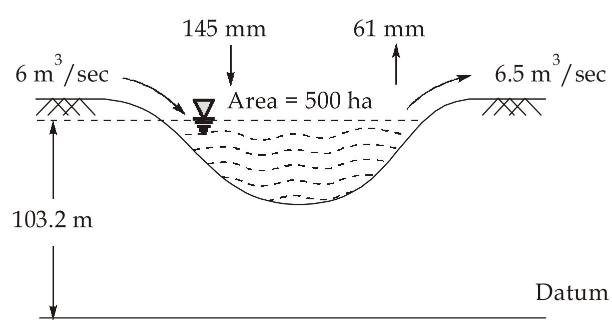
Detailed Solutions

ESE-2025 Mains Test Series

Civil Engineering Test No : 10

Section - A

Q.1 (a) Solution:



Given: Elevation, H = 104.5 m

Average inflow = 6 cumecs

Average outflow = 6.5 cumes

Received rainfall, P = 145 mm

Evaporation, E = 6.1 cm

Time interval, Δt = 1 month

Average surface area, A = 5000 hectares

Water surface elevation of the lake at end of month = ?

In a time interval Δt the water budget equation for the lake can be written as

Input volume– output volume = Change in storage of the lake

$$\Rightarrow \quad (\bar{I}\Delta t + PA) - (\bar{Q}\Delta t + EA) = \Delta S \quad \text{...(i)}$$

Inflow volume, $\bar{I}\Delta t$ = $6.0 \times 30 \times 86400$

= 15.552×10^6 m^3 = 15.552 Mm^3

Outflow volume, $\bar{Q}\Delta t$ = $6.5 \times 30 \times 86400$

= 16.848×10^6 m^3 = 16.848 Mm^3

Input due to precipitation, PA = $0.145 \times 5000 \times 10^4$ m^3 = 7.25 Mm^3

Output due to evaporation, EA = $0.061 \times 5000 \times 10^4$ m^3 = 3.05 Mm^3

From eq. (i)

$$\Delta S = (15.552 + 7.25) - (16.848 + 3.05) = 2.904 \text{ Mm}^3$$

Change in elevation,
$$\Delta z = \frac{\Delta S}{A} = \frac{2.904 \times 10^6}{5000 \times 10^4} = 0.05808 \text{ m}$$

New water surface elevation at the end of the month

$$= 104.5 + 0.05808 \simeq 104.558 \text{ m}$$

$\because$ ΔS = Positive

$\therefore$ Inflow > Outflow

So, free surface of water in lake will rise.

Q.1 (b) Solution:

Given: Well diameter, d = 0.61 m

Discharge, Q = 2.21×10^{-2} m^3/sec

Storage coefficient, S = 2.74×10^{-4}

Transmissivity, T = 2.63×10^{-3} m^2/sec

Drawdown at the end of 100 days, S = ?

$$\text{Radius, } r = \frac{0.61}{2} = 0.305 \text{ m}$$

$$\because \quad u = \frac{r^2 S}{4Tt}$$

$$\Rightarrow \quad u = \frac{(0.305)^2 \times 2.74 \times 10^{-4}}{4 \times 2.63 \times 10^{-3} \times 100 \times 86400}$$

$$\Rightarrow \quad u = 2.8 \times 10^{-10}$$

From the given table, well function

$$W(u) = 21.4190$$

Now, drawdown at time t is given by

$$s = \frac{Q}{4\pi T} W(u)$$

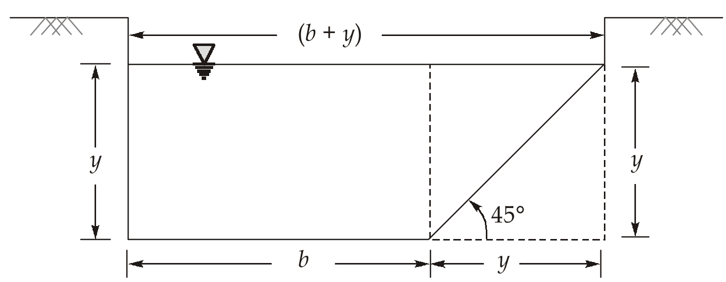
$$\Rightarrow \quad s = \frac{2.21 \times 10^{-2}}{4\pi \times 2.63 \times 10^{-3}} (21.4190)$$

$$\Rightarrow \quad s = 14.32 \text{ m}$$

Q.1 (c) Solution:

Given: Discharge, $Q = 30 \text{ m}^3/\text{sec}$

Velocity, $V = 1 \text{ m/sec}$



Let the bottom width of the channel be 'b'.

$$\text{Top width, } T = (b + y)$$

$$\text{Area of flow, } A = \frac{1}{2}y^2 + by = \frac{Q}{V} = \frac{30}{1} = 30 \text{ m}^2$$

$$\Rightarrow \quad 30 = \frac{y}{2}(2b + y)$$

$$\Rightarrow \quad 60 = y(2b + y)$$

$$\Rightarrow \quad b = \frac{1}{2}\left(\frac{60}{y} - y\right) \quad \text{...(i)}$$

Now, wetted perimeter $P = y + b + \sqrt{2}y$

On putting the value of b from equation (i)

$$P = y + \frac{1}{2}\left(\frac{60}{y} - y\right) + \sqrt{2}y$$

$$\Rightarrow \quad P = \left(\frac{1}{2} + \sqrt{2}\right)y + \frac{30}{y}$$

For the condition of minimum lining area, wetted perimeter should be minimum

$$\frac{dP}{dy} = 0$$

$$\Rightarrow \quad \left(\frac{1}{2}+\sqrt{2}\right)-\frac{30}{y^2} = 0$$

$$\Rightarrow \quad y = \sqrt{\frac{30}{(0.5+\sqrt{2})}}$$

$\therefore$ Flow depth, y = 3.9588 mm

$$\text{Bed width, } b = \frac{1}{2}\left(\frac{60}{3.9588}-3.9588\right)$$

$$\Rightarrow \quad b = 5.5987 \text{ m}$$

$$\text{Top width, } T = b + y = 9.5575 \text{ m}$$

$$\text{Wetted perimeter, } P = T+\sqrt{2}y = 15.156 \text{ m}$$

$$\text{Hydraulic radius, } R_h = \frac{A}{P}=\frac{30}{15.156}=1.979\,\text{m}$$ **Ans.**

$$\text{Hydraulic depth, } D_h = \frac{A}{T}=\frac{30}{9.5575}=3.139\,\text{m}$$ **Ans.**

Q.1 (d) Solution:

Power developed, $P = wQH_n$ where H_n is the net head utilized

$$\Rightarrow \quad H_n = \frac{P}{wQ}=\frac{675\times10^3}{9810\times0.55} = 125 \text{ m}$$

$$\text{Total head loss} = 145 - 125 = 20 \text{ m}$$

$$\text{Velocity of jet, } V_1 = K_0\sqrt{2gH} = 0.97\sqrt{2\times9.81\times145} = 51.74 \text{ m/s}$$

Mean peripheral velocity of the water wheel,

$$u = \frac{\pi DN}{60}=\frac{\pi\times0.9\times500}{60} = 23.56 \text{ m/s}$$

Relative velocity at inlet $V_{r1} = V_1 - u = 51.74 - 23.56 = 28.18$ m/s

If friction is neglected at the buckets, $V_{r2} = V_{r1} = 28.18$ m/s

Since the jet gets deflected through 165°, the blade angle at exit is,

$$\beta_2 = 180° - 165° = 15°$$

$$V_{r2} = V_{r1}\sin15° = 28.18 \sin15° = 7.29 \text{ m/s}$$

$$V_{w2} = V_{r1}\cos15° = 28.18 \cos 15° = 27.22 \text{ m/s}$$

Absolute velocity at outlet, $V_2 = \sqrt{V_{f2}^2 + (V_{w2} - u)^2}$

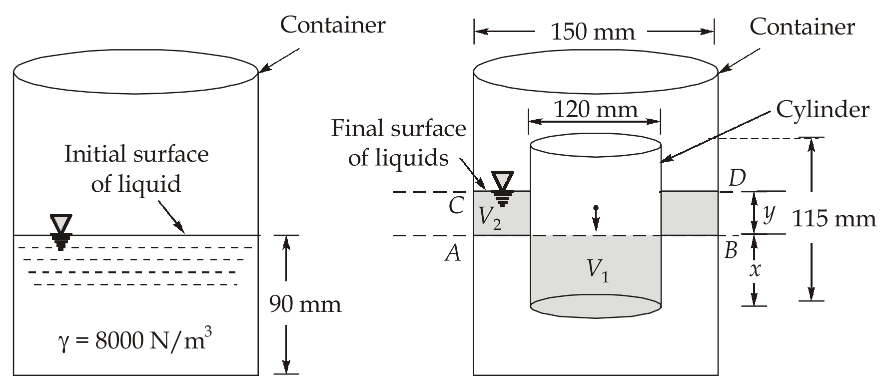
$$= \sqrt{(7.29)^2 + (27.22 - 23.56)^2} = 8.16 \text{ m/sec}$$

Q.1 (e) Solution:

Given: Height of cylinder = 115 mm

Diameter of cylinder = 120 mm

Weight of cylinder = 4 N



Since the volume of the liquid remains unchanged therefore, volume of liquid displaced by cylinder is equal to the volume of liquid above the initial surface of liquid

$$V_1 = V_2 \quad \text{...(i)}$$

Let the bottom of the cylinder be x mm below the initial liquid level AB and the rise in liquid level be y above the initial liquid level AB,

Now, V_1 = (Area of cylinder) × x

$$\Rightarrow \quad V_1 = \frac{\pi}{4}(120)^2 x$$

$$V_2 = \frac{\pi}{4}(150^2 - 120^2)y$$

From equation (i)

$$\frac{\pi}{4}(120)^2 x = \frac{\pi}{4}(150^2 - 120^2)y$$

$$\Rightarrow \quad x = 0.5625y \quad \text{...(ii)}$$

From Archimede's principle

Force of buoyancy = Weight of the cylinder

$\Rightarrow \quad \gamma_{liquid}$ × (Volume of liquid displaced by cylinder) = 4 N

$$\Rightarrow \qquad 8000 \times \frac{\pi}{4}(0.120)^2\left(\frac{x+y}{1000}\right) = 4$$

$$\Rightarrow \qquad x + y = 44.21 \qquad \text{...(ii)}$$

From equation (ii) and (iii)

$$0.5625y + y = 44.21$$

$$\Rightarrow \qquad y = 28.29 \text{ mm}$$

$$\therefore \qquad x = 15.92 \text{ mm}$$

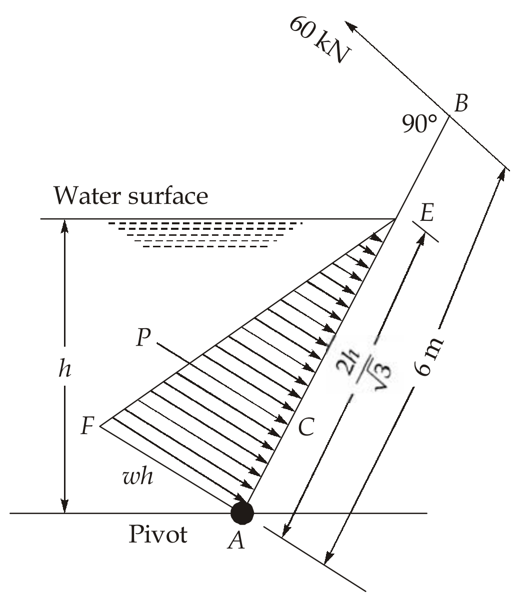
Final liquid level in the cylinder = 90 + y

$$= 90 + 28.29 = 118.29 \text{ mm}$$

Q.2 (a) Solution:

(i)

Pressure distribution on gate AB.



Pressure intensity at E = 0

Pressure intensity of A = $\gamma_w h$

Side AE of the pressure diagram = h cosec 60° = $\dfrac{2h}{\sqrt{3}}$

Total pressure on the gate AB = P = [Area of gate under water] × Average pressure intensity

$$= \left[\frac{2h}{\sqrt{3}} \times 2\right] \frac{\gamma_w h}{2} = \frac{2}{\sqrt{3}} \gamma_w h^2 \text{ acting at } C.$$

Now, $$AC = \frac{1}{3} AE = \frac{1}{3} \cdot \frac{2h}{\sqrt{3}} = \frac{2h}{3\sqrt{3}}$$

Taking moments about the pivot,

$$\frac{2}{\sqrt{3}} \gamma_w h^2 \left(\frac{2h}{\sqrt{3}}\right) = W_{\text{block}} \times 6$$

$$\Rightarrow \quad \frac{4}{9} \gamma_w h^3 = 6\, W_{\text{block}}$$

$$\Rightarrow \quad h^3 = \frac{6W \times 9}{4\gamma_w} = \frac{6 \times 60 \times 9}{4 \times 9.81}$$

$$\therefore \quad h = 4.355 \text{ m}$$

(ii)

Let l = Length of the block

γ_w = Specific weight of water

γ_s = Specific weight of steel = 7.85 γ_w

γ_m = Specific weight of mercury = 13.6 γ_w

$$\text{Weight of the block} = bl\,(y_1 + y_2)\,\gamma_s = bl\,(y_1 + y_2)\, 7.85\, \gamma_w$$

$$= bly_1\,\gamma_w + bly_2 \times 13.6\,\gamma_w = bl\,(y_1 + 13.6\, y_2)\gamma_w$$

$$\Rightarrow \quad 7.85\, y_1 + 7.85\, y_2 = y_1 + 13.6\, y_2$$

$$\Rightarrow \quad 6.85\, y_1 = 5.75\, y_2$$

$$\Rightarrow \quad \frac{y_1}{y_2} = \frac{5.75}{6.85} = 0.8394$$

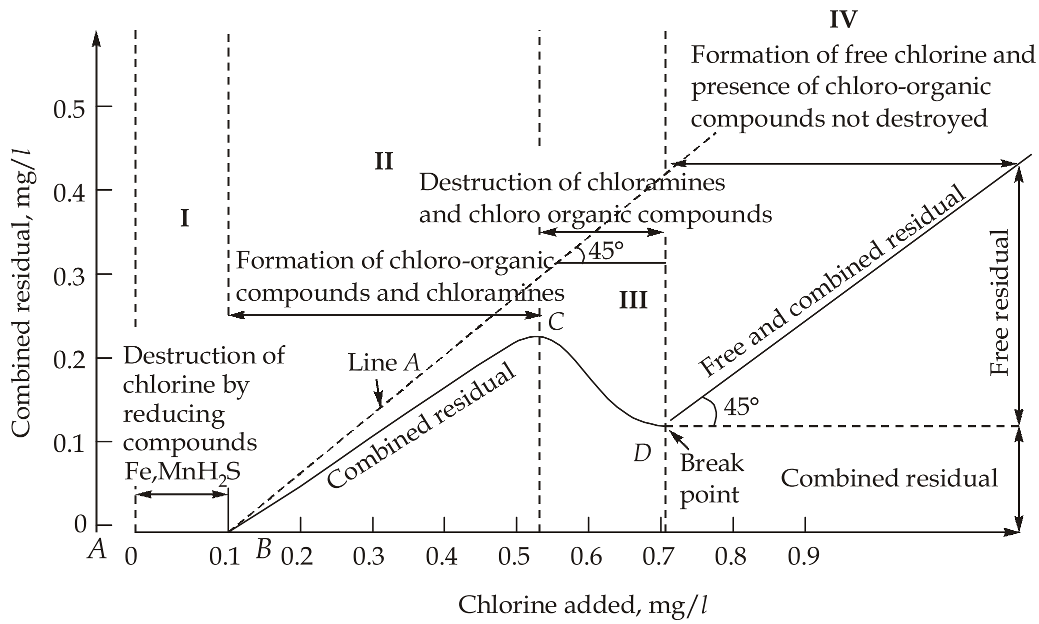
Q.2 (b) Solution:

(i)

Break-point chlorination: Break point chlorination is a term which gives us an idea of the extent of chlorine added to the water. In fact, it represents, that much dose of chlorination, beyond which any further addition of chlorine will equally appear as free residual chlorine.

When chlorine is added to the water, it first of all, generally reacts with the ammonia present in the water, so as to form chloramines.

These chloramines respond to the D.P.D. test in the same manner as does free chlorine. Therefore, the D.P.D. tests will indicate the quantum of total residual chlorine, "combined" as well as "free". Hence, if chlorine is slowly added to the water, and the residual is tested, it will be found that the residual will go on increasing with the addition of chlorine. However, some chlorine is consumed for killing bacteria, and thus the amount of residual chlorine shall be slightly less than that added, as shown by the curve AB in figure below.



Chlorine Reaction in Water

If the addition of chlorine is continued beyond the point *B*, the organic matter present in water starts getting oxidised, and therefore, the residual chlorine content suddenly falls down, as shown by the curve *BC*.

The point *C* is the point beyond which any further addition of chlorine will appear equally as free chlorine, since nothing of it shall be utilized. This point *C* is called the 'break point', as any chlorine that is added water beyond this point, breaks through the water, and totally appears as residual chlorine. The additional chlorine beyond break point is called break point chlorination.

(ii)

Intrusion of sea water in the coastal ground aquifer is a major problem. To control the contamination of ground water in coastal area following control measures can be adopted:

1. **Changing the pumping pattern:** Changing the location of ground water pumping higher to the upstream will increase the hydraulic gradient towards the sea. If this method is combined with reduction in pumping scale, sea water intrusion gets reduced.
2. **Artificial Recharge:** Groundwater level can be increased by applying artificial recharge practices of rain-water harvesting.
3. **Extraction Barrier:** Extraction barrier can be created by pumping saline water continuously to the well already exposed to seawater intrusion, so that it can't move towards the main land.

4. **Injection Barrier:** It can be created by filling the fresh water into injection well located at the coastline.

(iii)

Given: $G = 2.65, \rho_w = 998.5 \text{ kg/m}^3, d = 0.4 \text{ mm}$

$\mu = 1.005 \times 10^{-3} \text{ kg/m sec}$

$$\text{Settling velocity, } V_s = \frac{(G-1)\rho_w g d^2}{18\mu}$$

$$\Rightarrow V_s = \frac{(2.65-1)9.81\times 998.5\times\left(0.4\times10^{-3}\right)^2}{18\times\left(1.005\times10^{-3}\right)}$$

$$\Rightarrow V_s = 0.14295 \text{ m/sec}$$

We know that,

$$\text{Porosity of expanded bed, } n' = \left(\frac{V_B}{V_s}\right)^{0.22}$$

$$\Rightarrow 0.65 = \left(\frac{V_B}{0.0146}\right)^{0.22}$$

$$\Rightarrow V_B = 0.02 \text{ m/sec}$$

$$\Rightarrow V_B = 120 \text{ cm/min}$$

Since, head remains constant before and after expansion of bed.

$$\therefore h_L = h_L'$$

$$\Rightarrow (1-n)(G-1)(D) = (1-n')(G-1)(D')$$

$$\Rightarrow D' = 0.68\frac{(1-0.4)}{(1-0.65)}$$

$$\Rightarrow D' = 1.166 \text{ m}$$

Q.2 (c) Solution:

(i)

Given:

Dry unit weight of sand in loosest state

$$(\gamma_d)_{min} = 13.34 \text{ kN/m}^3$$

Dry unit weight of sand in densest state

$$(\gamma_d)_{max} = 21.40 \text{ kN/m}^3$$

$G = 2.67$, $n = 30\%$

For e_{max}: $(\gamma_d)_{min} = \dfrac{G\gamma_w}{1+e_{max}}$

$\Rightarrow$ $13.34 = \dfrac{2.67 \times 9.81}{1+e_{max}}$

$\Rightarrow$ $e_{max} = 0.963$

For e_{min}: $(\gamma_d)_{max} = \dfrac{G\gamma_w}{1+e_{min}}$

$\Rightarrow$ $21.4 = \dfrac{2.67 \times 9.81}{1+e_{min}}$

$\Rightarrow$ $e_{min} = 0.224$

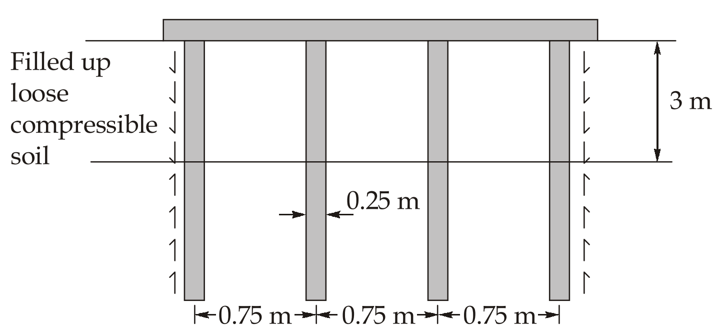
Now $e = \dfrac{n}{1-n} = \dfrac{0.3}{1-0.3} = 0.429$

Now, $D_r\% = \left(\dfrac{e_{max} - e}{e_{max} - e_{min}}\right) \times 100 = \left(\dfrac{0.963 - 0.429}{0.963 - 0.224}\right) \times 100$

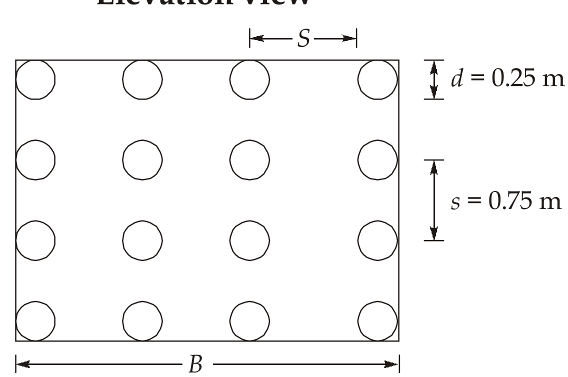
$= 72.26\%$

(ii)

The plan and section of the given pile group of 16 piles is shown in figure below.



Elevation view



Plan view

Size of pile group,

$$B = 3S + d$$
$$= 3 \times 0.75 + 0.25 = 2.5 \text{ m}$$

Negative skin friction for the pile group for the given cohesive soil is computed as maximum of following values:

Based on individual pile action:

$$Q_{nfg} = Q_{nf} \times 16$$

$$\Rightarrow \quad Q_{nfg} = \alpha \cdot \bar{C}_u (\pi d) \cdot L_c \times 16$$
$$= 0.4 \times 18 \times \pi \times 0.25 \times 3 \times 16$$
$$= 16.965 \text{ kN} \times 16$$

$$\therefore \quad Q_{nfg} = 271.44 \text{ kN} \quad \text{...(i)}$$

Based on block failure of pile group:

$$Q_{nfg} = \bar{C}_u (4B) \cdot L_c + \gamma A L_c$$

$$\Rightarrow \quad Q_{nfg} = 18 \times 4 \times 2.5 \times 3 + 15 \times (2.5 \times 2.5) \times 3$$

$$\Rightarrow \quad Q_{nfg} = 821.25 \text{ kN} \quad \text{...(ii)}$$

$$\text{Negative skin friction} = \text{Max}\begin{cases} 271.44 \text{ kN} \\ 821.25 \text{ kN} \end{cases} = 821.25 \text{ kN}$$ **Ans.**

Q.3 (a) Solution:

(i)

Area of strip, $A = 0.08 \text{ ha} = 0.08 \times 10^4 \text{ m}^2 = 800 \text{ m}^2$

Discharge, $Q = 0.03 \text{ m}^3/\text{sec}$

Infiltration capacity of soil, $f = 3.5 \text{ cm/hr}$

Average depth of flow on the field, $y = 7 \text{ cm} = 0.07 \text{ m}$

Now, approximate time required to irrigate a strip of land is given by

$$t = \frac{y}{f}\log_e\left(\frac{Q}{Q - fA}\right)$$

$$= \frac{0.07}{0.035}\log_e\left(\frac{0.03}{0.03 - \frac{3.5 \times 10^{-2}}{3600} \times 800}\right)$$

$$= 0.6 \text{ hr}$$

$$= 36 \text{ min}$$ **Ans.**

Also, maximum area that can be irrigated

$$A_{max} = \frac{Q}{f} = \frac{0.03 \times 3600}{3.5 \times 10^{-2}} = 3085.7 \text{ m}^2$$

$$\Rightarrow \quad A_{max} = \frac{3085.7}{10^4} ha = 0.309 \text{ ha}$$ **Ans.**

(ii)

Relative stability (S_r): It is defined as ratio of oxygen available in sewage effluent in any form (as dissolved oxygen or as molecular bonded oxygen) to the total amount of oxygen required to satisfy first stage BOD

$$S_r = \left(\frac{\text{Amount of oxygen available (as DO or MBO)}}{\text{Amount of oxygen required for first stage BOD}}\right) \times 100$$

Test to determine relative stability of sewage effluent:

- The sample of sewage is filled in a glass-stoppered bottle.
- A small quantity of methylene blue solution is added to the sample of sewage.
- The mixture is then incubated either at a temperature of 10°C or at 37°C.
- During incubation when the available dissolved oxygen in the mixture is consumed, the anaerobic bacteria start their function and enzymes produced during the metabolism of anaerobic bacteria decolourise the methlylene blue coloured solution.
- The period in days required for decolourisation of methylene blue colour is noted.

Relative stability is computed as:

$$S_r = \left[1 - (0.794)^{t_{20}}\right] \times 100 \qquad \text{or} \qquad S_r = \left[1 - (0.630)^{t_{37}}\right] \times 100$$

Where, t_{20} and t_{37} are the time in days required to decolourise methylene blue solution at 20°C and 37°C respectively.

Significance:

- Earlier the decolourisation take place, sooner the anaerobic condition develops, indicating the deficiency of oxygen in the system thereby represents its unstability.
- If sample decolourises in less than four days at 20°C it is termed as unstable.

Q.3 (b) Solution:

(i)

As spillway acts under gravitational forces, Froude model law becomes applicable, i.e.,

$$V_r = \sqrt{y_r} = \sqrt{L_r}$$

$$\Rightarrow \quad \frac{V_m}{V_p} = \sqrt{\frac{L_m}{L_p}} = \sqrt{\frac{1}{25}} = \frac{1}{5}$$

For model Height of model $= \frac{1}{25} \times 7 = 0.28\,\text{m}$

Length of model $= \frac{1}{25} \times 140 = 5.6\,\text{m}$

Head over model $= \frac{1}{25} \times 4 = 0.16\,\text{m}$

$$\frac{Q_m}{Q_p} = \frac{\text{Discharge through model}}{\text{Discharge through prototype}}$$

$$= A_r V_r = L_r^2 \sqrt{L_r} = L_r^{5/2}$$

$$\therefore \quad Q_m = \left(\frac{1}{25}\right)^{5/2} \times 2100 = 0.672\ \text{m}^3/\text{sec}$$

(ii)

Given:

For centrifugal pump

Outside diameter, D_2 = 1.2 m

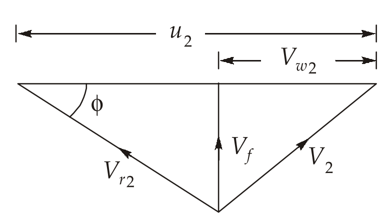
Inside diameter, D_1 = 60 cms = 0.6 m

Speed, N = 200 rpm

Discharge, Q = 1800 lps = 1.8 m^3/s

Manometric head, H = 6.5 m

Velocity of flow, V_f = 2.4 m/s



Velocity triangle at outlet

$$\text{Pump velocity at outlet, } u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 1.2 \times 200}{60} = 12.57\ \text{m/s}$$

From velocity triangle at outlet,

$$\tan\phi = \frac{V_f}{u_2 - V_{w2}}$$

$$\Rightarrow \quad \tan(180° - 150°) = \frac{2.5}{12.57 - V_{w2}}$$

$$\Rightarrow \quad V_{w2} = 8.24 \text{ m/s}$$

$$\text{Manometric efficiency, } \eta\% = \frac{gH_m}{V_{w2}u_2} \times 100$$

$$\Rightarrow \quad \eta\% = \frac{9.81 \times 6.5}{12.57 \times 8.24} \times 100 = 61.563\%$$

For minimum starting speed, N_1

$$\left(\frac{\pi D_2 N_1}{60}\right)^2 - \left(\frac{\pi D_1 N_1}{60}\right)^2 = 2gH$$

$$\Rightarrow \quad \left(\frac{\pi N_1}{60}\right)^2 (1.2^2 - 0.6^2) = 2 \times 9.81 \times 6.5$$

$$\Rightarrow \quad N_1 = 207.54 \text{ rpm}$$

Q.3 (c) Solution:

(i)

Impact of disposal of waste water into fresh water:

1. **Nutrients:** Eutrophication results from the over supply of nutrients, which leads to overgrowth of plant and algae. After such organisms die, the bacterial degradation of their biomass consumes the oxygen from the water creating the state of hypoxia. It is almost always induced by the discharge of nitrate or phosphate containing detergents, fertilizers or sewage into the aquatic system.

2. **Oil and Grease:** With excessive discharge of oil and grease into sewage system, problems may occur with clogging of sewers and pumping plants and with the interference of biological treatment processes.

3. **Suspended solids:** There is considerable effect of suspended and dissolved solids in the irrigation water on the growth of plants. The salts increase the osmotic potential of the soil water and increase in osmotic pressure of the soil solution increases the amount of energy which plants must expend to take up water from the soil.

(ii)

Given: Discharge, $Q = 60 \times 10^6\ l/\text{day}$

Length, $L = 20$ m

Breadth, $B = 12$ m

Height, $H = 3.5$ m

Four horizontal shafts with $r = 1.5 \times 10^{-2}$ m

and Speed, $N = 150$ rpm

$$\text{Velocity of paddle, } v_p = \frac{2\pi N}{60} \times r$$

$$\Rightarrow \quad v_p = \frac{2\pi \times 150}{60} \times 1.5 \times 10^{-2} = 0.2356 \text{ m/s}$$

$$\text{Mean velocity of water, } v_w = 0.2 v_p$$

$$\therefore \quad v_r = v_p - v_w = v_p - 0.2 v_p$$

$$\Rightarrow \quad v_r = 0.8\, v_p = 0.8 \times 0.2356 = 0.1885 \text{ m/s}$$

$$\text{Power, } P = \frac{1}{2} \rho_w C_D A_T v_r^3 n$$

$$\Rightarrow \quad P = \frac{1}{2} \times 10^3 \times 1.8 \times (10 \times 0.2) \times (0.1885)^3 \times (4 \times 4)$$

$$\simeq 192.9 \text{ W}$$

$$\text{Mean velocity gradient, } G = \sqrt{\frac{P}{\mu V}} = \sqrt{\frac{192.9}{(1.31 \times 10^{-4}) \times (20 \times 12 \times 3.5)}}$$

$$= 41.87 \text{ sec}^{-1}$$

$$\text{Detention time, } t_d = \frac{\text{Volume}}{Q} = \frac{20 \times 12 \times 3.5}{60 \times 10^6 \times 10^{-3}} \times 24 \times 60$$

$$= 20.16 \text{ min}$$

Q.4 (a) Solution:

(i)

Ozone Layer Depletion

- Ozone layer depletion is the most dreaded aspect of air pollution, having wide spread implications, extending over the entire atmosphere. This problem is caused by the reduction of naturally available ozone layer in the atmosphere.

- Out of all in the thickness of zones of the atmosphere, the second zone i.e. the stratosphere, remains the most important to humans and other living beings, as it is the stratosphere which primarily contains ozone gas (O_3) chiefly in the layers between 25 km and 40 km above the ground level.
- This ozone layer cuts off short wave length radiations (called ultraviolet radiation) from reaching the surface of the earth. Therefore, this process serves as a protective shield to human life against the adverse effects of UV rays like burn and skin cancer. It is obvious that any depletion of stratosphere ozone would be harmful to life on this earth. Hence ozone layer is termed as ozone umbrella.
- Primary reason for ozone layer depletion is CFC (chlorofluorocarbon) or freons. CFC contains chlorine, fluorine and carbon and it does not occur by itself in nature, but is produced only due to human activities. The freons are a group of cholorofluorocarbons used as aerosol propellants, refrigerants, solvents and as gases for the production of foamed plastics.
- Ozone is destroyed due to the photolytic reaction of CFC as shown below.

$$CFCl_3 \xrightarrow{UV} Cl + \text{other substances}$$

and

$$Cl + O_3 \xrightarrow{UV} ClO + O_2$$

- Methane, destroys Cl and thus affords protection to the ozone layer. Similarly, NO_2 reacts with Cl, and helps to prevent the depletion of ozone layer.
- When there is no chlorine present in fluorocarbons, they are called hydrofluorocarbons. These substances are very important replacement for chlorofluorocarbons because they pose no threat to the ozone layer as they do not contain chlorine.
- Due to presence of ozone layer, the UV rays do not reach the surface of the earth, and the temperature does not rise. The carbon dioxide in the atmosphere does not allow the release of the reflected solar radiation striking the earth's surface. Thus it protects the heat from being lost out of the atmosphere.
- Thus ozone and carbon dioxide both control the temperature on the earth's surface.

(ii)

Given: Population, $P = 50000$

Bed slope, $S = 1/700$

Manning's roughness coefficient, $n = 0.01$

Per capita water supply = 200 litres/person/day

Since 80% of water supplied emerges as sewage.

∴ Maximum discharge for which sewer should be designed while running full,

$$Q_D = \frac{3 \times (0.80 \times 200 \times 50,000 \times 10^{-3})}{24 \times 3600} \text{m}^3/\text{s} = 0.278 \text{ m}^3/\text{s}$$

Now, using Manning's formula we have

$$Q_D = \frac{1}{n} \times A \times R^{2/3} \times S^{1/2}$$

$$\Rightarrow \quad 0.278 = \frac{1}{0.01} \times \left(\frac{\pi}{4} \times D^2\right) \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{700}\right)^{1/2}$$

$$\Rightarrow \quad D^{8/3} = 0.236$$

$$\Rightarrow \quad D = (0.236)^{3/8}$$

$$\Rightarrow \quad D = 0.582 \text{ m}$$

Velocity of flow, when sewer is running full,

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

$$= \frac{1}{0.01} \times \left(\frac{0.582}{4}\right)^{2/3} \times \left(\frac{1}{700}\right)^{1/2}$$

$$= 1.046 \text{ m/s}$$

Q.4 (b) Solution:

(i)

Given: Area of basin, $A = 300 \text{ km}^2$

To Find: The ordinates of a 3-h unit hydrograph from the basin.

Column-2 of table below gives the 4-hr unit hydrograph while column-4 gives the ordinates of S-curve derived from it. Column-5 gives the ordinates of the offset S-curve by $t_o = 3$ hr. Column-6 gives the difference Δy between the ordinates of the two S-curves.

The ordinates of the 3-hr unit hydrograph are given by,

$$O = \Delta y(T_o/t_o) = (4/3)\, \Delta y$$

where, T_o = 4-hr unit hydrograph.

t_o = 3-hr unit hydrograph.

Time (hr)	4 h-Unit Hydrograph	Offset Ordinate	Ordinate of S-curve	Ordinate Offset S-curve	Δy	$O = \frac{4}{3}\Delta y$
Col. (1)	Col. (2)	Col. (3)	Col. (4)	Col. (5)	Col. (6)	Col. (7)
00	0	–	0	–	0	0
01	6	–	6	–	6	8
02	36	–	36	–	36	48
03	66	–	66	0	66	88
04	91	0	91	6	85	113.3
05	106	6	112	36	76	101.33
06	93	36	129	66	63	84
07	79	66	145	91	54	72
08	68	91	159	112	47	62.67
09	58	112	170	129	41	54.67
10	49	129	178	145	33	44
11	41	145	186	159	27	36
12	34	159	193	170	23	30.67
13	27	170	197	178	19	25.33
14	23	178	201	186	15	20
15	17	186	203	193	10	13.33
16	13	193	206	197	9	12
17	9	197	206	201	5	6.67
18	6	201	207	203	4	5.33
19	3	203	206	206	0	0
20	1.5	206	207.5	206	1.5	2
			207.5	207	0.5	0.67

(ii)

The checking and correction for inconsistency of a rainfall record is done by double-mass curve technique. Through this technique the old data can be simulated with present environment and land use condition.

Following steps are taken while checking for inconsistency of record:

- A group of 5 to 10 base stations in the neighbourhood of the problem station X is selected.
- The data of rainfall of the station X and the average rainfall of the group of station is arranged in reverse chronological order (i.e. the latest record as the first entry and the oldest record as the last entry in the list.)
- From this list, calculate the accumulated precipitation of the station X (ΣP_x) and accumulated values of average of the group of base stations (ΣP_{av}).

- A graph is plotted between ΣP_x and ΣP_{av} where ΣP_x is taken as ordinate and ΣP_{av} is taken as abscissa.
- Find the break in slope in the plot. If there is any inconsistency, then the slope will change immediately.
- Now correct the reading of the plot, by using

$$P_{cx} = P_x \frac{M_c}{M_a}$$

where,

P_{cx} = Corrected precipitation at any time period t_1 at station X

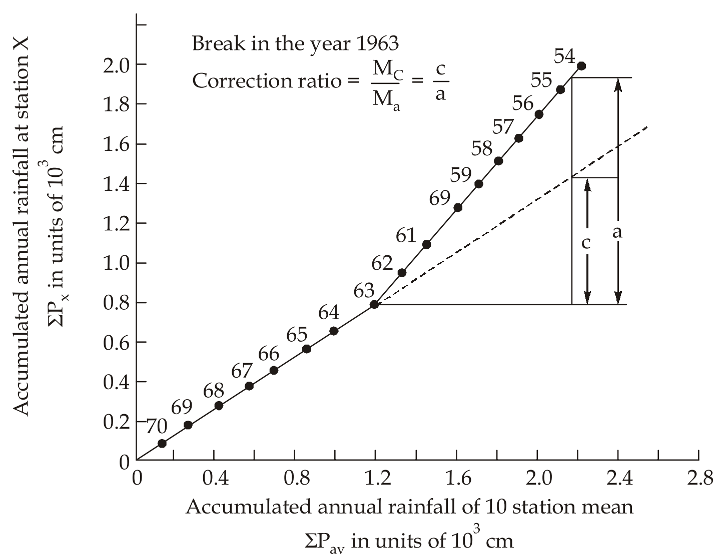
P_x = Original recorded precipitation at time period t_1 at station X

M_c = Corrected slope of double mass curve

M_a = Original slope of double mass curve

The term, $\left(\frac{M_c}{M_a}\right)$ is known as correction ratio

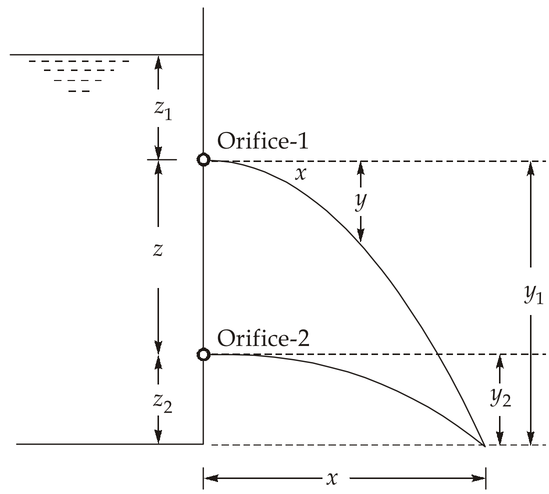
$\therefore$ Correction ratio $= \frac{M_c}{M_a} = \frac{c}{a}$



Double mass curve technique

Q.4 (c) Solution:

(i)



From the measurement of jet co-ordinates, the coefficient of velocity for an orifice is given by:

$$C_v = \frac{x}{\sqrt{4yh}}$$

For orifice-1

$$C_{v1} = \frac{x_1}{\sqrt{4y_1h_1}} = \frac{x}{\sqrt{4(z+z_2)z_1}}$$

For orifice-2

$$C_{v2} = \frac{x_2}{\sqrt{4y_2h_2}} = \frac{x}{\sqrt{4z_2(z_1+z)}}$$

Since both the orifices are identical, they will have the same value of coefficient of velocity and accordingly:

$$\frac{x}{\sqrt{4(z+z_2)z_1}} = \frac{x}{\sqrt{4z_2(z_1+z)}}$$

$\Rightarrow$ $$(z+z_2)z_1 = z_2(z_1+z)$$

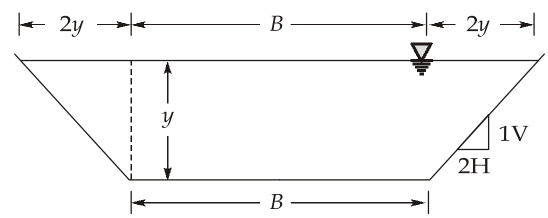
$\Rightarrow$ $$zz_1 + z_1z_2 = z_1z_2 + z_2z$$

$\Rightarrow$ $$z_1 = z_2$$

(ii)

Given: Discharge, $Q = 40\ m^3/s$

Velocity, $V = 2\ m/s$



Bed width to depth ratio, $\frac{B}{y} = 5$

$\Rightarrow$ $B = 5y$

Flow area of channel, $A = \frac{Q}{v} = \frac{40}{2}$

$A = 20\ m^2$

$\Rightarrow$ $\frac{y}{2}(B+B+4y) = 20$

$\Rightarrow$ $y(B + 2y) = 20$

$\Rightarrow$ $y(5y + 2y) = 20$

$\Rightarrow$ $7y^2 = 20$

$\therefore$ $y = 1.69\ m$

$\therefore$ $B = 5 \times 1.69 = 8.45\ m$

Wetted perimeter, $P = B + 2y\sqrt{1+m^2}$

$\Rightarrow$ $P = 8.45 + 2 \times 1.69\sqrt{1+2^2}$

$\Rightarrow$ $P = 16\ m$

From Manning's equation, $Q = \frac{A}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$

$\Rightarrow$ $40 = \frac{20}{0.02} \times \left(\frac{20}{16}\right)^{2/3} S^{1/2}$

$\therefore$ Bed slope, $S = \frac{1}{841.576}$

Section - B

Q.5 (a) Solution:

$$\frac{x_2^2 - x_1^2}{t_2 - t_1} = \frac{2K_u}{S_n}(h_o + h_c) \quad \text{...(i)}$$

where x_1 = reading of wetted surface at t_1

n = percentage of porosity

x_2 = reading of wetted surface at t_2

h_o = pressure head

K_u = coefficient of permeability

h_c = capillary head

S = percentage of saturation

Ist Stage	IInd Stage
Given $x_1 = 1.5$ cm; $x_2 = 7$ cm	$x_1 = 7$ cm; $x_2 = 18.5$ cm
$t_2 - t_1 = 7$ minutes; $h_{01} = 60$ cm	$t_2 - t_1 = 24$ minutes; $h_{02} = 180$ cm
$S_1 = 0.85$	$S_2 = 0.85$
$n_1 = 35\%$	$n_2 = 35\%$

Substituting the values in equation (i), we get

$$\frac{7^2 - 1.5^2}{7} = \frac{2K_u}{0.85 \times 0.35}(60 + h_c) \quad \text{...(ii)}$$

$$\frac{(18.5)^2 - 7^2}{24} = \frac{2K_u}{0.85 \times 0.35}(180 + h_c) \quad \text{...(iii)}$$

Dividing eq. (ii) and (iii),

$$\frac{6.67857}{12.21875} = \frac{K_u(60 + h_c)}{K_u(180 + h_c)}$$

$$\Rightarrow \quad 0.5465837\,(180 + h_c) = (60 + h_c)$$

$$\Rightarrow \quad 38.39 = 0.4534163\, h_c$$

$$\Rightarrow \quad h_c = 84.67 \text{ cm}$$

$$\therefore \quad k_u = 6.87 \times 10^{-3} \text{ cm/min} = 4.122 \times 10^{-3} \text{ m/sec}$$

Q.5 (b) Solution:

$$R_{branch} = 344 \text{ m}$$

$$R_{main} = 860 \text{ m}$$

Branch line, V_{max} = 35 km/h

Equilibrium superelevation, $e = \frac{GV^2}{127R} = \frac{1.676 \times 35^2}{127 \times 344} = 0.047$ m = 4.7 cm

Negative cant on branch line = 4.7 – 7.6 = – 2.9 cm

Superelevation on the main line = 2.9 cm

Theoretical superelevation on main line = 2.9 + 7.6 = 10.5 cm

$$\therefore \quad \frac{10.5}{100} = \frac{GV^2}{127R}$$

$$\Rightarrow \quad \frac{10.5}{100} = \frac{1.676 \times V^2}{127 \times 860}$$

$$\Rightarrow \quad V_{max} = 82.72 \text{ kmph}$$

Revised formula on BG track $V = \sqrt{\dfrac{(C_d + C_d)R}{13.76}} = \sqrt{\dfrac{(29+76)860}{13.76}} = \sqrt{6562.5}$ kmph

Q.5 (c) Solution:

Frequency distribution and cumulative frequency values of spot speed data

Speed range, (kmph)	Mid speed, (kmph)	Frequency, f	Frequency, %	Cumulative frequency, (at or below the speed),%
0 – 10	5	10	1.25	1.25
10 – 20	15	12	1.50	2.75
20 – 30	25	65	8.125	10.875
30 – 40	35	70	8.75	19.625
40 – 50	45	200	25	44.625
50 – 60	55	250	31.25	75.875
60 – 70	65	115	14.375	90.25
70 – 80	75	40	5	95.25
80 – 90	85	30	3.75	99
90 – 100	95	8	1	100
Total		**800**	**100.00**	

(i) Upper speed limit for regulation = 85th percentile speed

$$= 55 + \frac{(65-55)}{(90.25-75.875)}(85-75.875) = 61.35 \text{ kmph}$$

(ii) Speed to check geometric design elements = 98th percentile speed

$$= 75 + \frac{(85-75)}{(99-95.25)} \times (98-95.25) = 82.33 \text{ kmph}$$

Q.5 (d) Solution:

B.S.	*I.S.*	*F.S.*	**Rise**	**Fall**	*R.L.*	**Remarks**
1.735					68.235	A. Bench mark
	1.625		0.110		68.345	B
	1.580		0.045		68.390	C
1.115		1.250	0.330		68.720	D. Change point
	2.010			0.895	67.825	E
1.055		1.325	0.685		68.510	F. Change point
	1.095			0.040	68.470	G
	1.110			0.015	68.455	H
		0.955	0.155		68.610	I. End point

Arithmetical check:

$$\Sigma \text{ B. S.} - \Sigma \text{ F. S.} = 3.905 - 3.530 = 0.375 \text{ m}$$

$$\Sigma \text{ Rise} - \Sigma \text{ Fall} = 1.325 - 0.950 = 0.375 \text{ m}$$

$$\text{Last R.L.} - \text{First R.L.} = 68.610 - 68.235 = 0.375 \text{ m} \quad \text{(OK)}$$

Q.5 (e) Solution:

Given:

Duration of rainfall excess = 3 hr

Infiltration loss for 3 hr = $0.3 \times 3 = 0.9$ cm

Total depth of rainfall = 5.9 cm

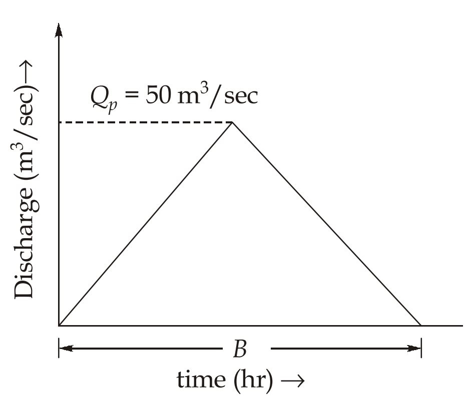
$\therefore$ Runoff depth = $5.9 - 0.9 = 5.0$ cm

Now,

Peak of flood hydrograph = 270 m^3/sec

Peak of DRH = 270 – Base flow = 270 – 20 = 250 m^3/sec

$$\therefore \quad \text{Peak of 3 hr UH} = \frac{\text{Peak of DRH}}{\text{Runoff depth}} = \frac{250}{5} = 50 \text{ m}^3/\text{sec}$$



$$\text{Volume} = 576 \times 10^6 \times \frac{1}{100} = \frac{1}{2} B(50) \times 3600$$

$$\Rightarrow \quad B = 64 \text{ hr}$$

Q.6 (a) Solution:

(i)

Explosive is a chemical compound which under favorable conditions detonates quickly and produces tremendous high pressure.

It is a powerful source of energy. Without explosives, it would not be possible to get large quantities of coal, limestone, iron ore and other minerals. Furthermore explosives are extensively used in all forms of rock excavation (either open cut or tunnelling), for making roadways through hilly areas, for demolishing of structures etc.

Upon initiation of the explosives, tremendous amount of heat is generated which expands the gases and causes them to exert enormous pressure, thereby breaking the rock.

The following properties of an explosive are of much concern to users:

- Strength (energy content to be released)
- Velocity of detonation
- Density
- Water resistance
- Sensitivity
- Oxygen balance

Types of explosives:

The explosives are classified on the following basis:

Based on the chemical nature, the explosives fall into three main classes:

1. **Low explosive:** On initiation of low explosives, the explosive composition burns over a relatively sustained period of time, without the production of an intense shock wave and thereby the gases are released at lower pressures. It is used where a slow heaving action is required. Black blasting powder (gun powder) belongs to this class. It is used extensively in quarries particularly in the production of building and monumental stones. The approximately content of main constituents are sulphur 10%, charcoal 15%, sodium/potassium nitrate 75%.
2. **High explosive:** High explosives usually contain either nitroglycerine (NGL) or trinitrotoulene (TNT) as the main explosive ingredient and are initiated by detonator. An intense shock wave is followed by the production of large volume of gases, at exceptionally high pressure. Hence, the action of high explosive is extremely fast and violent.

High explosives generally fall into two distinct groups viz. Nitroglycerine and Non-nitroglycerine explosives.

3. **Initiating explosive:** Initiating explosives, as the name suggests, are used to initiate the explosion. When ignited, they produce an intense local blow or shock which starts the reaction in less sensitive high explosives.

Other high explosives:

Several special type high explosives are being manufactured these days with the following names but these should be used under the guidance of the expert crew:

TNT = Tri-Nitro-Toluene

RDX = Rapid Detonating Explosive

PENT = Penta-Enythrital

(ii)

Spacing of the three cross hairs = 0.60 mm

Distance between the stadia hairs, i = 0.60 + 0.60 = 1.20 mm

Focal length of the object glass, f = 216 mm

$$\text{Multiplying constant, } k = \frac{f}{i} = \frac{216}{1.20} = 180$$

$$\text{Additive constant, } C = f + c = 216 + 115 = 331 \text{ mm} = 0.331 \text{ m}$$

$$\text{Staff intercept, } s = 2.025 - 1.105 = 0.920 \text{ m}$$

$$\text{Horizontal distance, } D = \frac{f}{i} s\cos^2\theta + (f + c)\cos\theta$$

$$\Rightarrow \quad D = 180 \times 0.920\cos^2 9° + 0.331\cos 9° = 161.874 \text{ m}$$

$$V = \frac{ks}{2}\sin 2\theta = \frac{180}{2}(0.92)\sin 18° = 22.587 \text{ m}$$

R.L. of the insturment station

= R.L. of staff station + Central hair reading – V – Height of instrument

= 185.750 + 1.565 – 25.587 – 1.375 = 160.353 m

Q.6 (b) Solution:

(i)

The following factors should be studied while planning a harbour:

- To carry out a thorough survey of the neighbourhood including the fore shore and depths of water in the vicinity is necessary.
- The nature of the harbour, whether sheltered or not should be studied.
- The existence of sea insects which undermine the foundations should be studied.

- The problem of silting or erosion of coast line should be studied carefully.
- To ascertain the character of the ground, borings and soundings should be taken.
- The know the probable surface conditions on land, borings on land should also be made. It will be helpful in locating the harbour works correctly.
- The natural meteorological phenomenon should be studied at site with respect to frequency of storms, rainfall, range of tides, maximum and minimum temperatures, direction and intensity of winds, humidity, directions and velocity of currents etc.
- The size and number of ships to be accommodated in the harbour at a time.
- The length and width needed for movement of ships to and from berths.

(ii)

Simpson's 1/3 rule: No. of ordinates must be odd

1. Using h_1 as first offset and applying upto h_{13}.

$$= \frac{10}{3}[8.25+12.25+4(13.85+10.85+13.60+16.85+17.35$$
$$+15.90)+2(12.25+12.25+15.25+14.95+20.05)]$$
$$= 1745.33^2$$

Area of last two offsets by trapezoidal rule

$$= \frac{12.25+12.0}{2}\times 10 = 121.25 \text{ m}^2$$

$$\text{Hence, total area} = 1866.58 \text{ m}^3$$

2. Taking h_{14} as first offset and h_2 as last offset for applying Simpson's rule;

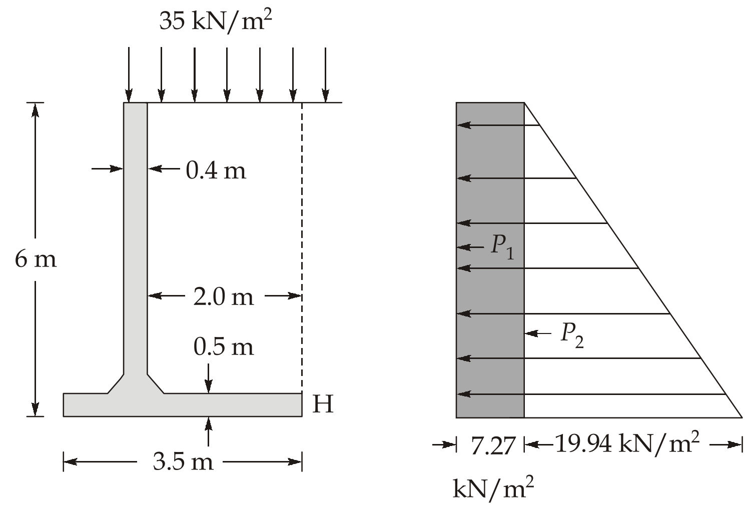
$$A = \frac{10}{3}[h_{14}+h_2+4\left(h_{13}+h_{11}+h_9+h_7+h_5+h_3\right)+2$$
$$(h_{12}+h_{10}+h_{08}+h_{06}+h_{04})$$
$$= \frac{10}{3}[12+13.85+4\left(12.5+20.5+14.95+15.25+12.25+12.25\right)$$
$$+2\left(15.9+17.35+16.85+13.6+10.85\right)$$
$$= 1743.1667 \text{ m}^2$$

Area of last two offsets by trapezoidal rule

$$= \frac{8.25+13.85}{2}\times 10 = 110.5 \text{ m}^2$$

$$\text{Total area} = 1863 \text{ m}^2$$

Q.6 (c) Solution:



Cantilever retaining wall and earth pressure diagram

Active earth pressure coefficient, $K_a = \dfrac{1-\sin 41^\circ}{1+\sin 41^\circ} = 0.2077$

For a cantilever retaining wall, the active earth pressure is calculated on the vertical plane passing through the heel of the wall. Since no shear stresses act on this plane. Rankine's theory can be used without introducing any error or approximation.

$$P_A = K_a P_v = K_a(\gamma z + q)$$

At depth $Z = 6$ m, $P_A = 0.2077 \times 35 + 0.2077 \times 16 \times 6$

$$= (7.27 + 19.94)\ \text{kN/m}^2 = 27.21\ \text{kN/m}^2$$

The active pressure distribution is shown in figure.

To determine the distance $\bar{x}$ of the base reaction from the heel H, the moments of the forces about the heel are taken. Consider 1 m length of the wall.

Force (kN)	Moment arm (m)	Moment (kNm)
$P_1 = 7.27 \times 6 = 43.62$	$\frac{6}{2} = 3$	130.86
$P_2 = \frac{1}{2} \times 19.94 \times 6 = 59.82$	$\frac{6}{3} = 2$	119.64
Horizontal force $R_H = 43.62 + 59.82 = 103.44$		
Weight of stem = 5.50 × 0.4 × 24 = 52.8	2 + 0.2 = 2.2	116.16
Weight of base = 3.50 × 0.5 × 24 = 42.0	$\frac{3.5}{2} = 1.75$	73.50
Weight of backfill = 5.50 × 2.0 × 16 = 176.0	1.0	176.00
Surcharge load = 2.0 × 35 = 70.0	1.0	70.00
Vertical reaction $R_y = 52.8 + 42 + 176 + 70 = 340.8$ kN		$\Sigma M = 686.16$ kNm

$$R_V\bar{x} = 686.16$$

$$\Rightarrow \quad \bar{x} = \frac{686.16}{340.8} = 2.01 \text{ m}$$

Hence, the resultant acts within the middle-third of the base.

Eccentricity of the resultant (base reaction),

$$e = \bar{x} - \frac{B}{2} = 2.01 - 1.75 = 0.26 \text{ m}$$

The maximum and minimum base pressures are given by:

$$q_{max} = \frac{R_V}{B}\left(1 + \frac{6e}{B}\right)$$

$$\Rightarrow \quad q_{max} = \frac{340.8}{3.5}\left(1 + \frac{6 \times 0.26}{3.5}\right)$$

$$q_{max} = 140.77 \text{ kN/m}^2 < \text{SBC } (= 200 \text{ kN/m}^2) \qquad \text{(OK)}$$

$$\text{and} \quad q_{min} = \frac{R_V}{B}\left(1 - \frac{6e}{B}\right)$$

$$\Rightarrow \quad q_{min} = \frac{340.8}{3.5}\left(1 - \frac{6 \times 0.26}{3.5}\right)$$

$$\Rightarrow \quad q_{min} = 53.97 \text{ kN/m}^2 > 0 \qquad \text{(OK)}$$

$$\text{FOS against sliding} = (\text{FOS})_s \frac{R_V \tan\delta'}{R_H}$$

$$= \frac{340.8 \times \tan\left(\frac{2}{3} \times 41°\right)}{103.44} = 1.7 > 1.5 \qquad \text{(OK)}$$

Q.7 (a) Solution:

(i)

Distance between A and B = 750 m = 0.75 km

Instrument at	Reading on	
	A	**B**
A	1.543	2.847
B	1.422	2.622

Now, true difference of levels between A and B.

$$(\Delta h)_{AB} = \frac{(b_1 - a_1) + (b_2 - a_2)}{2}$$

$$= \frac{(2.847 - 1.543) + (2.622 - 1.422)}{2} = 1.252 \text{ m}$$

$$(\Delta h)_{AB} = (b_1 - e) - a_1 \quad \text{...(i)}$$

where, $e = e_c + e_r + a_l$ ...(ii)

e_c = Error due to curvature

e_r = Error due to refraction

e_l = Error due to collimation

$e_c = 0.0785\, d^2$ m

$= 0.0785(0.75)^2 = 0.04416$ m

$$e_l = \frac{0.002}{100} \times 750 = 0.015 \text{ m}$$

From eq. (i) $1.252 = (2.847 - e) - 1.543$

$\Rightarrow$ $e = 0.052$ m

From eq. (ii) $0.052 = 0.04416 + e_r + 0.015$

$\Rightarrow$ $e_r = -0.00716$ m

$\therefore$ Extent of refraction correction $= -0.00716$ m

(ii)

Ballast: Ballast is a layer of broken stones gravel, moorum or any other gritty material which is placed and packed around and below sleepers to distribute the load from sleeper to formation and for providing drainage to track as well as giving lateral and longitudinal stability to track.

Uses/Functions of Ballast in Railway track:

(a) To transfer and distribute the vertical load from sleepers to larger area of formation.

(b) To provide necessary resistance to sleepers and track for lateral longitudinal stability.

(c) To provide effective drainage to track.

(d) To provide elasticity and resilience to track for getting proper riding comfort.

(e) To provide flexibility and means to maintain geometric alignment of track.

Different types of ballast used:

1. Stone aggregate
2. Brick aggregate
3. Sand ballast

4. Moorum ballast
5. Coal ash ballast

Necessity to replace stone ballast from time to time: Stone ballast needs to be cleaned time to time to maintain its drainage properly. However cleaning can only be done a certain number of time before the ballast is damaged to the point that it cannot be reused. Further track ballast that is completely fouled cannot be corrected by shoulder cleaning, in such cases it is necessary to replace the ballast altogether.

Q.7 (b) Solution:

(i)

1. If the soil is submerged but no seepage is occurring, the factor of safety against slippage will be the same as for 'dry' case, as long as there is no change in the value of ϕ'.

$$\text{FOS} = \frac{\tan\phi'}{\tan\beta}$$

$$\Rightarrow \quad \tan\beta = \frac{\tan 35^\circ}{1.3} = 0.5386$$

$$\therefore \quad \beta = \tan^{-1}(0.5386) = 28.31^\circ$$

$$\therefore \quad \beta = 28.31^\circ \text{ for both dry and submerged soil}$$

2. When the flow occurs at and parallel to the ground surface.

$$\text{FOS} = \frac{\gamma'}{\gamma_{sat}} \cdot \frac{\tan\phi'}{\tan\beta}$$

$$\therefore \quad \tan\beta = \left(\frac{19 - 9.81}{19}\right)\frac{\tan 35^\circ}{1.3} = 0.26$$

$$\therefore \quad \beta = 14.6^\circ$$

3.

$$\text{FOS} = \left(1 - \frac{\gamma_w h}{\gamma_{sat} z}\right)\frac{\tan\phi'}{\tan\beta}$$

$$z = 4 \text{ m};\ h = 4 - 1.5 = 2.5 \text{ m};\ \beta = 28^\circ$$

$$FOS = \left(1 - \frac{9.81 \times 2.5}{19 \times 4.0}\right)\frac{\tan 35^\circ}{\tan 28^\circ} = 0.892$$

(ii)

$$c = 68 \text{ kN/m}^2,\ \phi = 20^\circ,\ \gamma = 18.2 \text{ kN/m}^3$$

$$A = 0.45,\ B = 0.85$$

The height of the fill has been increased from 2 m to 5 m. This will result in the development of increased pressures at the base of the bund, where shear strength is to be determined. Now, increase in pore pressure due to additional overburden pressure is given by equation, as

$$\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)] \quad \text{...(i)}$$

Where, $\Delta\sigma_1$ = Increase in the vertical pressure due to additional 3 m fill

$\Delta\sigma_3$ = Increase in the lateral pressure

$$= \frac{\Delta\sigma_1}{3} \text{ (as given in question)}$$

We will first calculate $\Delta\sigma_1$.

$\Delta\sigma_1$ = Increase in vertical pressure due to 3 m extra overburden

$= \gamma$(depth of overburden) = 18.2 × 3 = 54.6 kN/m²

$$\therefore \quad \Delta\sigma_3 = \frac{\Delta\sigma_1}{3} = \frac{54.6}{3} = 18.2 \text{ kN/m}^2$$

Substituting values in equation (i), we get

$$\Delta u = 0.85[18.2 + 0.45(54.6 - 18.2)] \text{ kN/m}^2 = 29.4 \text{kN/m}^2$$

Initial vertical pressure,

$$\sigma_1 = \gamma \times \text{Initial depth of over-burden}$$

$$= 18.2 \times 2 = 36.4 \text{ kN/m}^2$$

Increase in σ_1, $\Delta\sigma_1 = 54.6 \text{ kN/m}^2$

Decrease in σ_1 due to part of this pressure going as pore pressure

$$= \Delta u = 29.4 \text{ kN/m}^2$$

Hence, the net effective pressure at the base, immediately on construction is,

$$\sigma' = \sigma_1 + \Delta\sigma_1 - \Delta u$$

$$= 36.4 + 54.6 - 29.4 = 61.6 \text{ kN/m}^2$$

Shear strength developed at the base, immediately after construction

$$= c + \sigma' \tan\phi$$

$$= (68 + 61.6 \times \tan 20°) \text{ kN/m}^2 = 90.42 \text{kN/m}^2$$

Q.7 (c) Solution:

(i)

$$\text{Radius of relative stiffness, } l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4} = \left[\frac{2.8\times10^5\times(20)^3}{12\times2.8\times(1-0.15^2)}\right]^{1/4}$$

$\Rightarrow \quad l = 90.88 \text{ cm}$

Warping stress,

At longitudinal edge, $S_l = \dfrac{C_x Eet}{2} = \dfrac{1.03 \times 2.8 \times 10^5 \times 8 \times 10^{-6} \times 1}{2}$

$= 1.1536 \text{ kg/cm}^2/°\text{C}$

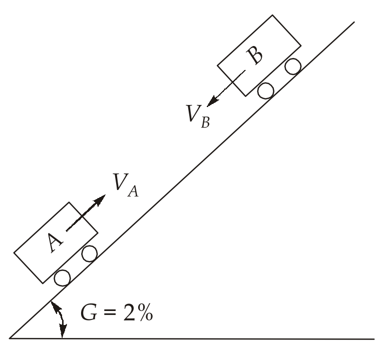
At transverse edge, $S_l = \dfrac{C_y Eet}{2} = \dfrac{0.35 \times 2.8 \times 10^5 \times 8 \times 10^{-6} \times 1}{2}$

$= 0.392 \text{ kg/cm}^2/°\text{C}$

At corner, $S_c = \dfrac{Eet}{3(1-\mu)}\sqrt{\dfrac{a}{l}} = \dfrac{2.8 \times 10^5 \times 8 \times 10^{-6} \times 1}{3 \times (1-0.15)} \times \sqrt{\dfrac{16}{90.88}}$

$= 0.3686 \text{ kg/cm}^2/°\text{C}$

(ii)



$$V_A = 85 \text{ kmph} = 85 \times \frac{5}{18} \text{m/s} = 23.61 \text{ m/s}$$

$$V_B = 65 \text{ kmph} = 65 \times \frac{5}{18} \text{m/s} = 18.06 \text{ m/s}$$

Reaction time, t_r = 2.5 seconds

Friction coefficient, f = 0.37

Brake efficiency, η = 80%

Gradient of road, G = 2%

Distance travelled by car A before stopping

$$d_A = V_A t_r + \frac{V_A^2}{2g(\eta f + G)} = 23.61 \times 2.5 + \frac{23.61^2}{2 \times 9.81(0.80 \times 0.37 + 0.02)}$$

$$= 59.03 + 89.91 = 148.94 \text{ m}$$

Distance travelled by car B before stoppage.

$$d_B = V_B t_r + \frac{V_B^2}{2g(\eta f - G)} = 18.06 \times 2.5 + \frac{18.06^2}{2 \times 9.81(0.80 \times 0.37 - 0.02)}$$

$$= 45.15 + 60.23 = 105.38 \text{ m}$$

$\therefore$ Safe SSD distance, $d = d_A + d_B$

$$= 148.94 + 105.38 = 254.32 \text{ m}$$

Q.8 (a) Solution:

(i)

Following two corrections are applied to standard penetration resistance (N), obtained below water table

1. **Overburden pressure correction:** When soil is at deeper depth, soil is subjected to higher overburden pressure. So it's response to SPT will be better to the same soil, at shallow depth. For this, overburden pressure correction is applied.
   If N_0 is observed value

   Corrected value, $$N_1 = N_o \times \frac{350}{\bar{\sigma} + 70}$$

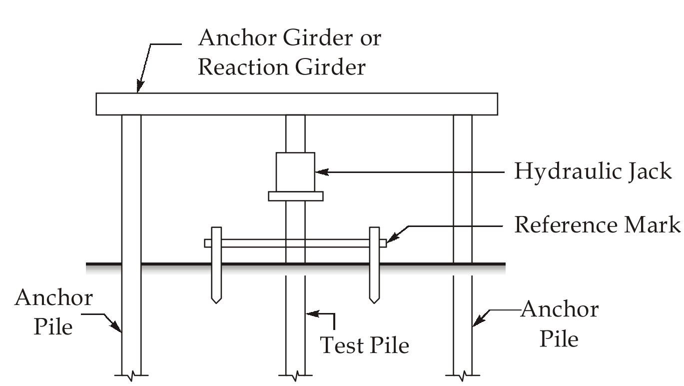
   If $\bar{\sigma} > 280$ kN/m^2 $\Rightarrow$ No correction is applied
   If $\bar{\sigma} < 280$ kN/m^2 $\Rightarrow$ Correction is applied

2. **Dilatancy correction:** For soils situated below water table, as pore pressure is not able to get dissipated, hence during dynamic loading pore water offers a temporary resistance to load, which leads to high value of 'N', so dilatancy correction is applied.

$$N_2 = 15 + \frac{1}{2}[N_1 - 15] \text{ if } N_1 > 15$$

If $N_1 < 15 \Rightarrow N_2 = N_1$

(ii)

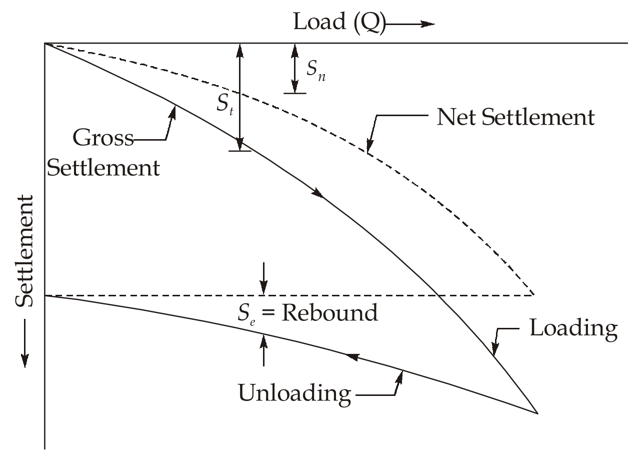


Pile Laod Test

Pile Load Test: The most reliable method for determining the load carrying capacity of a pile is the pile load test. The set-up generally consists of two anchor piles provided with an anchor girder or a reaction girder at their top.

The test pile is installed between the anchor piles in the manner in which the foundation piles are to be installed. The test pile should be at least 3B or 2.5 m clear from the anchor piles.

The load is applied through a hydraulic jack resting on the reaction girder. The measurements of pile movement are taken with respect to a fixed reference mark.



Load Settlement Curve

The test is conducted after a rest period of 3 days after the installation in sandy soils and a period of one month in silts and soft clays. The load is applied in equal increment of about 20% of the allowable load. Settlements should be recorded with three dial gauges. Each stage of the loading is maintained till the rate of movement of the pile top is not more than 0.1 mm per hour in sandy soils and 0.02 mm per hour in case of clayey soils or a maximum of two hours (IS : 2911-1979). Under each load increment, settlements are observed at 0.5, 1, 2, 4, 8, 12, 1,6 20, 60 minutes.

The loading should be continued upto twice the safe load or the load at which the total settlement reaches a specified value. The load is removed in the same decrements at 1 hour interval and the final rebound is recorded 24 hours after the entire load has been removed.

Figure above shows a typical load-settlement curve (firm line) for loading as well as unloading obtained from a pile load test. For any given load, the net pile settlement (s_n) is given by

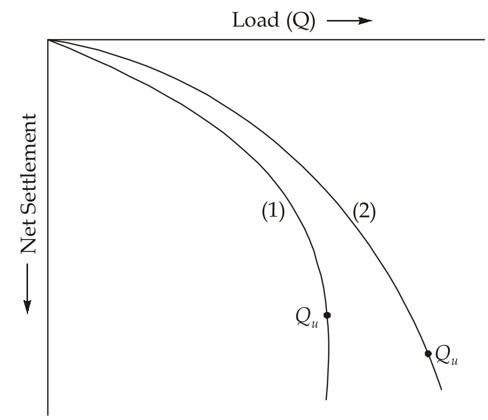
$$s_n = s_t - s_e$$

where s_t = total settlement (gross settlement), s_e = elastic settlement (rebound). Figure above also shows the net settlement (chain dotted line).

Figure below shows two load-net settlement curves. Curve (2) in linear or there is a sharp break as in the curve (1), as shown in the figure. The safe load is usually taken as one half of the ultimate load.

According to IS : 2911, the safe load is taken as one half of the load at which the total settlement is equal to 10 per cent of the pile diameter (7.5 per cent in case of under-reamed piles) or two-thirds of the final load at which the total settlement is 12 mm whichever is less. According to another criterion, the safe load is taken as one half to two thirds of the load which gives a net settlement of 6 mm.

The limiting settlement criteria are also sometimes specified. Under the load twice the safe load, the net settlement should not be more than 20 mm or the gross settlement should not be more than 25 mm.



The test described above is known as initial test. It is carried out on a test pile to determine the ultimate load capacity and hence the safe load. The pile load test described in this section is a type of load-controlled test, in which the load is applied in steps.

Other types of pile load tests

1. **Constant rate of penetration test:** In a constant rate test, the load on the pile is continuously increased to maintain a constant rate of penetration (from 0.25 to 5 mm per minute). The force required to achieve that rate of penetration is recorded, and a load settlement curve is drawn. The ultimate load can be determined from the curve.

   The test is considerably faster than load controlled test.

2. **Routine load test:** This test is carried out on a working pile with a view to determine the settlement corresponding to the allowable load. As the working pile would ultimately form a part of the foundation, the maximum load is limited to one and a half times the safe load or upto the load which gives a total settlement of 12 mm.

3. **Cyclic load test:** The test is carried out for separation of skin friction and point resistance of a pile. In this test, an incremental load is repeatedly applied and removed.

4. **Lateral load test:** The test is conducted to determine the safe lateral load on a pile. A hydraulic jack is generally introduced between two piles to apply a lateral load. The reaction may also be suitably obtained from some other support. The test may also be carried out by applying a lateral pull by a suitable set-up.

5. **Pull out test:** The test is carried out to determine the safe tension for a pile. In the set-up, the hydraulic jack rests against a frame attached to the top of the test pile such that the pile gets pulled up.

Q.8 (b) Solution:

Given: $$g_1 = +\frac{3}{100} = +0.03;\ g_2 = -\frac{2.5}{100} = -0.025$$

$$g_2 - g_1 = -0.025 - 0.03 = -0.055 \text{ or } |g_2 - g_1| = 0.055$$

The length of the curve required to provide the adequate sight distance for stopping can be obtained as follows:

Assume $h_1 = 1.2$ m, $h_2 = 0.15$ m. Further, assume $L \geq S$, then

$$L = \frac{NS^2}{2\left(\sqrt{H}+\sqrt{h}\right)^2}$$

$$= \frac{0.055 \times 180^2}{2\left(\sqrt{1.2}+\sqrt{0.15}\right)^2} = 405.27 > S\,(= 280 \text{ m}) \quad \text{(OK)}$$

Further, the minimum value of the length L as suggested by IRC is 60 m. Hence, the final design value remains as 405 m.

The location of the vertical point of curve is calculated as follows:

- The horizontal distance of vertical point of curve from the benchmark

$$= \text{Horizontal distance of vertical point } - \frac{L}{2}$$

$$= 1000 - \frac{405}{2} = 797.5 \text{ m}$$

- The elevation of vertical point of curve is given as

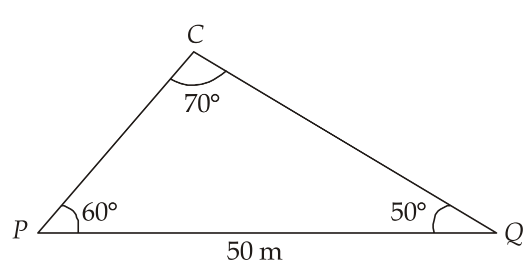
Elevation of vertical point of curve = Elevation of intersection $- \frac{L}{2} g_1$

$$= 100 - \frac{405}{2} \times 0.03 = 93.95 \text{ m} \simeq 93.9 \text{ m}$$

Hence, the coordinates of vertical point of curve are (797.5, 93.9).

Q.8 (c) Solution:

(i)

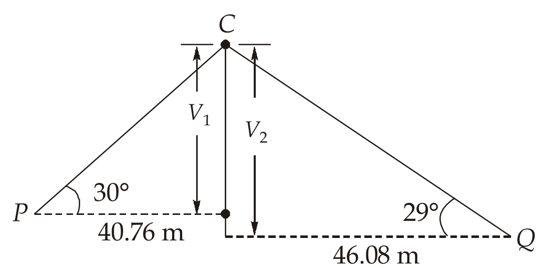


PLAN

Now, $$\frac{PC}{\sin 50°} = \frac{QC}{\sin 60°} = \frac{PQ}{\sin 70°}$$

∴ $$PC = \frac{\sin 50°}{\sin 70°} \times 50 = 40.76 \text{ m}$$

$$QC = \frac{\sin 60°}{\sin 70°} \times 50 = 46.08 \text{ m}$$



ELEVATION

Elevation of top of chimney

$$\tan 30° = \frac{V_1}{40.76} \Rightarrow V_1 = 23.53 \text{ m}$$

$$\tan 29° = \frac{V_2}{46.08} \Rightarrow V_2 = 25.54 \text{ m}$$

∴ RL of top of chimney from P

$$= 22.5 + 23.53 = 46.03 \text{ m}$$

RL of top of chimney from Q = 20.5 + 25.54 = 46.04 m

Average RL of top of chimney = $\frac{46.03 + 46.04}{2}$ = 46.035 m

(ii)

We know,

$$\text{Scale of photograph} = \frac{\text{Photo distance}}{\text{Ground distance}} = \frac{\text{Focal length } (f)}{\text{Flying height (H) – Avg elevation } (h_{avg})}$$

$$\Rightarrow \quad \frac{f}{H - h_{avg}} = \frac{8.50}{250}$$

$$\Rightarrow \quad 250 \times 20 = 8.50\,H - 8.50 \times 250$$

$$\Rightarrow \quad H = 838.235 \text{ m}$$

Let h_2 be the height of tower and r_2 be the distance of image of the top of tower on photograph.

We know,

∴ Displacement, d in image of top w.r.t image of the bottom is given by,

$$d = \frac{r_2 h_2}{H - h_{avg}}$$

⇒ $$0.46 = \frac{6.46 \times h_2}{838.235 - 250}$$

⇒ $$h_2 = 41.887 \text{ m}$$

■■■■