Ans. **(c)**

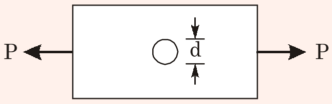


Figure 1

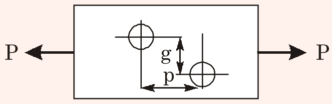


Figure 2

Tensile strength of plate in arrangement (2) will be greater than in arrangement (1)

* As per IS code 800:2007 close 6.3

$$\left(0.9A_{net}\frac{f_{up}}{\gamma_{m1}}\right)_2 > \left(0.9A_{net}\frac{f_{up}}{\gamma_{m1}}\right)_1$$

$$(A_{net})_2 > (A_{net})_1$$

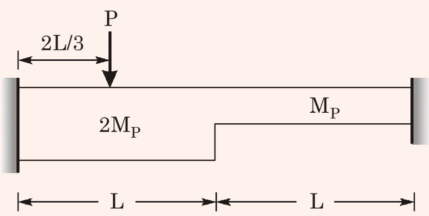
$$\left[\left(B-2d+\frac{p^2}{4g}\right)t\right]_2 > [(B-d)t]_1$$

$$B-2d+\frac{p^2}{4g} > B-d$$

$$\frac{p^2}{4g} > d$$

$$p^2 > 4gd$$

Q.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) $\frac{7.5M_P}{L}$

(b) $\frac{5.0M_P}{L}$

(c) $\frac{4.5M_P}{L}$

(d) $\frac{2.5M_P}{L}$

Ans. **(a)**

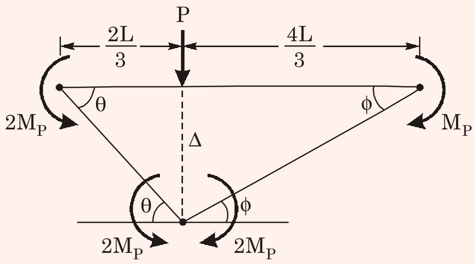
$D_S = 2$

$\therefore$ Number of plastic hinge required for complete collapse

$= D_S + 1$

$= 2 + 1 = 3$

Mechanism 1:



$$\Delta = \frac{2L}{3\theta} = \frac{4L}{3}$$

$$\Rightarrow \qquad \theta = 2\theta$$

For principal of virtual work done,

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

$$\Rightarrow \qquad 4M_P\theta + 3M_P\phi = \frac{2PL}{3}\theta$$

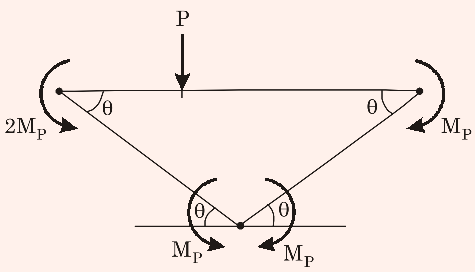
$$\Rightarrow \qquad 8M_P\phi + 3M_P\phi = \frac{4PL}{3}\phi$$

$$\Rightarrow \qquad 11M_P = \frac{4P_uL}{3}$$

$$\Rightarrow \qquad P_u = \frac{33}{4}\frac{M_P}{L}$$

$$\therefore \qquad P_u = 8.25\frac{M_P}{L}$$

Mechanism 2:



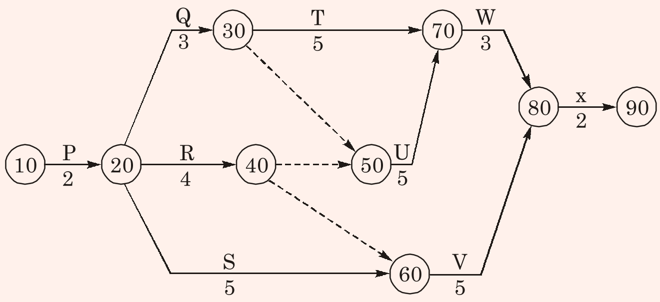
$$2M_P\theta + M_P\theta + M_P\theta + M_P\theta = P\left(\frac{2L}{3}\right)$$

$$\Rightarrow \qquad 5M_P = \frac{2PL}{3}$$

$$\Rightarrow \qquad P_u = \frac{15M_P}{2L}$$

$$\therefore \qquad P_u = 7.5\frac{M_P}{L}$$

Q.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.

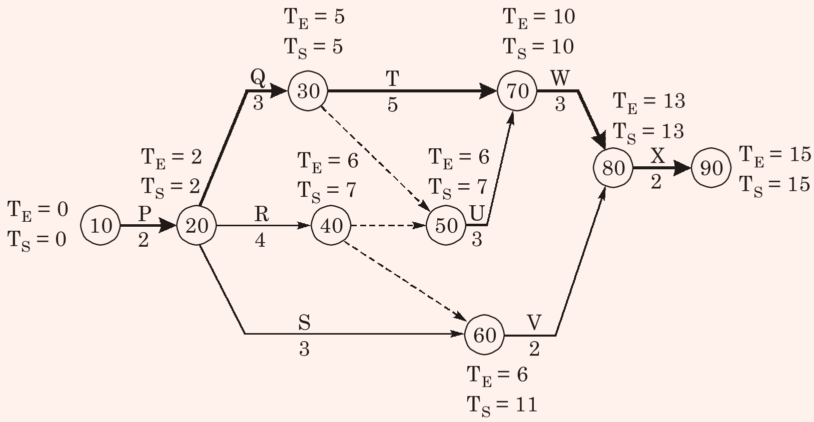


The critical duration for this construction project is

(a) 13 days (b) 14 days

(c) 15 days (d) 16 days

Ans. **(c)**



The critical duration is 15 days which is observed along the path P-Q-T-W-X which is the critical path of the project.

Note: Critical path is the one which consumes maximum amount of time.

Q.40 The seepage occurring through an earthen dam is represented by a flownet comprising of 10 equipotential 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 cm^3/s per *m* length of the dam) through the earthen dam is_______

Ans. **(500)**

$$q = \frac{KH \cdot N_f}{N_d}$$

$$K = \frac{3\ \text{mm}}{\text{min}} = \frac{3 \times 10^{-3}\ \text{m}}{60}\ \text{m/s}$$

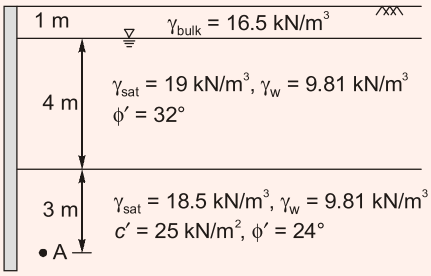
$$H = 5\ \text{m},\quad N_f = 20,\quad N_d = 10$$

$$q = \frac{3\times10^{-3}}{60}\times5\times\frac{20}{10}\ m^3/\text{sec per m length of dam}$$

$$q = \frac{3\times10^{-3}\times5\times20}{60\times10}\times10^6\ cm^3/\text{sec per m length of dam}$$

$$q = 500\ cm^3/\text{sec per m length of dam}$$

Q.41 The soil profile at a site consists of a 5 m thick sand layer underlain by a *c*-ϕ soil a 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_______.



Ans. **(69.65)**

In c-ϕ soil

Earth pressure $p_a = k_a\sigma_v - 2c\sqrt{k_a}$

$$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 24}{1+\sin 24} = 0.4217$$

Note: Below water table, water pressure will not be multiplied by k_a

at point A $\sigma_v = 1\times\gamma_b + 4\gamma_{sat} + 3\gamma_{sat}$

$\sigma_v = 1\times\gamma_b + (4\times\gamma' + 4\times\gamma_w) + (3\gamma' + 3\gamma_w)$

$\sigma_v = (1\times\gamma_b + 4\gamma' + 3\gamma') + (4\gamma_w + 3\gamma_w)$

Earth Pressure at 'A'

$$p_a = k_a\sigma_v - 2c\sqrt{k_a}$$

$$= k_a[\gamma_b + 4\gamma' + 3\gamma'] + 4\gamma_w + 3\gamma_w - 2\times c'\sqrt{k_a}$$

$$= 0.4217[16.5 + 4(19-9.81) + 3(18.5-9.81)]$$

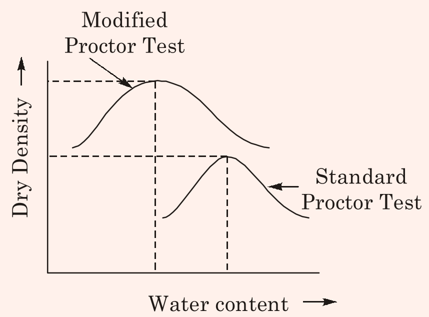
$$+7\times9.81 - 2\times25\times\sqrt{0.4217}$$

$$p_a = 69.65\ kN/m^2$$

Q.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?

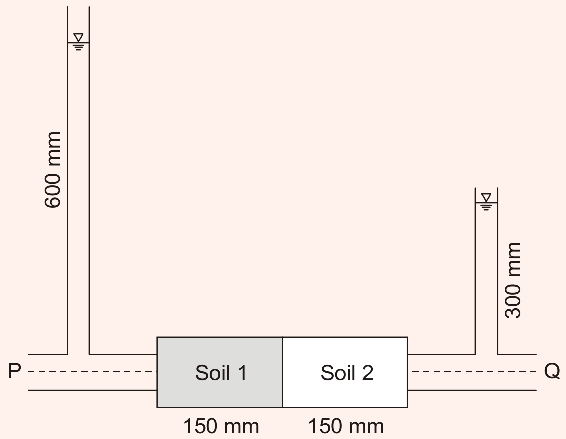
(a) OMC-SP < OMC-MP and MDD - SP < MDD-MP
(b) OMC-SP > OMC-MP and MDD - SP < MDD-MP
(c) OMC-SP < OMC-MP and MDD - SP >MDD-MP
(d) OMC-SP > OMC-MP and MDD - SP > MDD-MP

Ans. **(b)**



$$\text{OMC} - \text{SP} > \text{OMC} - \text{MP}$$
$$\text{MDD} - \text{SP} < \text{MDD} - \text{MP}$$

Q.43 Water flows from P to Q through two soil samples, Soil 1 and Soil 2, having cross sectional area of 80 cm^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___



Ans. **(0.045)**

$$\text{Discharge} = \frac{200\text{ ml}}{15\text{ min}} = \frac{200\text{ cm}^3}{15\times 60\text{ sec}} = \frac{200\times 10^3}{900}\ \frac{\text{mm}^3}{\text{sec}}$$

As per Darcy $q = k_{avg} iA$

$$k_{avg} = \frac{\Sigma Z_i}{\Sigma \frac{Z_i}{k_i}} \quad (\because \text{ flow is normal to bedding plane})$$

$$k_{avg} = \frac{150+150}{\frac{150}{0.02}+\frac{150}{k}}$$

$$i = \frac{\text{Head difference}}{\text{length}} = \frac{600-300}{300} = 1$$

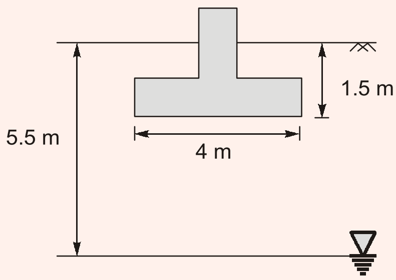
$$A = 80 \text{ cm}^2 = 80 \times 10^2 \text{ mm}^2$$

$$q = \left[\frac{150+150}{\frac{150}{0.02}+\frac{150}{k}}\right] \times 1 \times 80 \times 10^2 = \frac{200 \times 10^3}{900}$$

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

Q.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, $\phi' = 28.63°$, $\gamma_{sat} = 19$ kN/m^3, $\gamma_{bulk} = 17$ kN/m^3 and $\gamma_w = 9.81$ kN/m^3. The values of bearing capacity factors for different ϕ' are given below.

ϕ'	N_c	N_q	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_______

Ans. **(298.48)**

Local shear failure is occuring hence modified c and ϕ should be used

$$c_m = \frac{2}{3}c = \frac{2}{3} \times 35 = 23.33 \text{ kN/m}^2$$

$$\tan\phi_m = \frac{2}{3}\tan\phi = \frac{2}{3}\tan 28.63$$

$$\phi_m = 20°$$

for $\phi_m = 20°,\ N_c = 17.7,\ N_q = 7.4,\ N_\gamma = 5.0$

⇒ Water table is at

$D_f + B = 1.5 + 4 = 5.5$ m hence no effect on bearing capacity

⇒ As per Terzaghi for strip footing

$$q_u = cN_c + 8D_f N_q + 0.5 B\gamma N_\gamma$$

$$q_u = \frac{2}{3}\times 35\times 17.7 + 17 + 1.5\times 7.4 + 0.5 \times 4 \times 17 \times 5$$

$$q_u = 771.7 \text{ kN/m}^2$$

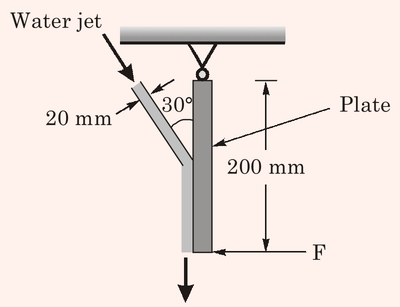
$$q_{nu} = q0\, q_u - \bar{\sigma} = q_u - \gamma D_f = 771.7 - 17 \times 1.5$$

$$q_{nu} = 746.2 \text{ kN/m}^2$$

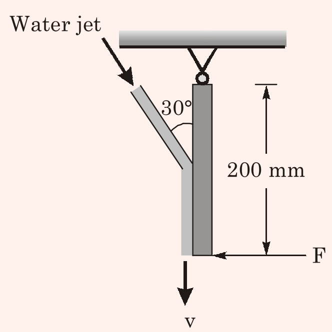
Net safe bearing capacity

$$q_{ns} = \frac{q_{nu}}{F} = \frac{746.2}{2.5} = 298.48 \text{ kN/m}^2$$

Q.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_____



Ans. **(7.85)**



Force exerted by jet in x-direction

$$F_x = \dot{m}[v\sin\theta - 0]$$

$$= \rho \times q \times v \sin\theta$$

$$= (10^3)\left|\frac{\pi}{4}(0.02)^2 \times 10\right| 10 \sin 30°$$

$$= 15.7079 \text{ N}$$

Taking moment about hinge

$$F_x \times \frac{0.2}{2} = F \times 0.2$$

$$F = 7.85 \text{ N}$$

Q.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________.

Ans. **(60)**

Time (1)	Ordinate of 1 hr UH (m^3/s) (2)	Offset ordinate (m^3/s) (3)	Ordinate of 2 hr DRH (m^3/s) (4) = (2) + (3)	Ordinate of DRH of 4 cm rainfall excess (m^3/s) (5)= (4)×4/2	Ordinate of flood hydrograph (m^3/s) (6) = (5) +20
10 : 00 am	0	–	0	0	20
11 : 00 am	3	0	3	6	26
12 : 00 pm	12	3	15	30	50
01 : 00 pm	8	12	20	40	60
02 : 00 pm	6	8	14	28	48
03 : 00 pm	3	6	9	18	38
05 : 00 pm	0	3	3	6	26
			0	0	20

Ordinate of 01 : 00 pm = 60 m^3/s

Q.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 g 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_____.

Ans. **(0.20)**

The maximum hump (ΔZ) that can be provided is given by

$$y + \frac{Q^2}{2gA^2} = \Delta Z_{\text{hump}} + \frac{3}{2} y_c$$

Here, $A = 3 \times 0.5 = 1.5 \text{ m}^2$

$$y_c = \left(\frac{Q^2}{gB^2}\right)^{1/3} = \left(\frac{6^2}{9.81 \times 3^2}\right)^{1/3} = 0.7415 \text{ m}$$

$$\Rightarrow \qquad 0.5 + \frac{6^2}{2 \times 9.81 \times 1.5^2} = \Delta Z_{hump} + \frac{3}{2} \times 0.7415$$

$$\Rightarrow \qquad \Delta Z_{hump} = 0.20 \text{ m}$$

Q.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________.

Ans. **(6570)**

Apply energy equaiton at the free surface of reservior and exit of nozzle

$$500 = \text{Head loss} + \frac{v_1^2}{2g}$$

$$500 = 0.05\frac{v_1^2}{2g} + \frac{v_1^2}{2g}$$

$$\sqrt{\frac{2 \times 10 \times 500}{1.05}} = v_1$$

$$v_1 = 97.59 \text{ m/sec}$$

$$\text{Water Power (W.P)} = \frac{1}{2}\dot{m}v_1^2$$

$$= \frac{1}{2}(10^3) \times \frac{\pi}{4}(0.15)^2(97.59) = 8212.178 \text{ kW}$$

Now,
$$\eta_0 = \frac{\text{Shaft power (S.P)}}{\text{W.P}}$$

$$0.8 = \frac{\text{S.P}}{8212.178}$$

$$\text{S.P} = 6569.74 \text{ kW}$$

$$\simeq 6570 \text{ kW}$$

Q.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 3 m 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

Ans. **(d)**

Seepage velocity

$$V_s = \frac{v}{n} = \frac{\text{distance}}{\text{time}}$$

as per Darcy $v = ki$

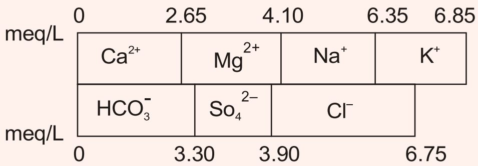
$$\frac{ki}{n} = \frac{100 \text{ m}}{100 \text{ days}}$$

$$i = \frac{\text{head difference}}{\text{length}} = \frac{3}{100}$$

$$\frac{k \times 3}{0.15 \times 100} = \frac{100}{100} \text{ m/day}$$

$$k = 5 \text{ m/day}$$

Q.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

Ans. **(a)**

$$Ca^{2+} = 2.65 \text{ meq}/l, \quad Mg^{2+} = 1.45 \text{ meq}/l$$

$$Na^{+} = 2.25 \text{ meq}/l, \quad K^{+} = 0.5 \text{ meq}/l$$

$$HCO_3^{-} = 3.3 \text{ meq}/l, \quad SO_4^{2-} = 0.6 \text{ meq}/l$$

$$Cl^{-} = 2.85 \text{ meq}/l$$

Hardness is due to multivalent metallic cations, i.e. Ca^{2+} and Mg^{2+}

Total hardness (mg/l as $CaCO_3$) = (Total meq/l) × (eq. weight of $CaCO_3$ in mg)
= (2.65 + 1.45) × 50 mg/l as $CaCO_3$
= 205 mg/l as $CaCO_3$

Alkalinity is due to the presence of HCO_3^- in this case

Alkalinity (mg/l as $CaCO_3$) = 3.3 × 50 mg/l as $CaCO_3$
= 165 mg/l as $CaCO_3$

Now, Carbonate Hardness = Min {Total Hardness, Alkalinity}
= 165 mg/l

∴ Non-carbonate hardness = Total Hardness – Carbonate Hardness

$= 205 - 165 = 40$ mg/l as $CaCO_3$

Q.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 ______dB.

Ans. **(67.98)**

$$L_2 = L_1 - \left|20 \log\left(\frac{R_2}{R_1}\right)\right|$$

$$= 74 - 20 \log 0.5$$

$$= 67.98 \text{ dB}$$

Q.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_____.

Ans. **(276.19)**

$$BOD_5 = L_0\left(1 - e^{-0.22\times5}\right) \quad \text{...(i)}$$

$$BOD_3 = L_0\left(1 - e^{-0.22\times3}\right) \quad \text{...(ii)}$$

From equation (i) and (ii), we get

$$\frac{BOD_5}{BOD_3} = \frac{\left(1 - e^{-0.22\times5}\right)}{\left(1 - e^{-0.22\times3}\right)}$$

$$BOD_5 = 200 \times \frac{0.667}{0.483}$$

$= 200 \times 1.38 = 276.19$ mg/l

Q.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 the 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

Ans. **(a)**

$$Y = y_1 + y_2 + y_3 = 0.30 + 0.25 + 0.25 = 0.80$$

Now Total lost time,

$$L = 10 \text{ sec (given)}$$

∴ Optimum cycle time,

$$C_0 = \frac{1.5L + 5}{1 - Y}$$

$$\Rightarrow \quad C_0 = \frac{(1.5 \times 10) + 5}{1 - 0.80} = \frac{15 + 5}{0.20} = \frac{20}{0.2} = 100 \text{ sec}$$

Now green times are calculated by,

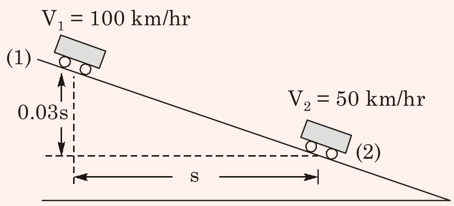
$$G_1 = \frac{y_1}{y}(C_0 - L) = \frac{0.30}{0.80}(100 - 10) = 33.75 \simeq 34 \text{ sec}$$

$$G_2 = \frac{y_2}{y}(C_0 - L) = \frac{0.25}{0.80}(100 - 10) = 28.11 \simeq 28 \text{ sec}$$

$$G_3 = \frac{y_3}{y}(C_0 - L) = \frac{0.25}{0.80}(100 - 10) = 28.11 \simeq 28 \text{ sec}$$

Q.54 A motorist traveling 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_______.

Ans. **(92.32)**



Total energy lost between point (1) and (2) = Work done by frictional force

$$\frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2 + mg \times 0.03s = f \times (mg) \times s$$

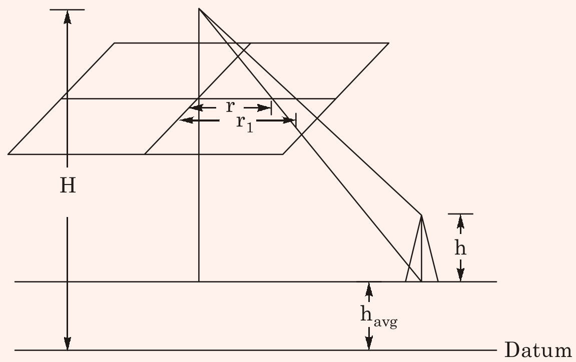
$$\frac{(0.278 \times 100)^2}{2} - \frac{(0.278 \times 50)^2}{2} + 9.81 \times 0.03 \times s = 0.35 \times 9.81 \times s$$

$$289.815 = 3.1392s$$

$$\Rightarrow \quad s = 92.32 \text{ m}$$

Q.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________

Ans. **(120.4)**



Given: $H = 700 \text{ m}, h_{avg} = 250$

Relief distance, $d = r_1 - r = 112.5 - 82.40 = 30.1 \text{ mm}$

$$\therefore \quad d = \frac{hr_1}{H - h_{avg}} \quad \text{[where h is height of tower]}$$

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

$$\therefore \quad h = 120.4 \text{ mm}$$

○○○○