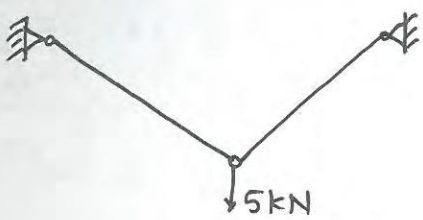
9. Cable Structure.

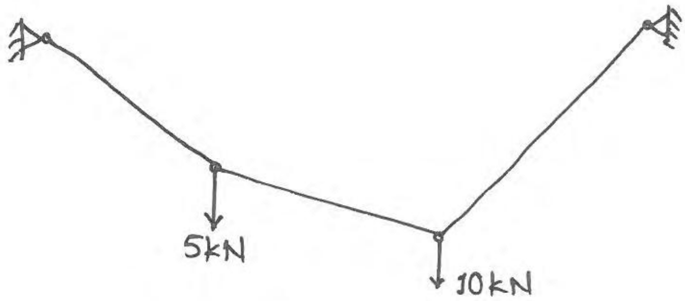
9.1 Assumptions:-

1) Cables are axially inextensible.
2) Cables are perfectly flexible so shear force and bending moment is zero everywhere.

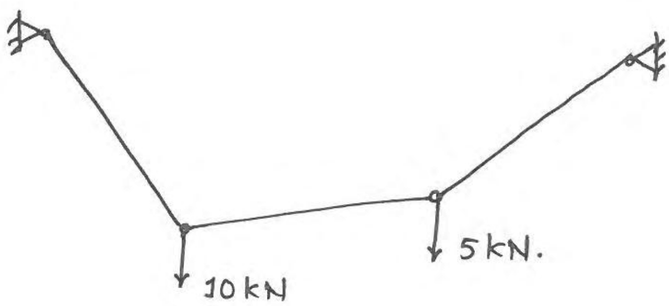
9.2 Stability of Cable Structure:-



DSI=0, Stable

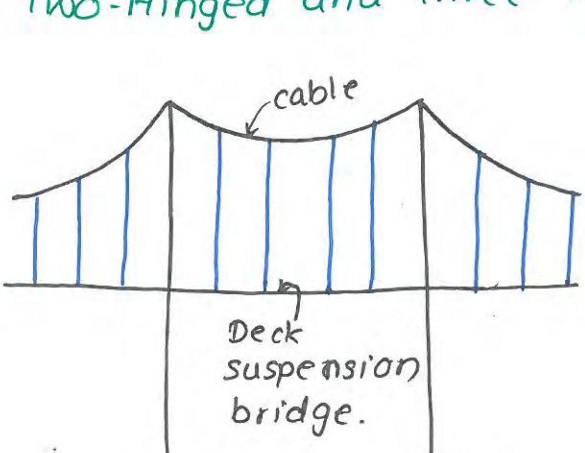


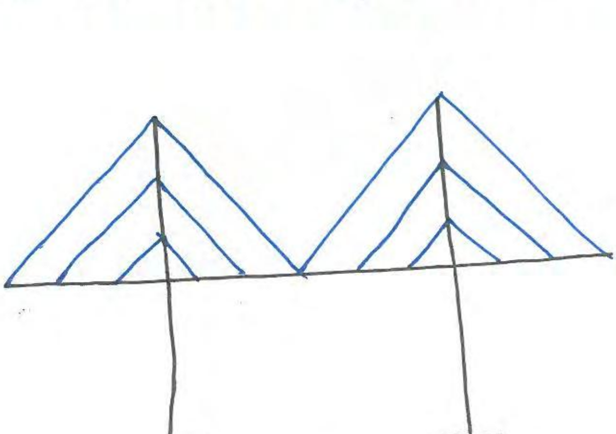
DSI = -1



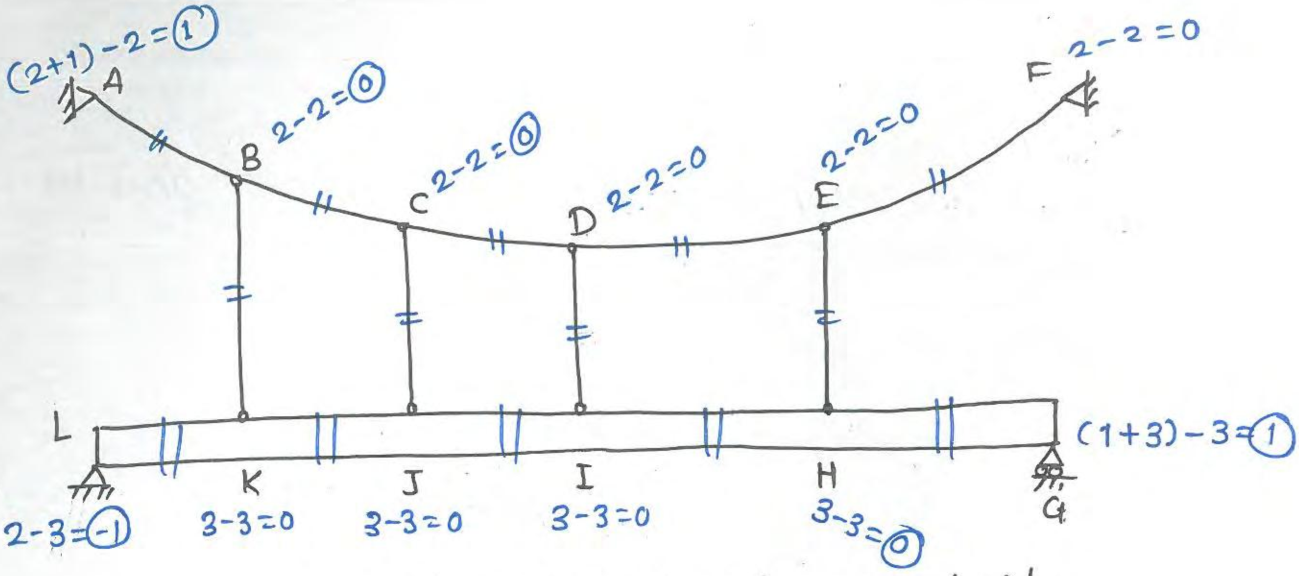
Cable structures with $DSI < 0$ may also be stable for particular load combination. If loading pattern of structure changes then shape of structure also changes. This makes a structure unstable.

9.3 Two-Hinged and Three Hinged Stiffned suspension Bridge:-





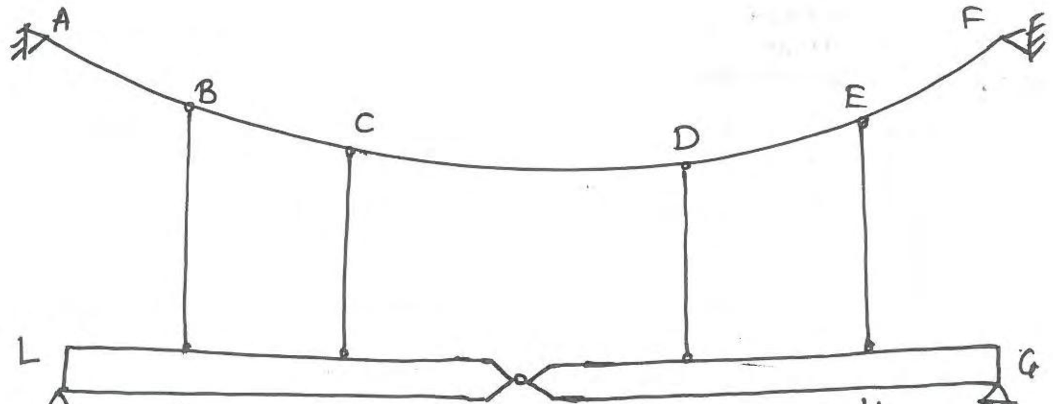
Cable stayed bridge.



2-Hinged Stiffened suspension bridge.

Seq. → A to L

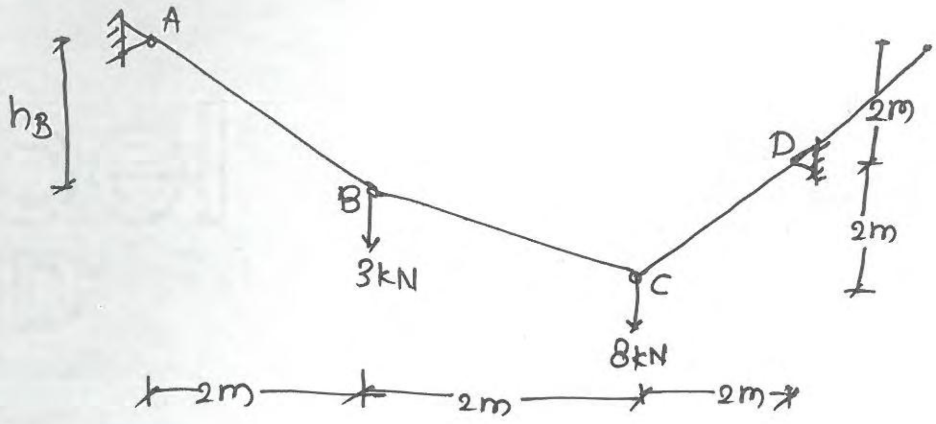
DSI = 1

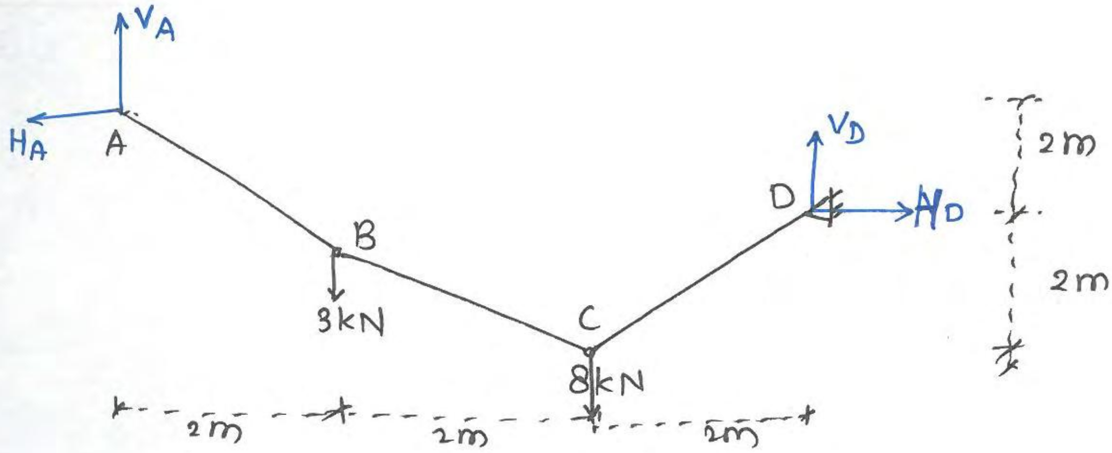


3-Hinged Stiffened Suspension bridge

DSI = 0

Ex. Calculate tension in each segment of cable and vertical sag at B.





$\Sigma F_x = 0$

$\Rightarrow -H_A + H_D = 0$ ---(i)

$\Sigma F_y = 0$

$V_A + V_D - 3 - 8 = 0$ ---(ii)

$\Sigma M_z = 0$

$\Sigma M_A = 0$

$-V_D \times 6 - H_D \times 2 + 3 \times 2 + 8 \times 4 = 0$ ---(iii)

$M_C = 0$ (RHS)

$H_D \times 2 - V_D \times 2 = 0$ ---(iv) from eqⁿ (i) to (iv)

$$H_A = H_D = 4.75\,kN$$

$$V_A = 6.25\,kN$$

$$V_D = 4.75\,kN.$$

$$T_{AB} = \sqrt{V_A^2 + H_A^2}$$

$$= \sqrt{6.25^2 + 4.75^2}$$

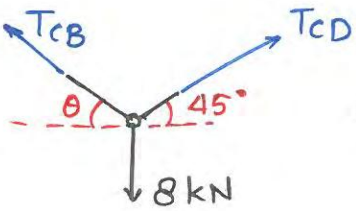
$$= 7.85\,kN$$

$$T_{CD} = \sqrt{V_D^2 + H_D^2}$$

$$= \sqrt{4.75^2 + 4.75^2}$$

$$= 6.72\,kN$$

Joint C:-



$$\Sigma F_x = 0$$

$$\Rightarrow -T_{CB}\cos\theta + T_{CD}\cos 45^\circ = 0 \quad \cdots (v)$$

$$\Sigma F_y = 0$$

$$T_{CB}\sin\theta + T_{CD}\sin 45^\circ - 8 = 0 \quad \cdots (vi)$$

from (v) and (vi)

$$T_{CB} = 5.75\,kN$$

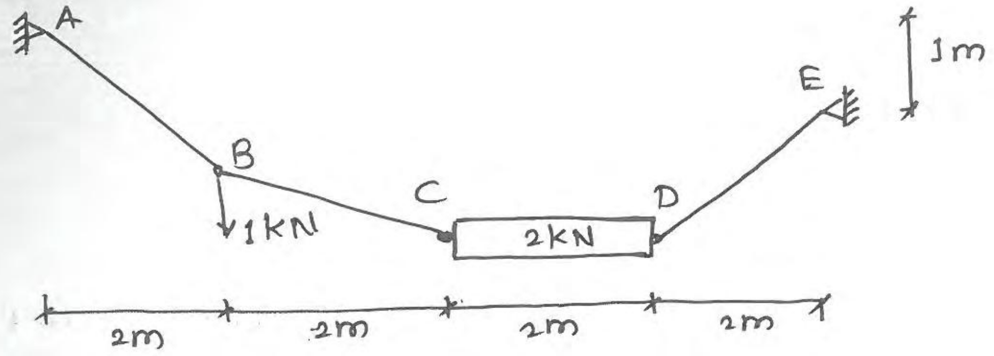
For vertical sag at B.

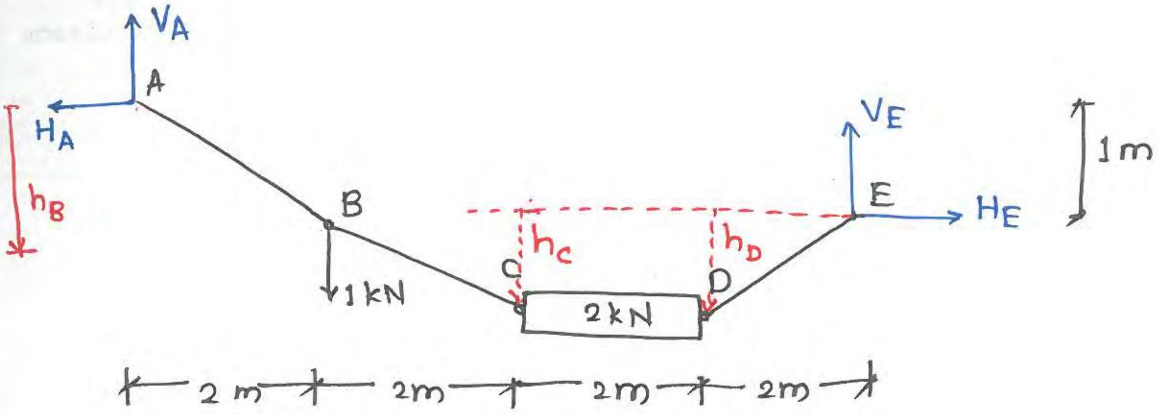
$$M_B = 0 \quad (LHS)$$

$$\Rightarrow V_A \times 2 - H_A \times h_B = 0$$

$$\Rightarrow h_B = 2.63\,m$$

Ex. Calculate support reactions and vertical sag at B w.r.t. A. Member CD is rigid and horizontal.





$\Sigma F_x = 0$

$\Rightarrow -H_A + H_D = 0$ ---(i)

$\Sigma F_y = 0$

$\Rightarrow V_A + V_E - 1 - 2 = 0$ ----(ii)

$\Sigma M_z = 0$

$\Rightarrow \Sigma M_A = 0$

$\Rightarrow 1 \times 2 + 2 \times 5 - V_E \times 8 - H_E \times 1 = 0$ ---(iii)

$M_D = 0$ (R.H.S.)

$H_E \times h_D - V_E \times 2 = 0$ ----(iv)

In above 4 equations, 5 unknowns are present so one more equation is required.

Since, member CD is horizontal

so, $h_c = h_D$

$M_c = 0$ (RHS)

$\Rightarrow 2 \times 1 + H_E \times h_D - V_E \times 4 = 0$ ---(V)

From equation (i) to (v)

$H_A = H_E = 4\,kN$

$V_A = 2\,kN$

$V_E = 1\,kN$

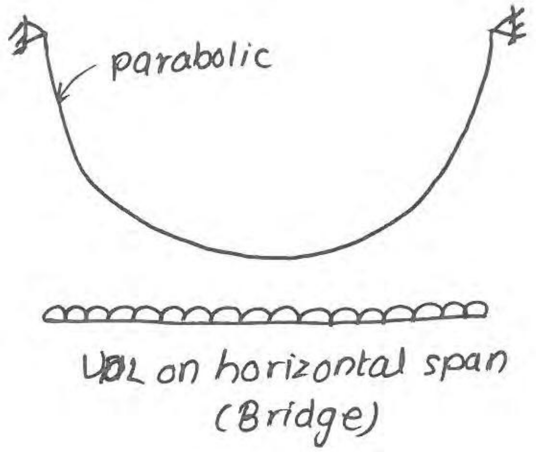
For h_B :-

$M_B = 0$ (L.H.S.)

$\Rightarrow V_A \times 2 - H_A \times h_B = 0$

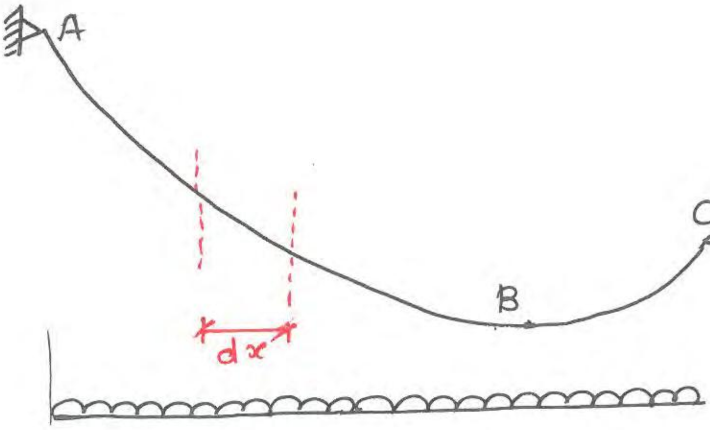
$\Rightarrow$ $\boxed{h_B = 2.63\,m}$

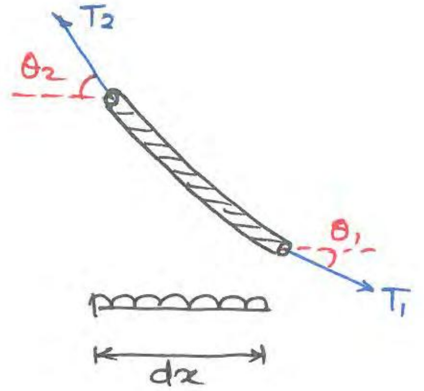
9.4 Cable subjected to udl:-



• Note:-
If vertical sag is small as compared to span then parabolic and caternary profiles are considered as same for practical purposes.

Considering a cable subjected to downward UDL on horizontal span and supported at unequal level as given below.





$$\Sigma F_x = 0$$

$$\Rightarrow T_1 \cos\theta_1 - T_2 \cos\theta_2 = 0$$

$$\Rightarrow T_1 \cos\theta_1 = T_2 \cos\theta_2$$

$\Rightarrow$ Horizontal component of force of cable = constant.

$$\Sigma F_y = 0$$

$$\Rightarrow T_2 \sin\theta_2 - T_1 \sin\theta_1 - w\,dx = 0$$

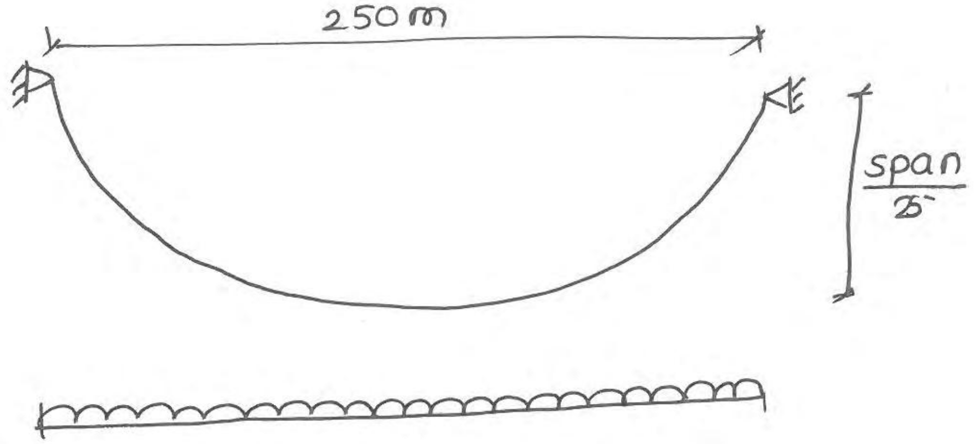
$$\Rightarrow T_2 \sin\theta_2 - T_1 \sin\theta_1 = w\,dx$$

$\Rightarrow$ Difference in vertical component of force of cable = Downward Loading on segment.

Since horizontal component is constant and vertical Component is varying so variation of force in cable depends on vertical component only.

Minimum tension in cable is corresponding to minimum vertical component (at lowest point of cable profile, B) and maximum tension is corresponding to maximum vertical component (at highest point of cable profile, A)

Ex. A cable suspends accross gap of 250m and carries udl of 10kN/m on horizontal span. Calculate maximum tension if maximum sag is $\frac{span}{25}$. Also compute sag at 50m from ends.



Ans:-

$V_A = V_B = 1250$

$H_A = H_B = 7812.5$ kN

$T_{max} = 7911.86$ kN

$h_{(50m)} = 6.4$m