$$

$\Rightarrow$ Variance is $\frac{a^3}{2}$

$\therefore$ Mean of f(x) and g(x) are same but variance of f(x) and g(x) are different.

28. The angle of intersection of the curves $x^2 = 4y$ and $y^2 = 4x$ at point (0, 0) is

(A) 0^o (B) 30^o (C) 45^o (D) 90^o

Key: (D)

Exp: Given curves $x^2=4y$ … (1) and $y^2=4x$ … (2)

Diff (1), (2) w.r.to 'x', we get

$$2x=4\frac{dy}{dx}\Rightarrow\left(\frac{dy}{dx}\right)_{(0,0)}=0=m_1\text{and (say)}$$

$$2y\frac{dy}{dx}=4\Rightarrow\left(\frac{dy}{dx}\right)_{\infty}\to\infty=m_2\text{ (say)}$$

Let $m_2=\frac{1}{m'}$, wherer $m'=0$

$$\tan\theta=\left|\frac{m_1-m_2}{1+m_1m_2}\right|=\left|\frac{m_1m'-1}{m'+m_1}\right|=\left|\frac{0-1}{0+0}\right|=\infty$$

$$\Rightarrow\theta=\frac{\pi}{2}=90^o,$$

29. The area between the parabola $x^2 = 8y$ and the straight line $y = 8$ is _______ .

Key: (85.33)

Exp: Parabola is $x^2=8y\Rightarrow y=\frac{x^2}{8}$ and straight line is y=8

At the point of intersection, we have

$$\frac{x^2}{8}=8\Rightarrow x=-8,8\text{ and }y=8\geq y=\frac{x^2}{8}$$

$\therefore$ Required area is $\int_{x=-8}^{8}\left(8-\frac{x^2}{8}\right)dx$

$=2\int_0^8\left(8-\frac{x^2}{8}\right)dx\left(\because 8-\frac{x^2}{8}\text{ is even function}\right)$

$=2\left[8x-\frac{x^3}{24}\right]_0^8=\frac{256}{3}=85.33\text{ Sq.units}$

30. The quadratic approximation of $f(x)=x^3-3x^2-5$ at the point $x=0$ is

(A) $3x^2-6x-5$ (B) $-3x^2-5$

(C) $-3x^2+6x-5$ (D) $3x^2-5$

Key: (B)

Exp: The quadratic approximation of f(x) at the point x=0 is

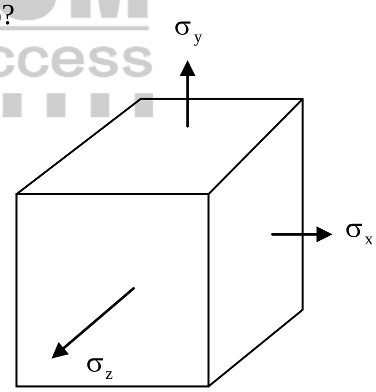
$f(x)=f(0)+\frac{x}{1!}f'(0)+\frac{x^2}{2!}f''(0)$

$=(-5)+x.\{0\}+\frac{x^2}{2}\{-6\}=-3x^2-5$

31. An elastic isotropic body is in a hydrostatic state of stress as shown in the figure. For no change in the volume to occur, what should be its Poisson's ratio?

(A) 0.00 (B) 0.25

(C) 0.50 (D) 1.00



Key: (C)

Exp: For no change in the volume

Volumetric strain $(\varepsilon_v)=0$

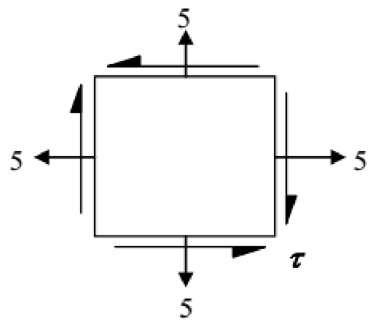
$\left(\frac{\varepsilon_x+\varepsilon_y+\varepsilon_z}{3}\right)(1-2\mu)=0$

$1-2\mu=0$

$1=2\mu$

Poissions ratio $\mu=\frac{1}{2}=0.5$

32. For the stress state (in MPa) shown in the figure, the major principal stress is 10 MPa.

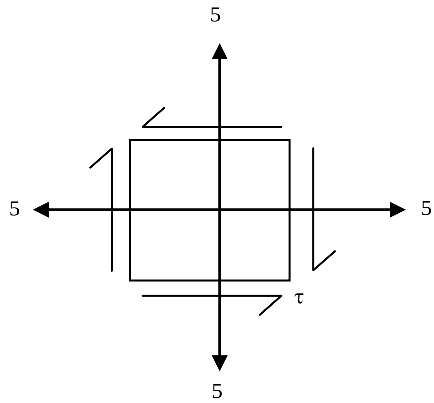


The shear stress τ is

(A) 10.0 MPa (B) 5.0 MPa (C) 2.5 MPa (D) 0.0 MPa

Key: (B)

Exp:



$\sigma_x = +5\text{MPa}$

$\sigma_y = +5\text{MPa}$

$\tau_{xy} = +\tau$

We know that

$$\sigma_{max/min} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

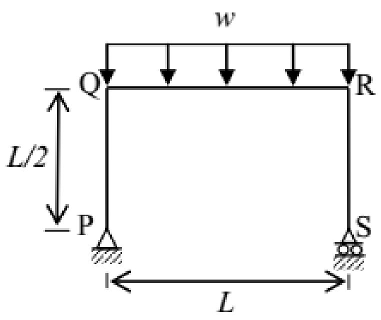
$$\sigma_{max} = \left(\frac{5+5}{2}\right) + \sqrt{\left(\frac{5-5}{2}\right)^2 + \tau^2}$$

$$10 = 5 + \sqrt{\tau^2} \Rightarrow 10 - 5 = \tau$$

$$\boxed{\tau = 5\text{MPa}}$$

33. The portal frame shown in the figure is subjected to a uniformly distributed vertical load *w* (per unit length).

The bending moment in the beam at the joint 'Q' is



The bending moment in the beam at the joint 'Q' is

(A) zero

(B) $\frac{wL^2}{24}$ (hogging)

(C) $\frac{wL^2}{12}$ (hogging)

(D) $\frac{wL^2}{8}$ (sagging)

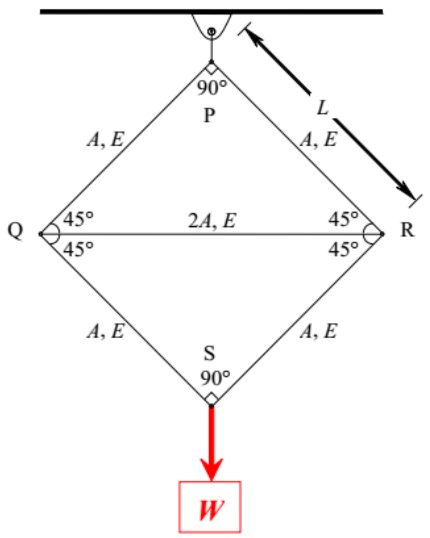
Key: (A)

Exp: Since there is no external horizontal load.

So, $H_p=0$

$\Rightarrow M_0 = 0$

34. Consider the structural system shown in the figure under the action of weight *W*. All the joints are hinged. The properties of the members in terms of length (*L*), area (*A*) and the modulus of elasticity (*E*) are also given in the figure. Let *L*, *A* and *E* be 1 m, 0.05 m2 and 30 × 106 N/m2, respectively, and *W* be 100 kN.



Which one of the following sets gives the correct values of the force, stress and change in length of the horizontal member QR?

(A) Compressive force = 25 kN; Stress = 250 kN/m^2; Shortening = 0.0118 m

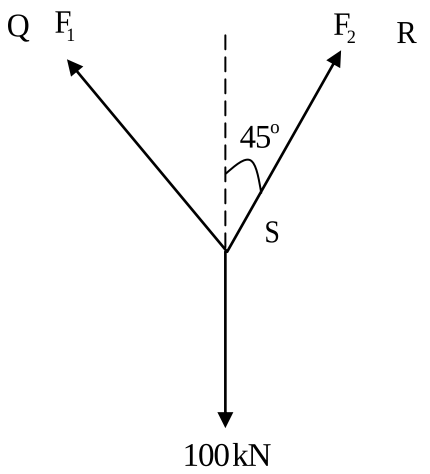
(B) Compressive force = 14.14 kN; Stress = 141.4 kN/m^2; Extension = 0.0118 m

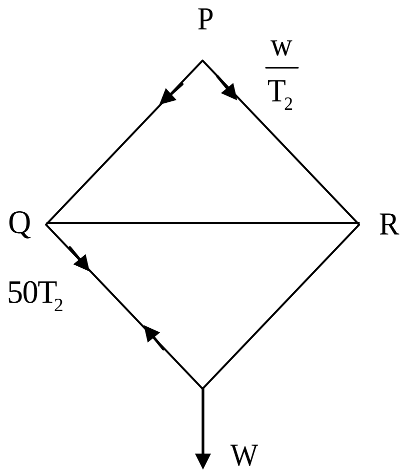
(C) Compressive force = 100 kN; Stress = 1000 kN/m^2; Shortening = 0.0417 m

(D) Compressive force = 100 kN; Stress = 1000 kN/m^2; Extension = 0.0417 m

Key: (C)

Exp:



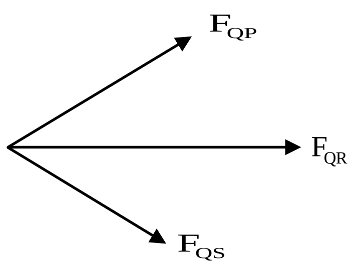


$F_{SQ} = F_{SR}$

$\Rightarrow 2F_{SQ}\cos 45^o = w \Rightarrow F_{SQ} = \frac{w}{\sqrt{2}}$

Similarly $F_{PQ} = F_{PR} = \frac{w}{\sqrt{2}}$

Now, Consider joint Q



$\sum Fx = 0$

$\Rightarrow F_{QP} \times \cos 45^o + F_{QS} \cos 45^o + F_{QR} = 0$

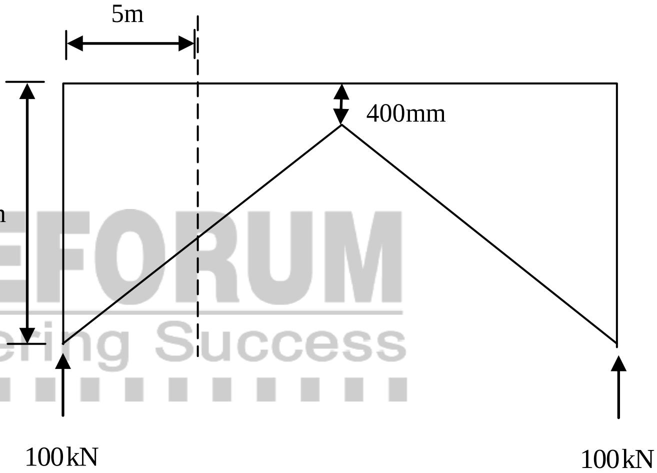
$\Rightarrow F_{QR} = w = 100kN(\text{Compressive})$

$\Delta_{QR} = \frac{F_{QR} \times L}{2A_E} = \frac{100 \times \sqrt{2}L}{4 \times 0.05 \times 0.3 \times 106} = 0.471 \ (\text{Shortening})$

35. A haunched (varying depth) reinforced concrete beam is simply supported at both ends, as shown in the figure. The beam is subjected to a uniformly distributed factored load of intensity 10 kN/m. The design shear force (expressed in kN) at the section X-X of the beam is __.

Key: (65)

Exp:



$\tau_v = \frac{V_x \pm \frac{M}{d}.\tan\beta}{bd}$

$\Rightarrow V_d = \tau_v.bd = V_x \pm \frac{M_x}{dx}\tan\beta$

$V_x = 100 - 10 \times 5 = 50kN; dx = 500mm$

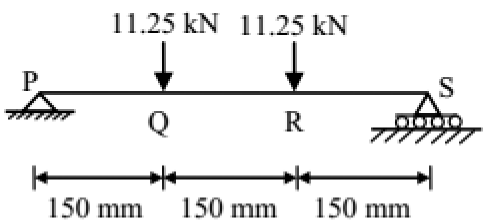
$M_x = 100 \times 5 - 10 \times \frac{5 \times 5}{2} = 375kN - m$

$V_d = 50 + \frac{375}{0.5} \times \tan\beta$

$\tan\beta = \frac{600 - 400}{10 \times 1000} = \frac{200}{10,000}$

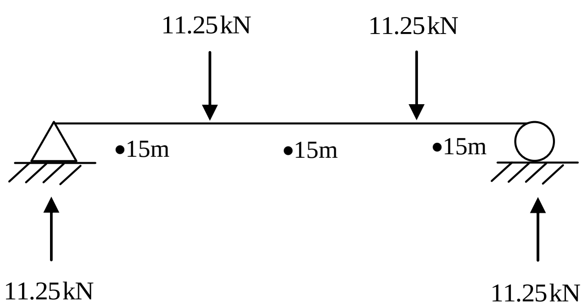
$V_d = 50 + \frac{375}{0.5} \times \frac{200}{10,000} = 50 + 15 = 65kN$

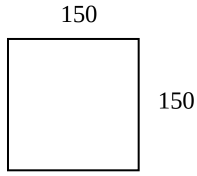
36. A 450 mm long plain concrete prism is subjected to the concentrated vertical loads as shown in the figure. Cross section of the prism is given as 150 mm × 150 mm. Considering linear stress distribution across the cross-section, the modulus of rupture (expressed in MPa) is ______ .

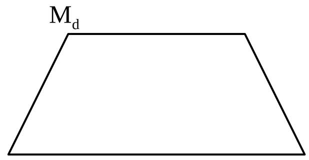


Key: (3)

Exp:







$M_d = 11.25 \times 0.15 = 1.6875 kN - m$

Section Modulus, $Z = \frac{bd^2}{6} = \frac{0.15 \times (0.15)^2}{6} = 0.000563 m^3$

Modulus of rupture, $f = \frac{M}{z} = \frac{1.6875}{0.000563} \times 10^{-3} MPa = 3MPa$

37. Two bolted plates under tension with alternative arrangement of bolt holes are shown in figures 1 and 2. The hole diameter, pitch, and gauge length are d, p and g, respectively.

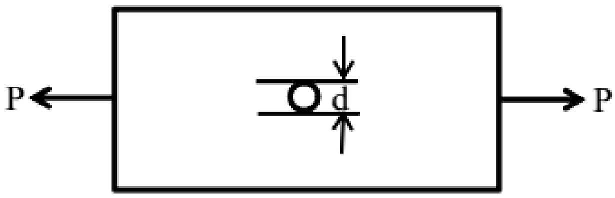


Figure 1

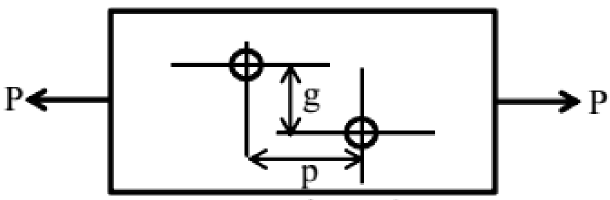


Figure 2

(A) $p^2 > 2gd$ (B) $p^2 < \sqrt{4gd}$

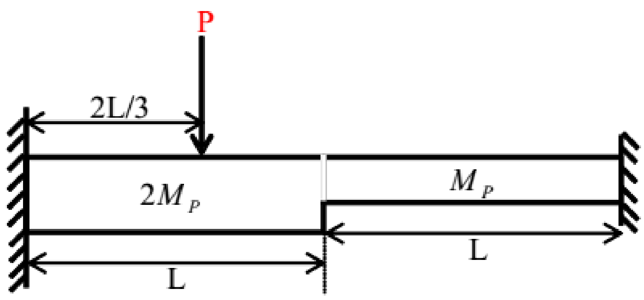
(C) $p^2 > 4gd$ (D) $p > 4gd$

Key: (C)

Exp: $p^2 > 4gd$

This question can be solved by trick, Option (B) and (D) are not dimensionally correct.

38. A fixed-end beam is subjected to a concentrated load (*P*) as shown in the figure. The beam has two different segments having different plastic moment capacities $(M_p, 2M_p)$ as shown.

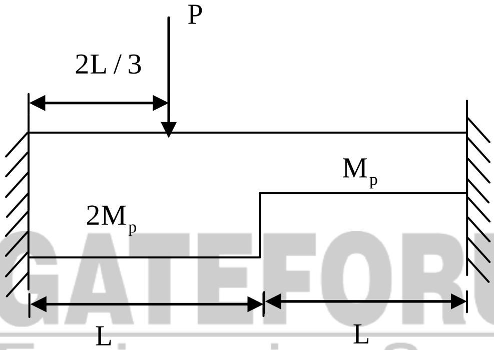


The minimum value of load (P) at which the beam would collapse (ultimate load) is

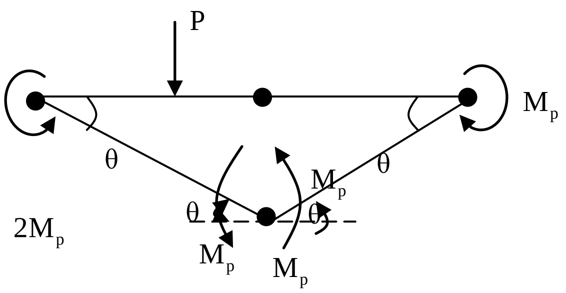
(A) $7.5M_p / L$ (B) $5.0M_p / L$ (C) $4.5M_p / L$ (D) $2.5M_p / L$

Key: (A)

Exp:



Mechanism -I



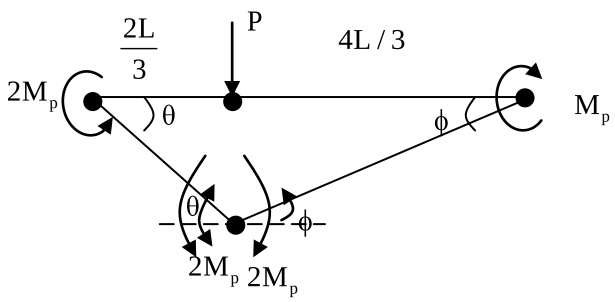
$$-2M_p\theta - M_p\theta - M_p\theta - M_p\theta + P\left(\frac{2L\theta}{3}\right) = 0$$

$$-5M_p\theta + \frac{2PL}{3}\theta = 0$$

$$\frac{2PL}{3} = 5M_p$$

$$\boxed{P = \frac{15M_p}{2L} = 7.5Mp / L}$$

Mechanism -II



$$\frac{2l}{3}\theta = \frac{4l}{3}\phi$$

$$\boxed{\theta = 2\phi}$$

$$-2M_p\theta - 2M_p\theta - 2M_p\phi - M_p\phi + P\left(\frac{2L}{3}\right)\theta = 0$$

$$-4M_p\theta - 3M_p\phi + \frac{2PL}{3}\theta = 0$$

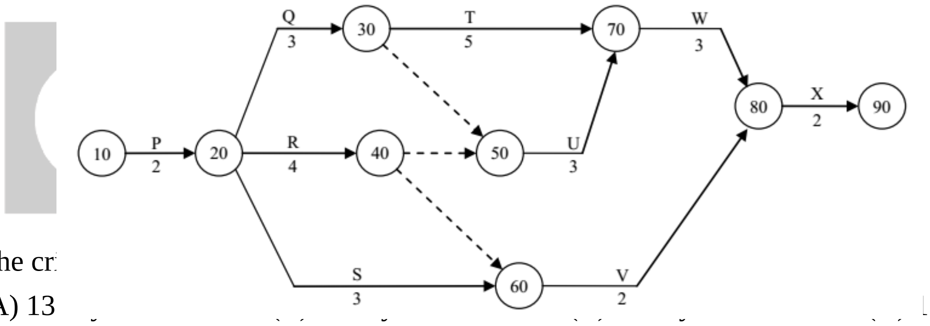
$$-4M_p\theta - 3M_p\left(\frac{\theta}{2}\right) + \frac{2PL}{3}\theta = 0$$

$$\frac{11}{2}M_p\theta = \frac{2PL}{3}\theta$$

$$\boxed{P = \frac{33}{4}M_p = 8.25M_p}$$

So the minimum value of load =7.5 M_p/L

39. The activity-on-arrow network of activities for a construction project is shown in the figure. The durations (expressed in days) of the activities are mentioned below the arrows.



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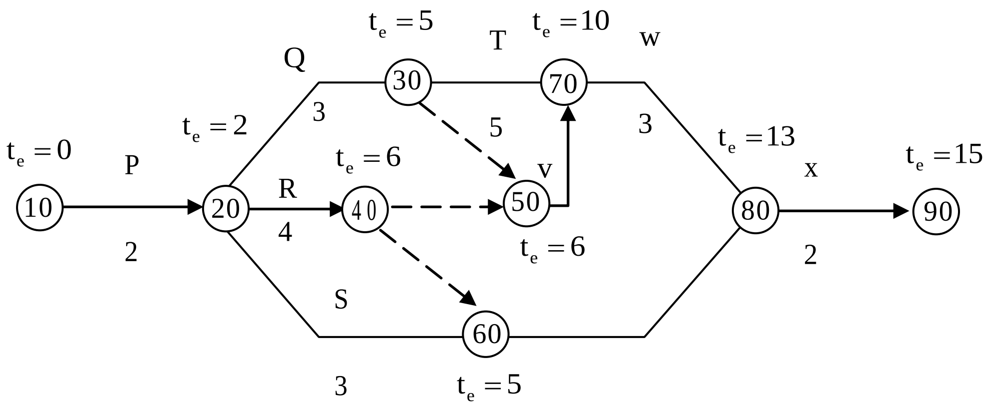
(A) 13 ... 16 days

Key: (C)

Exp:



40. The seepage occurring through an earthen dam is represented by a flow net comprising of 10 equi potential drops and 20 flow channels. The coefficient of permeability of the soil is 3 mm/min and the head loss is 5 m. The rate of seepage (expressed in cm3/s per m length of the dam) through the earthen dam is __________.

Key: (500)

Exp:

Given No. of flow channels (N_f) = 20

No. of equipotential drops (N_d)=10

Head loss (h) = 5m

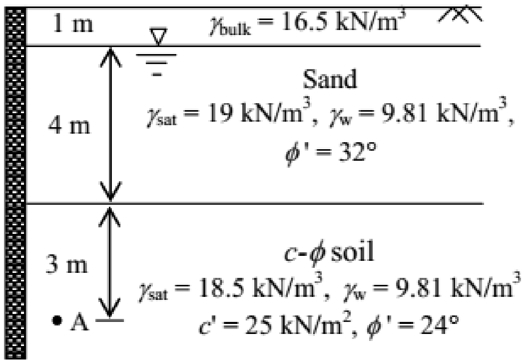
Coefficient of permeable = $3\text{mm/min} = \frac{3\times10^{-3}\text{m}}{60\,\text{sec}} = 0.5\times10^{-4}\,\text{m/sec}$

Seepage $q = kh\frac{N_f}{N_d} = 0.5\times10^{-4}\times5\times\frac{20}{10}\left(\frac{m^3}{sec}\right)$

$= 5\times10^{-4}m^3/sec \quad = 5\times10^{-4}\times10^{6}cm^3/sec$

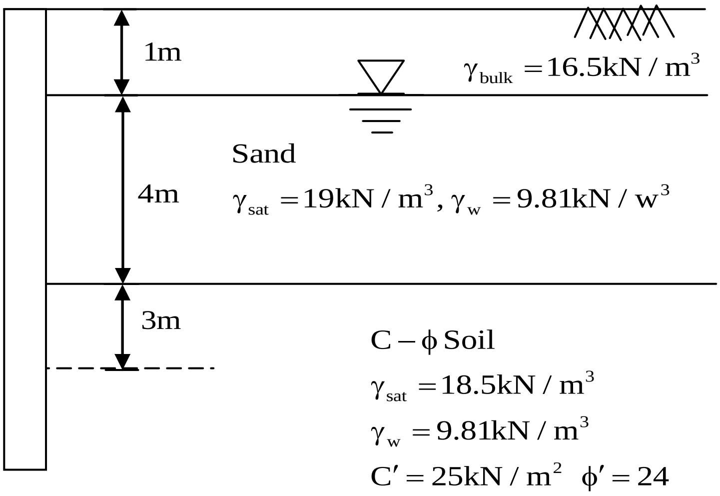
$q = 500\,cm^3/sec$

41. The soil profile at a site consists of a 5 m thick sand layer underlain by a *c*-φ soil as shown in figure. The water table is found 1 m below the ground level. The entire soil mass is retained by a concrete retaining wall and is in the active state. The back of the wall is smooth and vertical. The total active earth pressure (expressed in kN/m^2) at point A as per Rankine's theory is _



Key: (69.65)

Exp:



In $C-\phi$ soil

$k_A = \frac{1-\sin\phi'}{1+\sin\phi'} = \frac{1-\sin24}{1+\sin24} = 0.422$

Active earth pressure in $C-\phi$ soil at A is

$$\sigma_a = k_A.\sigma_A - 2c\sqrt{k_A}$$

$$\sigma_a = 0.422\left(1\times16.5+4\times(19-9.81)+3\times(18.5-9.81)\right)+7\times9.8-2\times25\times\sqrt{0.422}$$

$$=\left(0.422\times79.33\right)+68.67-50\times0.65$$

$$=33.48+68.67-32.5=69.65\ kN/m^2$$

42. OMC-SP and MDD-SP denote the optimum moisture content and maximum dry density obtained from standard Proctor compaction test, respectively. OMC-MP and MDD-MP denote the optimum moisture content and maximum dry density obtained from the modified Proctor compaction test, respectively. Which one of the following is correct?

(A) OMC-SP < OMC-MP and MDD-SP < MDD-MP

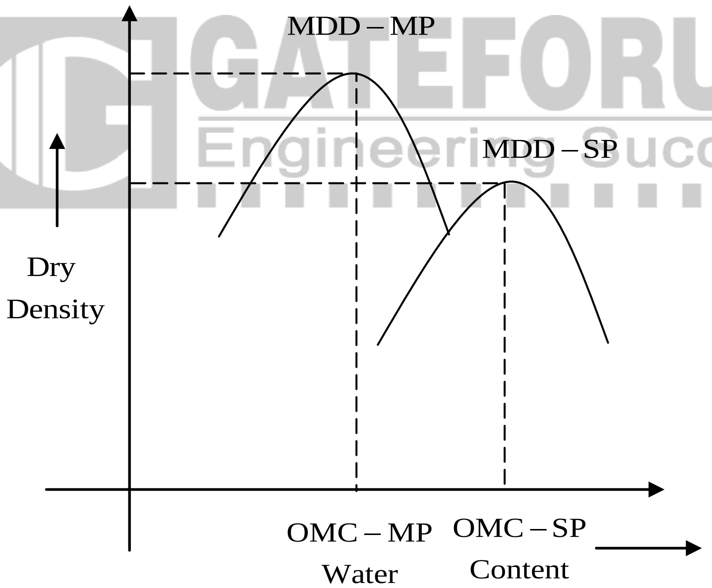
(B) OMC-SP > OMC-MP and MDD-SP < MDD-MP

(C) OMC-SP < OMC-MP and MDD-SP > MDD-MP

(D) OMC-SP > OMC-MP and MDD-SP > MDD-MP

Key: (B)

Exp:



So, OMC-SP>OMC-MP; MDD-SP<MDD-MP

43. Water flows from P to Q through two soil samples, Soil 1 and Soil 2, having cross sectional area of $80cm^2$ as shown in the figure. Over a period of 15 minutes, 200 ml of water was observed to pass through any cross section. The flow conditions can be assumed to be steady state. If the coefficient of permeability of Soil 1 is 0.02 mm/s, the coefficient of permeability of Soil 2 (expressed in mm/s) would be ________________

Key: (0.045)

Exp: As per Darcy's law,

$$Q = K_{avg} \times i \times A$$

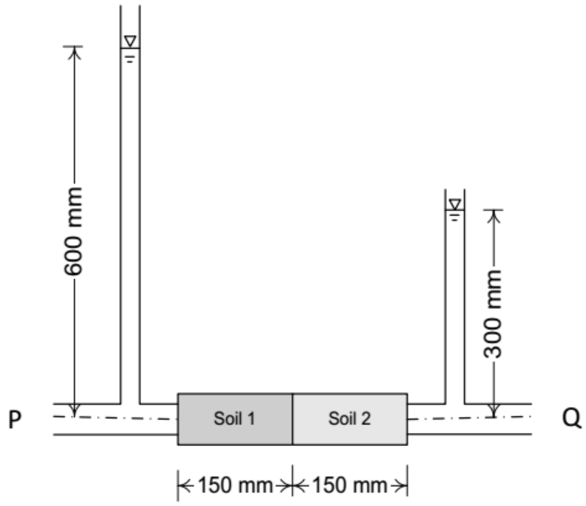
$$K_{avg} = \frac{\sum z_i}{\sum \frac{z_i}{k_i}} = \frac{150+150}{\frac{150}{0.02} + \frac{150}{k}}$$

$$K_{avg} = \frac{Q.L}{Aht} = \frac{Q}{Ait}$$

$$\Rightarrow \frac{150+150}{\frac{150}{0.02} + \frac{150}{k}} = \frac{200 \times 10^3}{15 \times 60} \times \frac{1}{80 \times 10^2} \times \frac{1}{1}$$

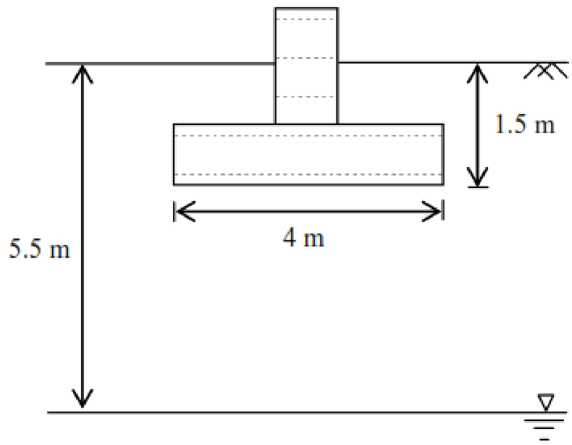
$$\Rightarrow \frac{300}{150 \times \left[50 + \frac{1}{k}\right]} = \frac{5}{180}$$

$$\Rightarrow k = 0.045 \text{ mm/sec}$$



44. A 4 m wide strip footing is founded at a depth of 1.5 m below the ground surface in a *c*-φ soil as shown in the figure. The water table is at a depth of 5.5 m below ground surface. The soil properties are: c' = 35 kN/m^2, φ' = 28.63°, γ_{sat} = 19 kN/m^3, γ_{bulk} = 17 kN/m3 and γ_w = 9.81 kN/m^3. The values of bearing capacity factors for different φ′ are given below.

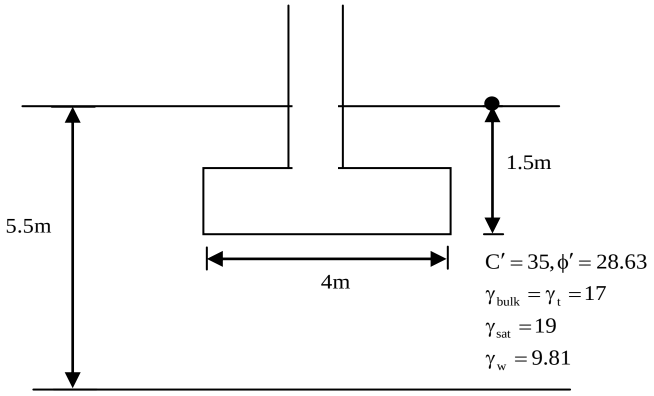
φ′	*Nc*	*Nq*	*N*γ
15°	12.9	4.4	2.5
20°	17.7	7.4	5.0
25°	25.1	12.7	9.7
30°	37.2	22.5	19.7



Using Terzaghi's bearing capacity equation and a factor of safety F_s = 2.5, the net safe bearing capacity (expressed in kN/m^2) for local shear failure of the soil is ______.

Key: (298.48)

Exp:



As per Teraghis for local shear failure

$$C_m = \frac{2}{3}C' = \frac{2}{3}\times 35$$

$$\phi_m = \tan^{-1}\left(\frac{2}{3}\tan\phi\right)$$

$$q_{nu} = C_m N_c^{'} + q.\left(N_q^{'} - 1\right) + \frac{1}{2}B.\gamma.N_r^{'}$$

$$q_{nu} = \left(\frac{2}{3}c\right)N_c^{'} + q.\left(N_q^{'} - 1\right) + \frac{1}{2}B.\gamma.N_r^{'}$$

$$\phi_m = \tan^{-1}\left(\frac{2}{3}\tan\phi\right) = \tan^{-1}\left(\frac{2}{3}\tan 28.63\right) = \tan^{-1}(0.3639)$$

$$\phi_m = 19.998 \cong 20^o$$

From Table

$$\text{for } \phi_m = 20' \Rightarrow N_c = 17.7,\ N_q = 7.4,\ N_r = 5$$

$$q_{nu} = \frac{2}{3}CN_c^{'} + \left(\gamma_t D_f\right)\left(N_q^{'} - 1\right) + \frac{1}{2}(B\gamma_t)N_r$$

$$= \frac{2}{3}\times 35\times 17.7 + 17\times 1.5\times(7.4-1) + \frac{1}{2}\times 4\times 17\times 5$$

$$= 413 + 163.2 + 170 = 746.2$$

$$\text{Net Safe bearing capacity } = \frac{q_{nu}}{F.O.S} = \frac{746.2}{2.5} = 298.48\text{kN}/\text{m}^2$$

45. A square plate is suspended vertically from one of its edges using a hinge support as shown in figure. A water jet of 20 mm diameter having a velocity of 10 m/s strikes the plate at its mid-point, at an angle of 30° with the vertical. Consider *g* as 9.81 m/s^2 and neglect the self-weight of the plate. The force F (expressed in N) required to keep the plate in its vertical position is __________

Key: (7.85)

Exp: For exerted by jet in X-direction

$F_x = \rho a (V - v)^2 \times \sin\theta$

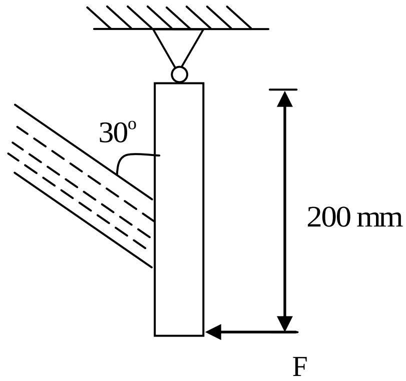
$= 10^3 \times \frac{\pi}{4} \times (0.02)^2 \times (10)^2 \times \sin 30^o$

$= 15.71 N$

Taking moment about hinge,

$F_x \times 0.1 = F \times 0.2$

$\Rightarrow F = \frac{F_x}{2} = \frac{15.71}{2} = 7.85 N$



46. The ordinates of a one-hour unit hydrograph at sixty minute interval are 0, 3, 12, 8, 6, 3 and 0 m^3/s. A two-hour storm of 4 cm excess rainfall occurred in the basin from 10 AM. Considering constant base flow of $20 m^3/s$, the flow of the river (expressed in m^3/s) at 1 PM is __

Key: (60)

Exp:

Time	Ordinate of 1 hr UH	Lag	Ordinate of 2h DRH	Ordinate of 2h UH
10:00	0		0	0
11:00	3	0	3	1.5
12:00	12	3	15	7.5
01:00	8	12	20	10
02:00	6	8	14	7
03:00	3	6	9	4.5
03:00	3	6	9	4.5
04:00	0	3	3	1.5
		0	0	0

Flow of river = rainfall excess × ordinate of 2-h UH + Base flow

$= 4 \times 10 + 20 = 60 \ m^3/s$

47. A 3 m wide rectangular channel carries a flow of $6 m^3/s$. The depth of flow at a section P is 0.5 m. A flat-topped hump is to be placed at the downstream of the section P. Assume negligible energy loss between section P and hump, and consider gg as 9.81 m/s^2 . The maximum height of the hump (expressed in m) which will not change the depth of flow at section P is _________

Key: (0.205)

Exp: The maximum height of hump Δz is given by

$E = E_{min} + \Delta z_{max}$

$$\Rightarrow y+\frac{q^2}{2gy^2}=\frac{3}{2}y_c+\Delta z_{max}$$

$$q=\frac{Q}{B}=\frac{6}{3}=2m^2/s, y=0.5m$$

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

$$\text{So, } 0.5+\frac{(2)^2}{2\times9.81\times(0.5)^2}=\frac{3}{2}\times0.74+\Delta z_{max}$$

$$\Rightarrow \Delta Z_{max}=0.205m$$

48. A penstock of 1 m diameter and 5 km length is used to supply water from a reservoir to an impulse turbine. A nozzle of 15 cm diameter is fixed at the end of the penstock. The elevation difference between the turbine and water level in the reservoir is 500 m. consider the head loss due to friction as 5% of the velocity head available at the jet. Assume unit weight of water = 10 kN/m^3 and acceleration due to gravity (g) = 10 m/s^2. If the overall efficiency is 80%, power generated (expressed in kW and rounded to nearest integer) is __

Key: (6570)

Exp: Energy equation,

$$H=\frac{P}{A}+\frac{V^2}{2g}+h_L$$

$$\Rightarrow 500=\frac{V^2}{2g}+0.05\times\frac{V^2}{2g}$$

$$\Rightarrow V=\sqrt{\frac{2\times10\times500}{1.05}}=97.59m/s$$

$$\text{Water power }=\frac{1}{2}mv_1^2$$

$$=\frac{1}{2}\times10^3\times\frac{\pi}{4}\times(0.15)^2\times(97.59)$$

$$=8212.5kw$$

$$\text{Power generated }=\eta_0\times w.p$$

$$=0.8\times8212.5$$

$$\simeq 6570kw$$

49. A tracer takes 100 days to travel from Well-1 to Well-2 which are 100 m apart. The elevation of water surface in Well-2 is 3m below that in Well-1. Assuming porosity equal to 15%, the coefficient of permeability (expressed in m/day) is

(A) 0.30 (B) 0.45 (C) 1.00 (D) 5.00

Key: (D)

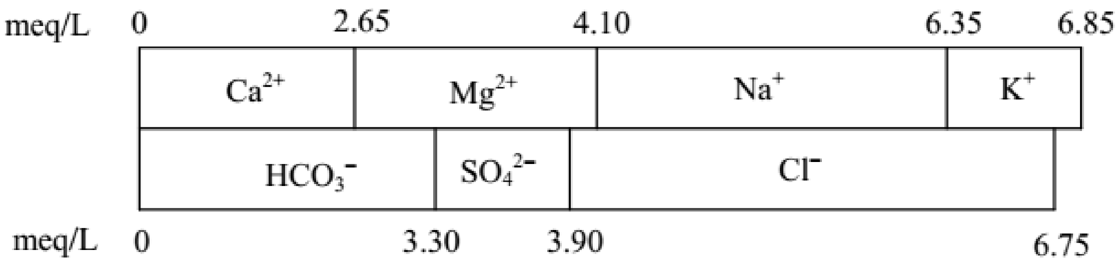
Exp: Seepage velocity $=\frac{100}{100}=1m/day$

Discharge Velocity = n × seepage velocity = 0.15 ×1=0.15 m/day

$$i = \frac{h}{L} = \frac{3}{100}$$

$$V = k.i \Rightarrow 0.15 = k \times \frac{3}{100} \Rightarrow k = 5m/day$$

50. A sample of water has been analyzed for common ions and results are presented in the form of a bar diagram as shown.



The non-carbonate hardness (expressed in mg/L as $CaCO_3$) of the sample is

(A) 40 (B) 165 (C) 195 (D) 205

Key: (A)

Exp: Total hardness = Mg/L of Ca^{2+} and mg^{2+}

= 4.1 ×50=205mg/L as $Caco_3$

Alkalinity = 3.3×50=165 mg/L as $CaCo_3$

NCH = TH-Alkalinity = 205-165= 40 mg/L

51. A noise meter located at a distance of 30 m from a point source recorded 74 dB. The reading at a distance of 60 m from the point source would be _______

Key: (67.9)

Exp: $$L_{60} = L_{30} - 20\log_{10}\left(\frac{60}{30}\right)$$

$$= 74 - 20\log_{10} 2$$

$$= 67.9dB$$

52. For a wastewater sample, the three-day biochemical oxygen demand at incubation temperature of 20°C ($BOD_{3day,\ 20°C}$) is estimated as 200 mg/L. Taking the value of the first order BOD reaction rate constant as 0.22 day^{-1}, the five-day BOD (expressed in mg/L) of the wastewater at incubation temperature of 20°C ($BOD_{5day,\ 20°c}$) would be ___

Key: (276.158)

Exp: Given

$(BOD)_3 = 200mg/L$

$k_D = 0.22/day$

$(BOD)_5 = ?$

$(BOD)_3 = L_0\left(1-e^{-k_D \times t}\right)$

$200 = L_0\left(1-e^{-0.22\times3}\right)$

$L_0 = \frac{200}{1-e^{-0.66}} = \frac{200}{0.483} = 413.95$

$(BOD)_5 = L_0\left(1-e^{-k_D\times t}\right) = 413.95\left(1-e^{-0.22\times5}\right) = 276.158\ mg/L$

53. The critical flow ratios for a three-phase signal are found to be 0.30, 0.25, and 0.25. The total time lost in the cycle is 10 s. Pedestrian crossings at this junction are not significant. The respective Green times (expressed in seconds and rounded off to the nearest integer) for the three phases are

(A) 34, 28, and 28 (B) 40, 25, and 25 (C) 40, 30, and 30 (D) 50, 25, and 25

Key: (A)

Exp: Given

$y_1 = 0.30, y_2 = 0.25, y_3 = 0.25$

Total cycle time (L) = 10

By Webster method

Cycle time $(C_0) = \frac{1.5L+5}{1-y}$

$$(C_0) = \frac{1.5L+5}{1-\left(y_1+y_2+y_3\right)}$$

$$C_0 = \frac{1.5\times10+5}{1-(0.3+0.25+0.25)}$$

$$= \frac{15+5}{1-.08} = \frac{20}{0.2} = 100s$$

$$G_1 = \frac{(C-L)(y_1)}{\sum y} = \frac{(100-10)\times0.30}{0.8} = 33.75sec \cong 34sec$$

$$G_2 = \frac{(C-L)(y_2)}{\sum y} = \frac{(100-10)\times0.25}{0.8} = 28.125sec \cong 28sec$$

$$G_3 = \frac{(C-L)y_3}{\sum y} = \frac{(100-10)\times0.25}{0.8} = 28.125sec \cong 28sec$$

54. A motorist travelling at 100 km/h on a highway needs to take the next exit, which has a speed limit of 50 km/h. The section of the roadway before the ramp entry has a downgrade of 3% and coefficient of friction (*f*) is 0.35. In order to enter the ramp at the maximum allowable speed limit, the braking distance (expressed in m) from the exit ramp is ______

Key: (92.14)

55. A tall tower was photographed from an elevation of 700 m above the datum. The radial distances of the top and bottom of the tower from the principal points are 112.50 mm and 82.40 mm, respectively. If the bottom of the tower is at an elevation 250 m above the datum, then the height (expressed in m) of the tower is ______.

Key: (120.4)

Exp: Relief displacement is given by, $d = \frac{r.h_2}{H - h_{avg}}$

$$d = 112.5 - 82.40 = 30.1mm$$

$$\Rightarrow 30.1 = \frac{h \times 112.5}{700 - 250}$$

$$\Rightarrow h = 120.4m$$