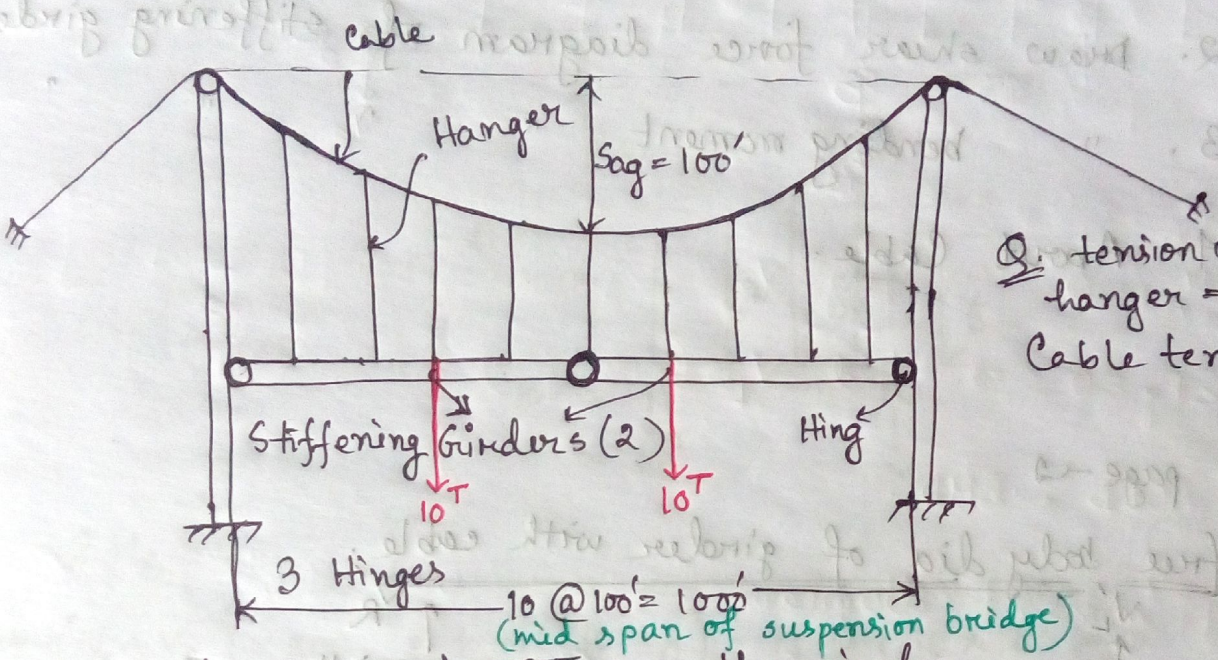
29.8.2015

CE-311

Suspension Bridge



Q. tension of hanger = ?
Cable tension = ?

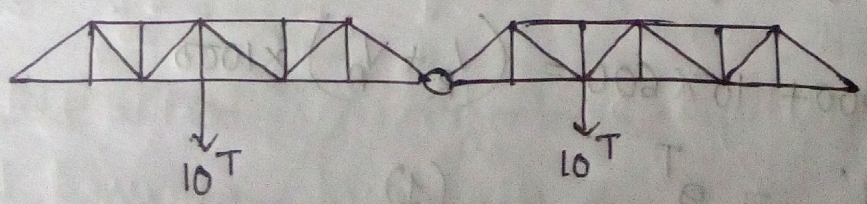
* Vehicle movement করছে over the girder.

* Cable + hanger ⇒ only tension

> W × spacing of the hanger = hanger force

⇒ Finally SFD, BMD of the Girders.

* Stiffening girders may be replaced by two stiffening trusses.



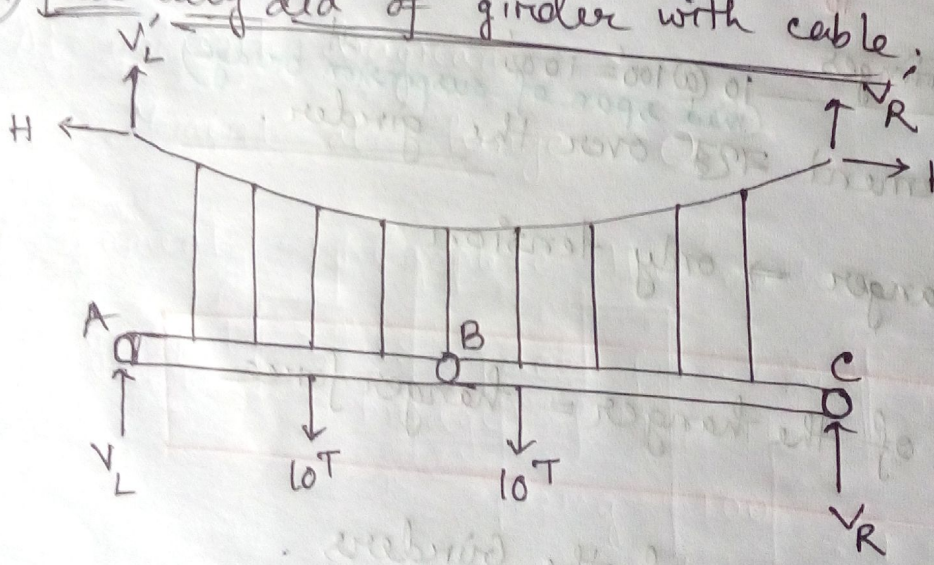
Determine —

for girder

1. Hanger force = ?
2. Draw shear force diagram of stiffering girder
3. " bending moment " " " "
4. About Cable.

New page →

(*) Free body dia of girder with cable:



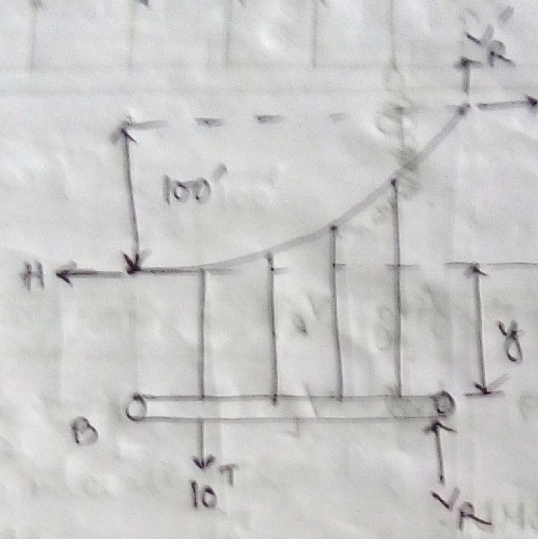
(Free body dia. of girder and cable)
whole structure

$\Sigma M_A = 0$ ↴

$\Rightarrow 10 \times 300 + 10 \times 600 = (V_R + V_R') \times 1000$

$\Rightarrow V_R + V_R' = 9^T$ . . . . (1)

* lowest point - ১ vertical component of cable tension আছে ।
only hor. component.



$\Sigma M_B = 0$ ↻+

$\Rightarrow -(V_R + V_R) \times 500 + H \times (100+y) - Hy + 10 \times 100 = 0$

$\Rightarrow -1500 + H \times (100+y) - Hy + 1000 = 0$

$\Rightarrow -3500 + 100H + Hy - Hy = 0$

$\Rightarrow 100H = 3500$

$\therefore H = 35^T$

According to GCT →

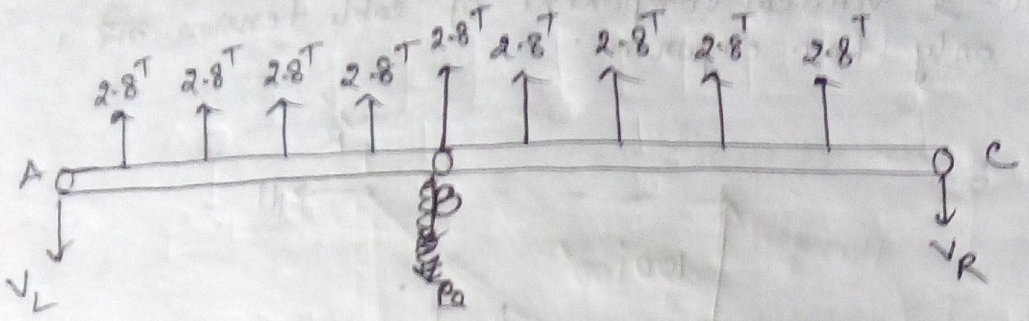
$$\text{Sag, } h = \frac{WL^2}{8H}$$

$$\Rightarrow 100 = \frac{W \times 1000^2}{8 \times 35}$$

$\Rightarrow W = 0.028^{Ton}$ / horizontal foot.

∴ Hanger force = W × spacing of hanger

$= 0.028 \times 100 = 2.8^{Ton}$.



$\Sigma M_A = 0 \Rightarrow$ fing V_R.

then $\Sigma F_y = 0 \Rightarrow$ find V_L

Then SFD, BMD.

At moment diagram $\Rightarrow$

Moment at hinge = 0.

Assignment $\Rightarrow$ 1. Complete the math in class note.

Assignments $\rightarrow$ 2. 8 spaces of a mid span suspension bridge ~~of~~ bet^n the hangers.

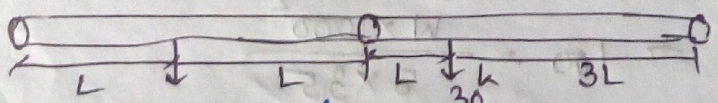
spacing = 100′, L = 800′

sag = 75′

Load = middle of the first girder = 50^k

B point থেকে quarter point - 1 = 30^k.

আগের math-এর মতই সব বের করব।



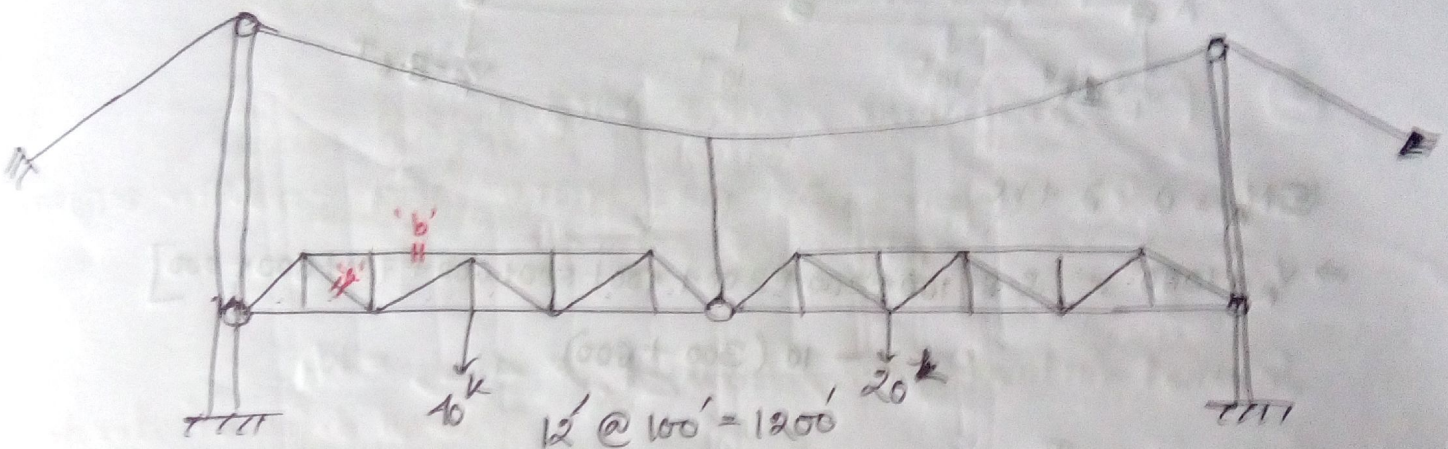
Hanger force = ?

Additional $\rightarrow$ Max^m tension of cable = T_{max} = ?

Unstressed, stressed length = ?

Stretch of the cable = ?

2. 12 spaces.

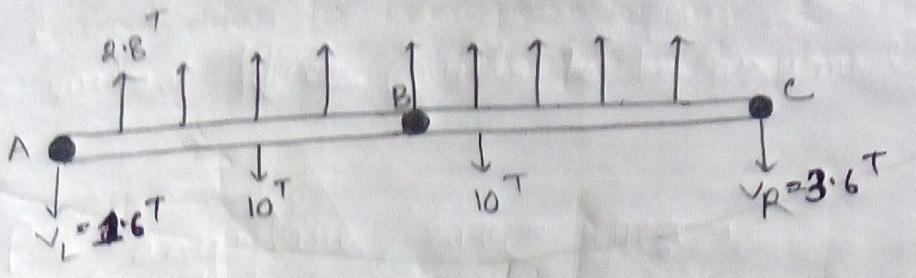


Hanger force = ?

two member forces = ?

'a', 'b' = ?

Home Work

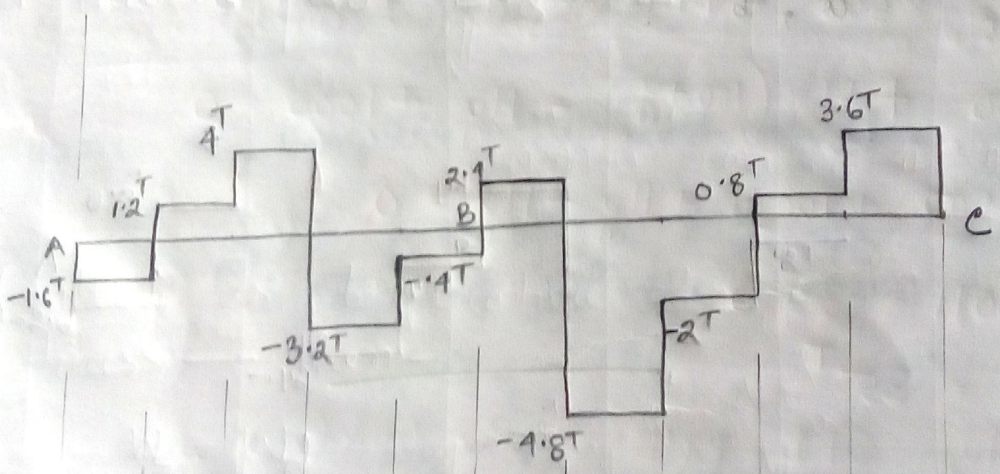


$\Sigma M_A = 0$ ↻ +ve

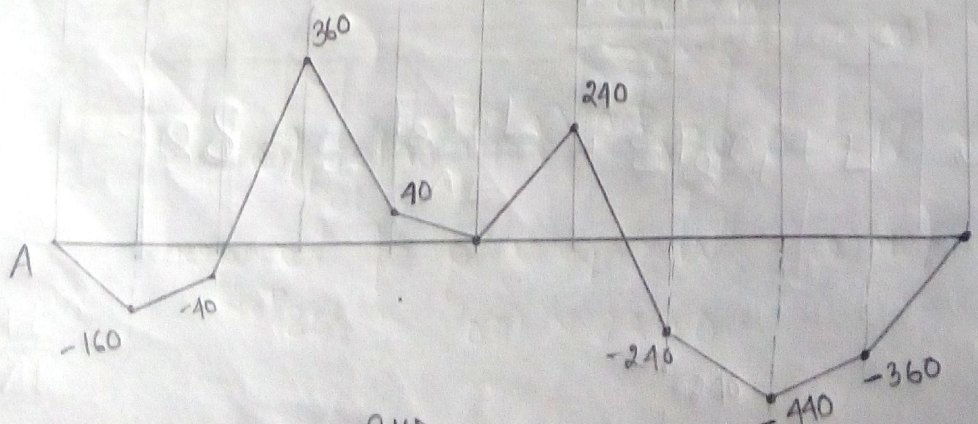
$\Rightarrow V_R \times 1000 = 2.8[100+200+300+400+500+600+700+800+900] - 10(300+600)$

$\Rightarrow V_R = 3.6^T$

$\Sigma F_y = 0$ ↑ +ve $\rightarrow V_L = 2.8 \times 9 - 20 - 3.6 = 1.6^T$



SFD



BMD

30·8·2015

Assignment-3

Spacing 50'

L = 600'

Truss Height = 40'

First force is = 40^k (same place-2)

2nd force = same

Deflection of Truss, Beam & Frame by Virtual Work Method

(Chapter-8)

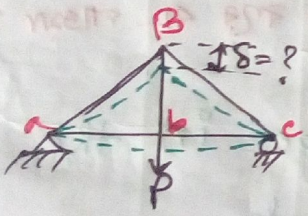


Fig-1

⇒ According to virtual work method

Principle ⇒ Actual virtual work done by virtual force is equal to internal virtual work done by virtual stresses.

$\therefore W_s = W_d$.

but for our case, W_s = external work

W_s = Force × deflection

W_d = internal work

W_d = Force × deformation.

Force = virtual force

deflection/deformation = for real force.

stress

always area নিয়ে কাজ করা যাও লাগতে পারে।

Q. Here, top chord deflection in fig (i) $\Rightarrow$, $\delta = ?$

P = given force i.e actual/Real force acting on structure

Q = virtual force (needs to be assumed)

(*) P = anywhere থাকতে পারে।

But, Q = যে point-এ ব্রের করতে হবে condition অনুযায়ী সেখানে load হবে।

Internal virtual force/stress $\Sigma F_Q \times \underbrace{\Delta L}_{\text{Internal deformation due to real force}} = W_d$.

and $W_s = Q\delta$

$\therefore$ For truss, $\boxed{Q\delta = \Sigma F_Q \times \Delta L}$ ←

Σ তে যতগুলো member আছে সবগুলোর $F_Q \Delta L$ বের করে যোগ করতে হবে।

- If there is temperature change in the member of truss — then —

$W_s = W_d$

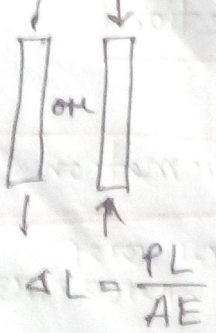
$\Rightarrow Q\delta = \Sigma F_Q \Delta L + \Sigma F_Q \alpha_t t L$ → Length.

(α_t ← coefficient of thermal expansion; t ← Temp. change)

+ for increase

− " decrease

Truss member



$\therefore \Delta L = \frac{PL}{AE}$

$\Rightarrow \boxed{Q\delta = \Sigma \frac{F_Q F_P L}{AE} + \Sigma F_Q \alpha_t t L}$ ←

যে member-এর temp. change নাই তা zero.

(*) We assume, $Q = 1$ (1^k unit force) or ($1^{k\cdot ft}$ unit moment.)

⇓

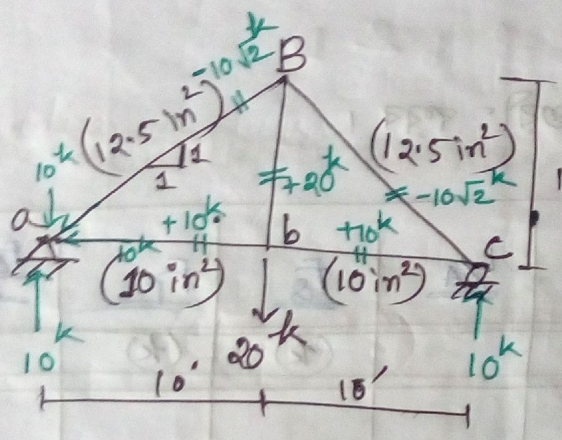
হিসাব করতে সুবিধা

- If $Q = 1$

  then, $\delta = \int \dots\dots$

* lower part - যে joint ⇒ lower case letters
* upper " " " ⇒ upper case letters.

Example



Area shown in parentheses.

$E = 29000$ ksi

Find vertical deflection at

Sol^n

(1) Analyse the structure for P or real Load —

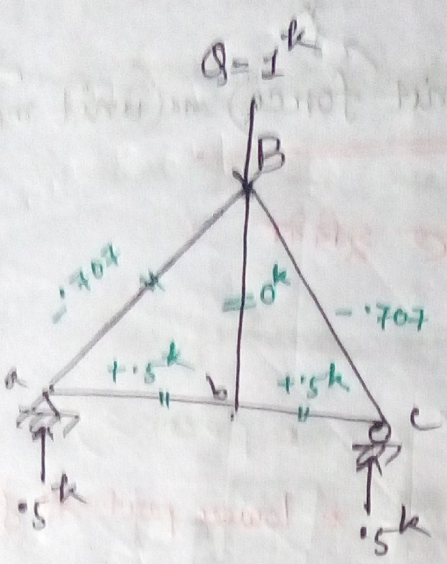
$F_{Bb} = +20^k$ (by joint analysis of b).

Analysis of 'P' force

P = 20 tension So, F_{aB} = compression - যে যেদিকে।

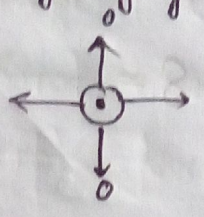
- All the member forces are F_p.

(2) Analyse the structure for Q force.



As B point-এ vertical deflection চাইছে।

analysing joint b →



E -এর জন্য Table তৈরী করব।

Bar	Length (ft)	Area (in²)	L/A	F_Q (k)	F_{PL} (k)	$F_Q F_{PL}$ / A	t °F	$F_Q tL$
Horiz. ab								
bc								
Vert. aB								
cB								
Diag. Bb								
							$E = +32.6$	$E = 0$

↓ no temp change given

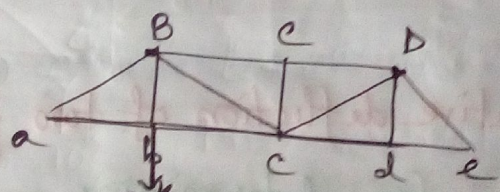
Applying principle of V.W →

$$\sum \delta_V = \sum \frac{F_Q F_P L}{A} + \sum F_Q \alpha t L^0$$

$$\Rightarrow 1^k \cdot \delta_{BV} = + \frac{32.6}{29000}$$

$$\therefore \delta_{BV} = +0.00112' \text{ (downward)}$$

Assigment – 4. Exp 8.1 ⇒ changed load = 80^k instead of 100^k



Find hor. deflection at point "D"

temp. change + load साथ में

" – 5. Exp 8.2 ⇒ changed load = 80^k instead of 100^k

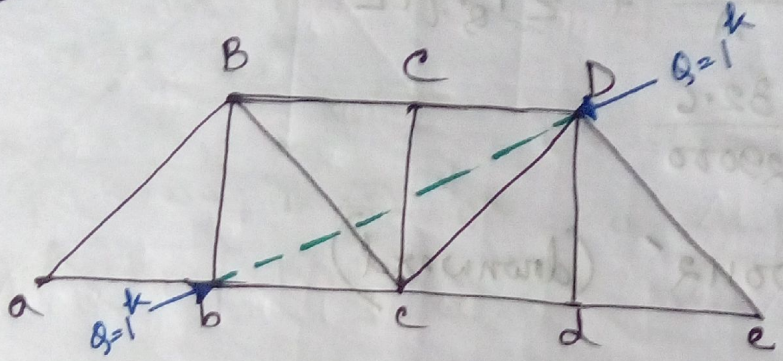
temp. change 40° F decrease in diagonals only.

Find ver. deflection at "E" (top chord)

12.09.15

* Fig - 8.10 vv. imp

Ex - 8.3 & 8.4



Relative deflection of b & D

↓

this means b & D কাছে আসবে নাকি দূরে সরে যাবে??

Relative deflection of two joints — (Ex-8.4)

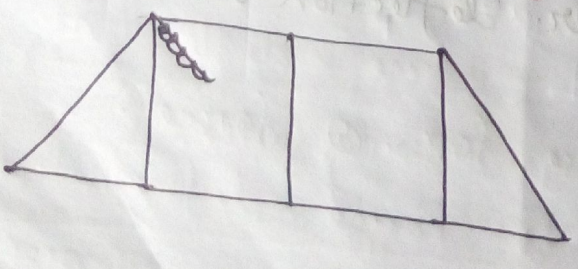
for determining,

if δ_{bD} = +ve ⇒ কাছাকাছি আসবে
δ_{bD} = -ve ⇒ দূরে সরে যাবে

} (Ex-8.4)

Assignment - 6

load same, dimension different. Find relative deflection of joints Bd. (Bar arrangement & load same as book)



15'

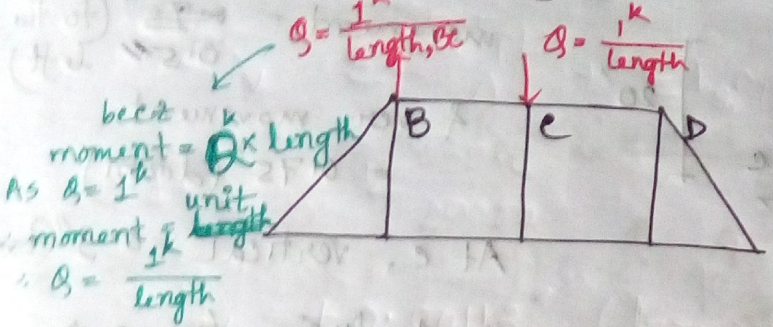
Only height different.

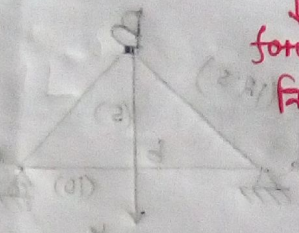
Rotation of a member/bar :- (Ex-8.5)

bar O° থাকে না কিভাবে downward/upward হবে?

↓

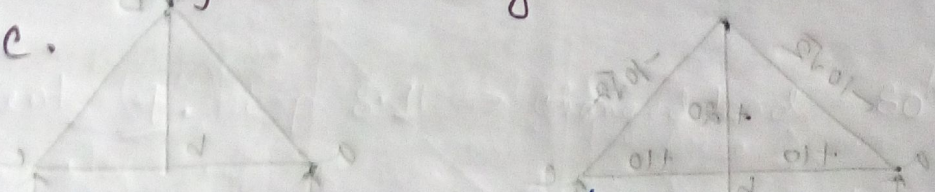
for this unit moment নিতে হবে ঐ bar-এর দুটো end point-এ.





Assignment-7

All other info same as assignment 6. Find rotation of bar BC.



Effect of support movement/settlement :-

↓

ফ্রেম এমন Building-এর joint displace হয়।

Principal of virtual work—

$$W_S + W_R = W_d$$

Here, W_R = work done by virtual support reaction on real support movement due to real load

↓

virtual ও force থেকে থেকে

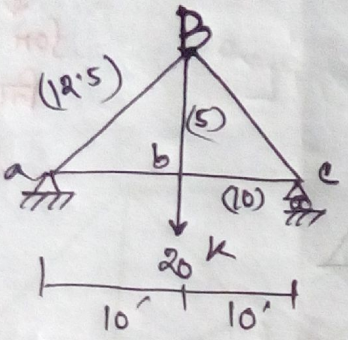
$W_R = \sum$ support reaction × deflection

↓

(উল্টা আকার)

⇒ কোন support এর movement না থাকলে অথবা $W_R = 0$.

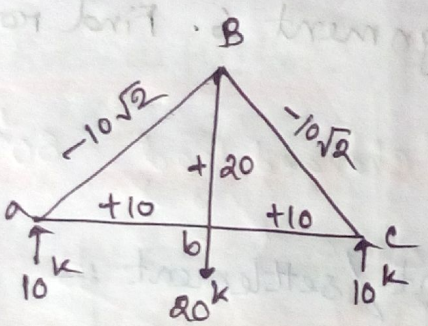
Example Compute vertical deflection of joint B. Given, E = ___ at support 'a' hor. movement = ~~0.75~~ 0.5" (to the left)



& ver. movement = 0.75" (down)

At c, vertical = 0.3" (down)

1) Analysing for P force



2) Analysis for Q force

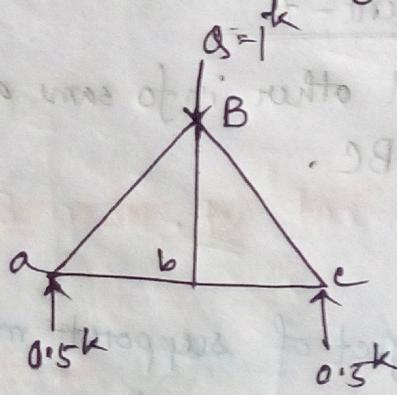


Table (from previous example)

			$\Sigma F_Q F_P L/A$	$\Sigma F_Q t L$
			$\Sigma = 82.6$	$\Sigma = 0$

Apply principle of V.W →

$$W_s + W_R = W_d$$

$$\Rightarrow 9\delta_{BV} + R_{Ay}\Delta_{Ay} + R_{ax}\Delta_{ax} + R_{cy}\Delta_{cy} = \Sigma F_Q F_P \frac{L}{AE} + \Sigma F_Q \alpha_t t L$$

$$\Rightarrow 9\delta_{BV} + \left(0.5 \times \left(-\frac{.75}{12}\right) + 0 + .5 \times \left(-\frac{.3}{12}\right)\right) = \frac{32.6}{29 \times 10^3} + 0$$

-ve bcz settlement বলতে force এর opposite-এ

$$\Rightarrow \delta_{BV} = 0.524$$

$$\Rightarrow \delta_{BV} = 0.00112' + 0.04375'$$

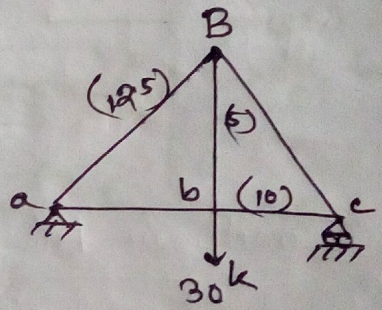
$$\Rightarrow \delta_{BV} = 0.04485' \; 0.04487'$$

Assignment-8

Compute hor. deflection of joint B.

Support movement

for a hor. = 0.6" (right)
" a ver. = 0.8" (down)
" c ver. = 0.5" (down)



Assignment-9

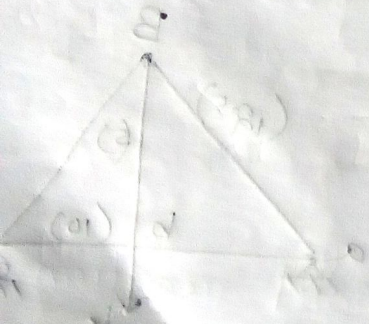
~~loading~~ Fig as given for assgnmt-7, no external loading. dimension same asgnmt-7.

Support movement

for a. hor. = 0.6" (right)
" a ver. = 0.8" (down)
" e ver. = 0.4" (down)

Determine ver. Δ hor. deflection at 'C' (top chord).

Class test → next class (upto Assignment-9)



03.9.2015

* Deflection of beams & frames by virtual Method –

$$\Sigma Q\delta = \underbrace{\int \frac{M_Q M_P}{EI} dx}_{①} + \underbrace{\Sigma F_Q F_P L/AE}_{②} + \underbrace{\Sigma F_Q \alpha_t t L}_{③}$$

① → Bending moment effect.

② → Axial force effect

③ → Temp. effect.

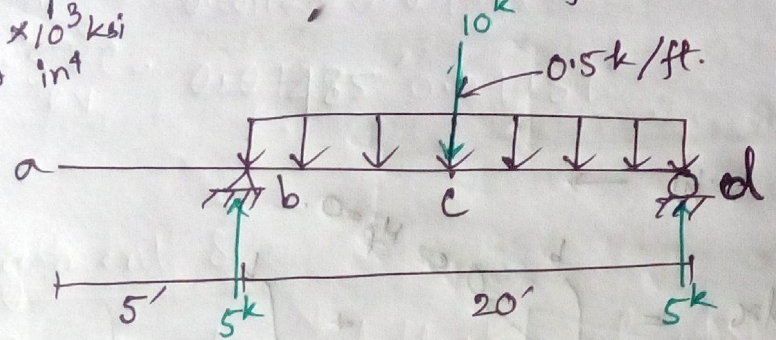
Imp [② & ③ এ integration form-এই আছে। But uniform বলে Σ দিয়েছি। যদি এগুলো non-uniform হয় তাহলে ∫ form-এ দিতে হবে। Similarly Moment ও যদি uniform হয় তাহলে Σ form-এ দিতে পারি।]

Exp-8.5

Compute vertical deflection of "a".

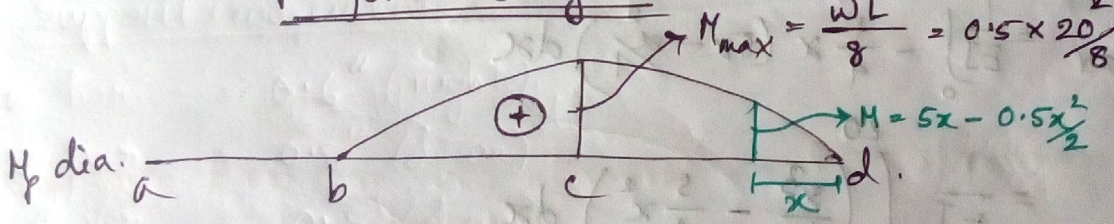
$E = 30 \times 10^3$ ksi

$I = 200$ in⁴

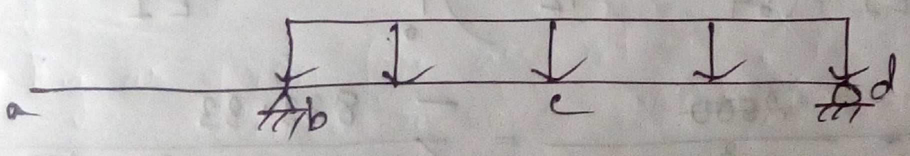


* এখানে no axial force. So, ② will be zero.

P – force analysis.

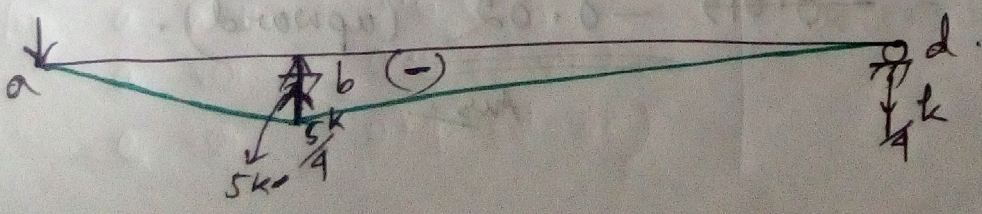


Q – force analysis



⇓

$Q = 1^k$.



Expression for M_Q and M_P)

Segment ab ($0 < x \leq 5'$)

$M_Q = -1x$

$M_P = 0$

Segment db : ($0 < x \leq 20'$)

$M_Q = -\frac{1}{4}x$

$M_P = 5x - \frac{x^2}{4}$.

Using Principle of V.W →

$$\Sigma Q \delta_{av} = \int \frac{M_Q M_P}{EI} dx = \int_a^b \to 0 \text{ as } M_P = 0. + \int_d^b$$

$Q = 1^k$.

$$\Rightarrow \delta_{av} = \frac{1}{EI} \int_0^{20} -\frac{1}{4}x\left(5x - \frac{x^2}{4}\right) dx$$

$$= \frac{1}{EI} \int_0^{20} \left(\frac{x^3}{16} - \frac{5}{4}x^2\right) dx$$

$$= \frac{1}{EI} \left(\frac{1}{64}x^4 - \frac{5}{12}x^3\right)\Big|_0^{20} = -\frac{833.33}{EI}$$

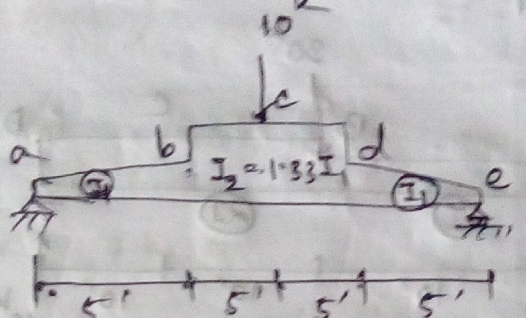
$$= -\frac{2500}{30 \times 10^3 \times 3 \times 200} = -\frac{833.33}{(30000 \times 144) \times \frac{200}{144^2}}$$

$$= -0.019 \quad -0.02 \text{ (upward)}.$$

Ans:

Ex-8.6

4 টি segment



$E = 30000$ ksi

$I_1 = 150$

Calculate change in slope at point "a".

Q will be = 1 unit moment.

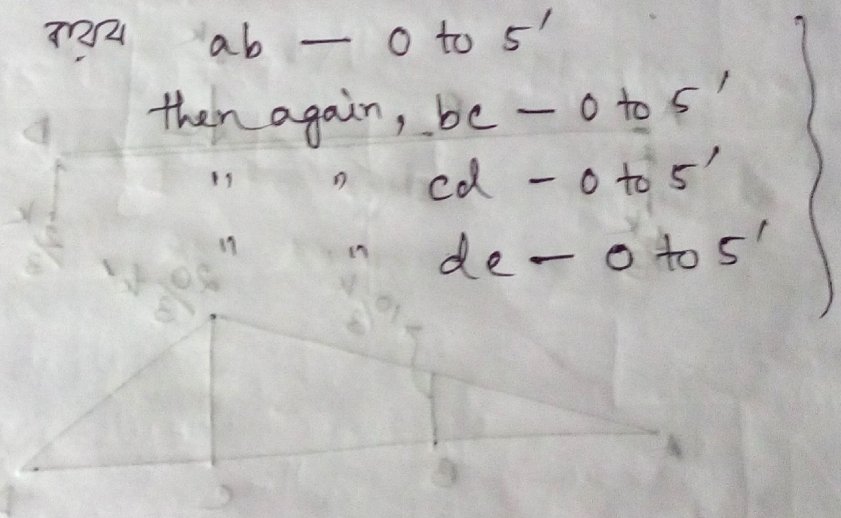
বইতে যেভাবে আছে 0 – 5', 5'–10' - - -

But আমরা নিব ab — 0 to 5'

then again, bc — 0 to 5'

" " cd — 0 to 5'

" " de — 0 to 5'

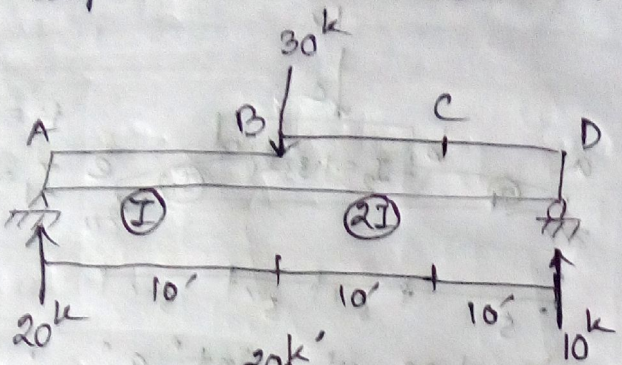


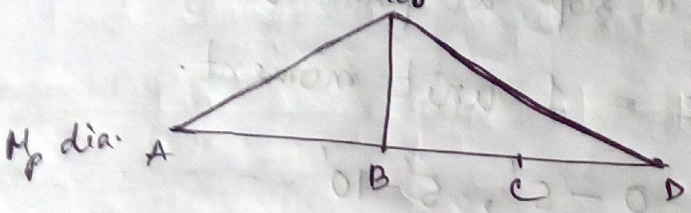
04.10.15

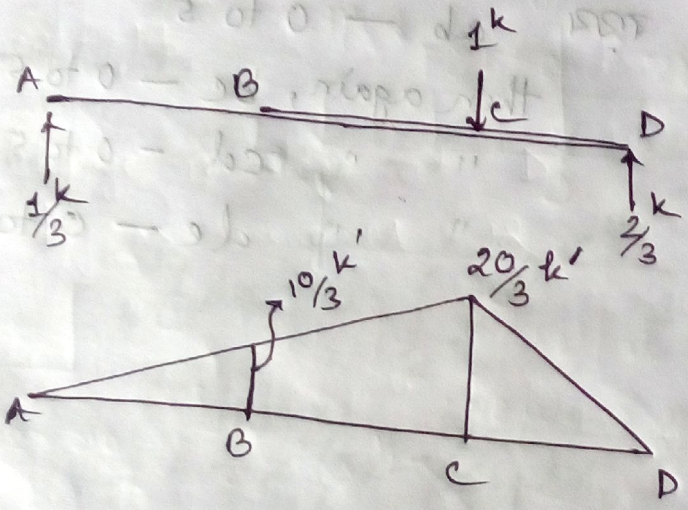
Problem-1 Compute vertical deflection at "c". Given,

$I = 200\ in^4$

$E = 30000\ ksi$







Ans: No of segments = ? ⇒ depends on moment diagram, Inertia etc.

Segment AB $(0 \leq x \leq 10)$:

$$M_Q = \frac{1}{3}x \quad , \quad M_p = 20x$$

Segment Be $(0 < x \leq 10')$:

$$M_Q = \frac{10}{3} + \frac{x}{3}$$

$$M_p = 200 - 10x$$

Segment DC ($0 < x \leq 10'$):

$$M_Q = \frac{2}{3}x \; ; \quad M_P = 10x$$

Using Principle of V.W →

$$\Sigma Q\delta = \int \frac{M_P M_Q}{EI}\,dx + \Sigma \frac{F_P F_Q L}{AE}\,(\to 0) + \Sigma F_Q \alpha \Delta t L\,(\to 0)$$

$$\Sigma Q\delta = \frac{1}{EI}\int_A^B 20x \cdot \frac{1}{3}x\,dx + \frac{1}{EI_2}\left\{\int_B^C \left(\frac{10+x}{3}\right)(200-10x)\,dx + \right.$$

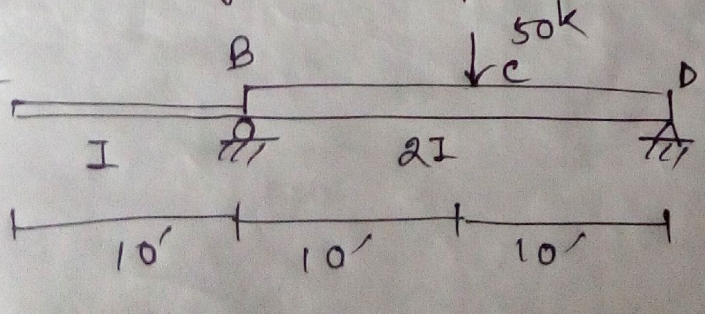
$$\Rightarrow \delta = 6944/EI$$

$$\therefore \delta = 0.166 \quad (\downarrow \text{ downward})$$

Assignment-11:

Find change in slope at "A" (for class figure)

Fig for ass-12



$E = 30 \times 10^3$ ksi

$I = 300$ in^4

Assignment - 12

Find ver. deflection at "A". Same fig. as previous page.

Assignment - 13

Find change in slope at "A".

Fig as assgnmnt - 12

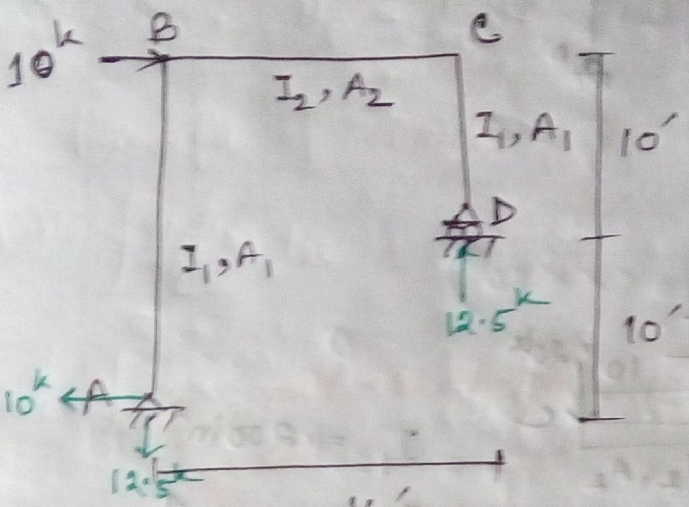
Assignment - 14

Find change in slope at "D"

Fig as assngmnt - 12

Frame

Problem-1



Compute hor. deflect^n at "B".

Given.

$I_1 = 300 in^4$

$I_2 = 200 in^4$

$E = 30 \times 10^3 ksi$

$A_1 = A_2 = 10 in^2$

Ans: a) $0.938'(\rightarrow)$ b) $0.9395'(\rightarrow)$

Two cases

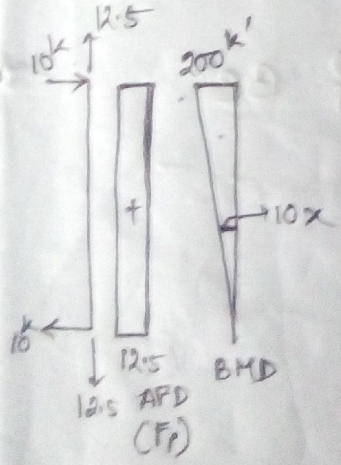
(a) Neglect Axial force effect

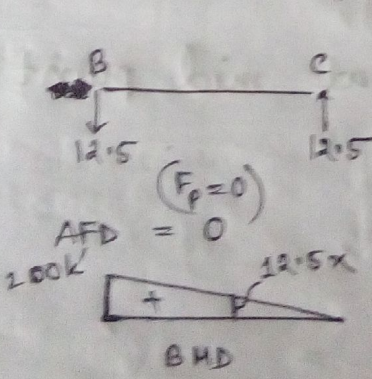
(b) include all effects.

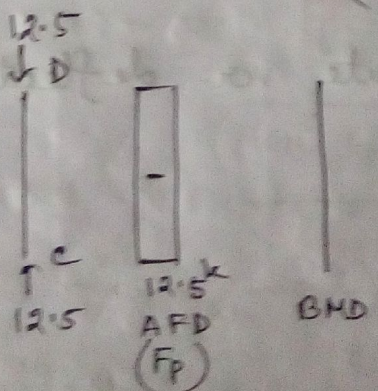
* (এখানে 10^k BC member-এ add হচ্ছে না কেন BC/CD member hor. load নিতে পারছে না। নিচ্ছে only AB. ⇓ So 10^k hor. load AB calculat^n-এ আসছে।)

$\Sigma M_A = 0 \; \curvearrowleft + \Rightarrow 10 \times 20 - R_{D_y} \times 16 = 0$

$\Rightarrow R_{D_y} = \frac{200}{16} = 12.5^k (\uparrow)$

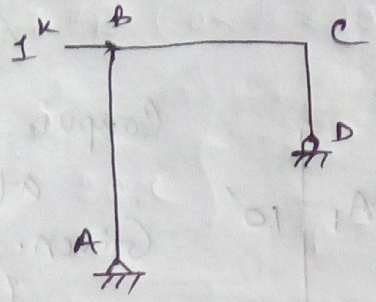




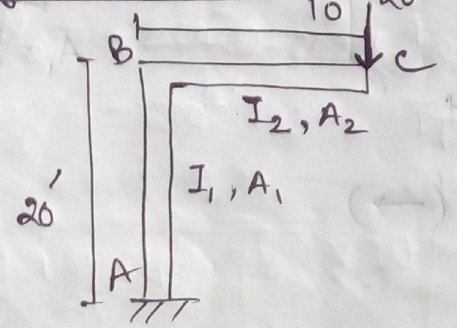


← Eye direct^n

* Complete the calculat^{n} for virtual load –



Assignment – 15



$I_1 = 200 \text{ in}^4$

$I_2 = 150 \text{ in}^4$

$A_1 = 15 \text{ in}^2$

$A_2 = 10 \text{ in}^2$

$E = 30 \times 10^3 \text{ ksi}$

Compute hor. deflect^{n} at "B".

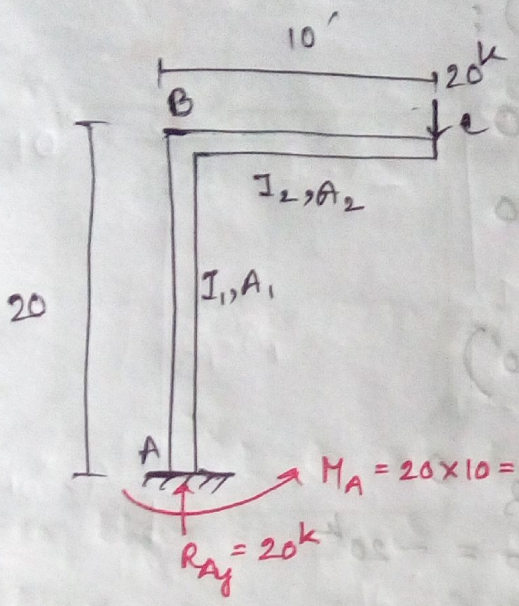
Assignment-16 ; change in slope at "C".

Ass – 17

Compute ver. deflect^{n} at mid point of BC.

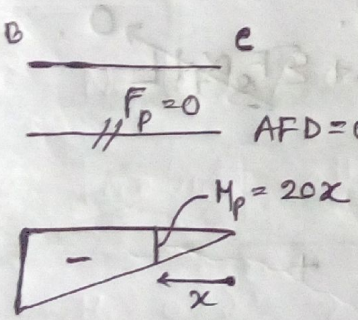
Assignment-15

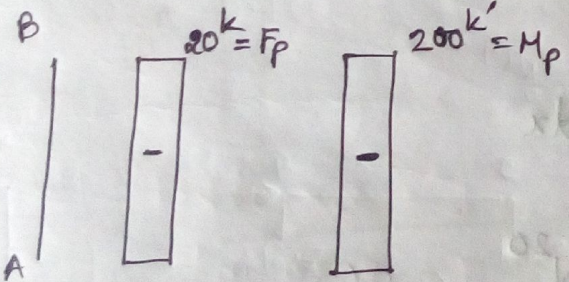
10.10.15



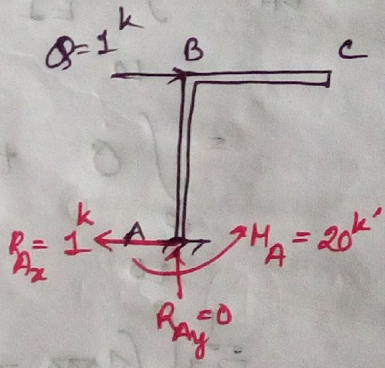
Find Hor. deflection at "B"

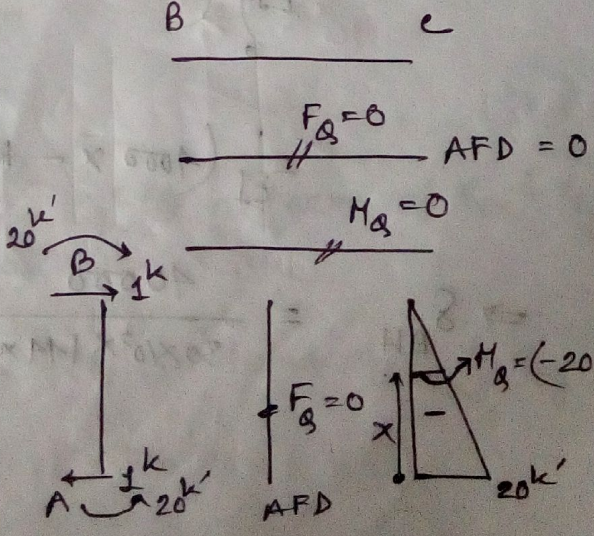
P-force Analysis





Q-force Analysis

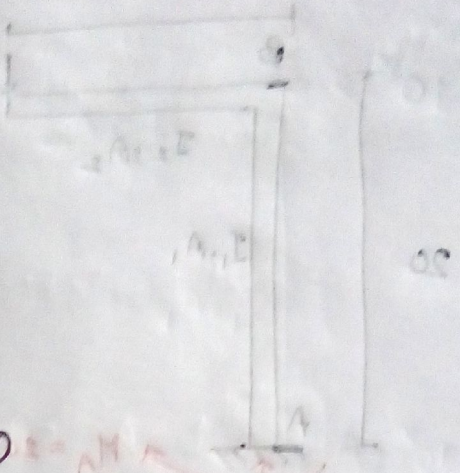




Segment CB $(0 < x \leq 10')$:

$M_Q = 0$ $\quad F_Q = 0$

$M_P = 20x$ $\quad F_P = 0$



Segment AB $(0 < x \leq 20')$

$M_Q = -200 - 20 + x$ $\quad F_Q = 0$

$M_P = -200^{k'}$ $\quad F_P = -20^{k}$

Using Principle of V.W. $\longrightarrow$

$$\Sigma Q\delta_{BH} = \int \frac{M_Q M_P}{EI} dx + \Sigma F_Q F_P \frac{L}{AE} + \Sigma F_Q \alpha_t t L$$

$$= \int_0^{10} 0 + \int_0^{20} 200(20-x)dx + \cdots$$

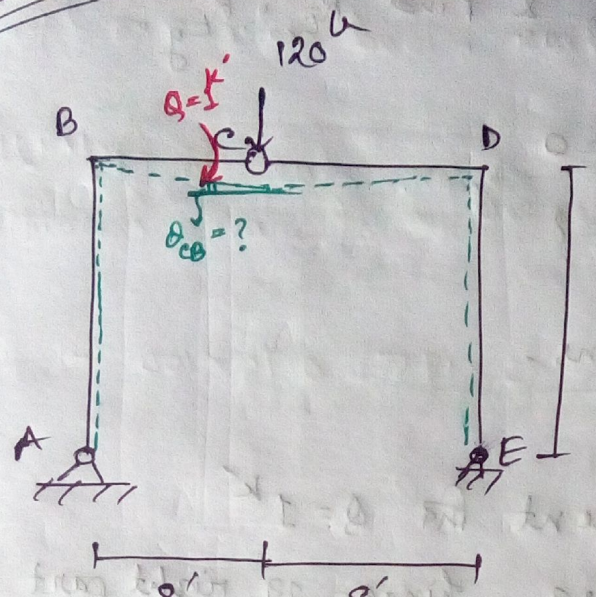
$$= \frac{1}{EI}\int_0^{20} (4000 - 200x)\,dx$$

$$= \frac{1}{EI}\left(4000x - 100x^2\right)\Big|_0^{20} = \frac{1}{EI}\left(4000\times 20 - 100\times 20^2\right)$$

$$\Rightarrow \delta_{BH} = \frac{40000}{30\times 10^3 \times 144 \times \frac{200}{144^2}} = \underline{0.96'}$$

Ans.

Example 8.7



$E = 30 \times 10^3$ ksi

$A = 20\ in^2$

$I = 2500\ in^4$

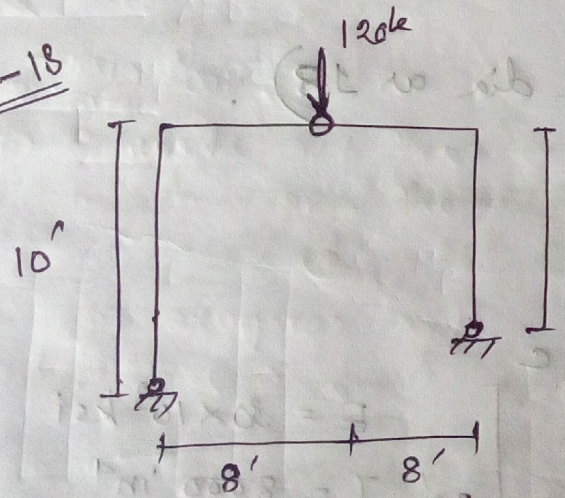
Compute change in slope for the cross-section on ~~depth~~ Left of hinge.

left বলতে AB না, BC part বোঝায়

⇓

unit moment দিব C - এ বামে C⁻ left of hinge বলা হচ্ছে

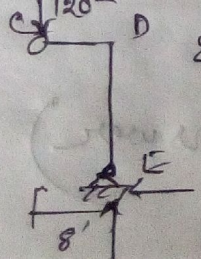
Assgn-18



Compute change in slope for the cross section on left of hinge.

Whole structure $\Sigma M_A = 0$ ⇒ Eq^n (1) in terms of R_{Ex} & R_{Ey}.

Hinge - এ বামে কাটব।



ΣM @ C = 0 ⇒ Eq^n (2) in terms of R_{Ex} & R_{Ey}.

Solve eq^n (1) & (2) & Find R_{Ex}, R_{Ey}.

$\left\{ \begin{array}{l} \Sigma F_x = 0 \\ R_{Ax} = ? \end{array} \right.$, $\left\{ \begin{array}{l} \Sigma F_y = 0 \\ R_{Ay} = ? \end{array} \right.$

Next diagrams.

⇓

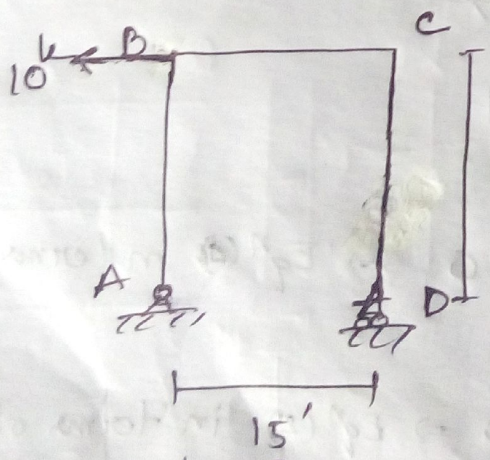
Then moment দিব $Q = 1^k$

In this case hinge-এর right part দিব না,
left part দিব। C এর right part-এ
moment নাই।

Assgn-19

$\delta_{BH} = ?$ (Same dia as 18).

Assgn-20



$E = 30 \times 10^3$ ksi

$I = 8000$ in^4

$A = 20$ in^2

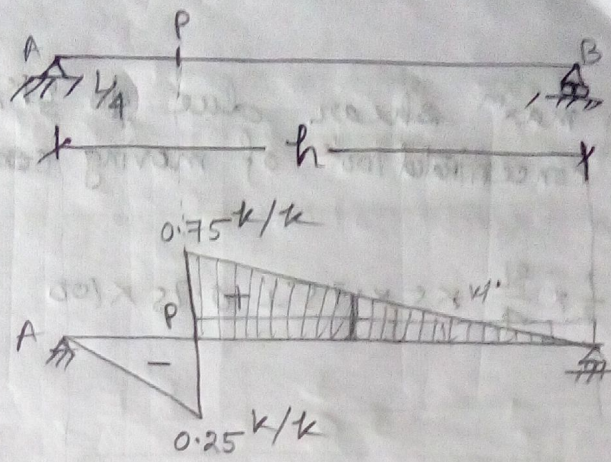
Find δ_{BH}, δ_{CH}, θ_B, θ_C

Chapter-8

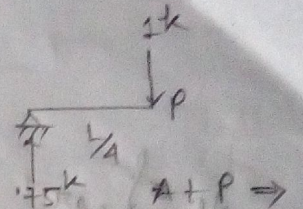
(See Excercise Problem with Answer)

11.10.15

• 1^k ⇒ moving unit load.



I Line for shear at quarter point from left support.



Q.(1) What is the maximum at quarter point due to moving 100k load of a wheel?

⇓

$= 0.75 \times 100^k = 75^k$.

↓

becz max^m is told.

⇓

max^m −ve shear বলতে

$.25^{k/k} \times 100^k = 25^k$ হবে.

Q.(2) What is the max^m shear at quarter point due to uniform moving load of $5^{k/ft}$. ?

⇓

load টি কোথায় place বসাতে হবে।

⇓

As uniform load, area of the IL dia. × Intensity of UDL

∴ Max^m shear $= \frac{1}{2} \times 3/4 \times 0.75^{k/k} \times 5^{k/'} = ?$ (+ve shear)

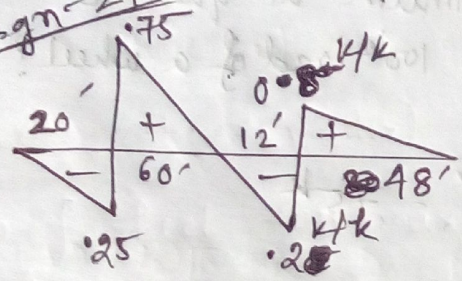
for max^m – ve shear, load place করব for AP.

Q(3) What is the max^m shear due to 5K/' UDL & concentrated 100^k of moving ~~concentrated~~ load.

$\therefore$ Max^m shear $= \frac{1}{2} \times \frac{3L}{4} \times 5 \times .75 + 0.25 \times 100 = \dots$ (+ve)

Example of IL for shear

Assgn-2



similar for -ve.

যেটা বড় আসবে 100^k বসাব

100^k যেকোন এক পাশে বসাতে পারব

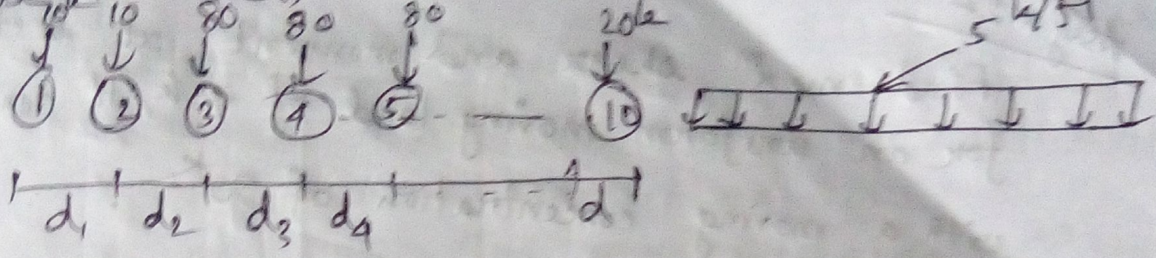
Q. (3) for this case ⇒ max^m +ve shear ও বের করব
max^m –ve " " " "

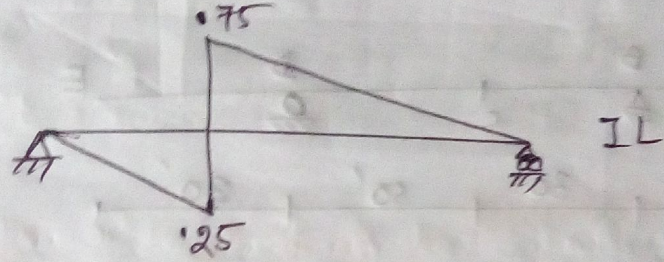
⇓

Then compare করে বলব কোনটা max^m ?

Assign Problem-2

Suppose 10 wheels





Trial 1

upto 7 ⇒ shear = wheel load × coordinate

from 8 to 10 ⇒ 0.

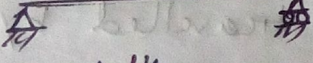
Trial 2: একেক অবস্থানে অবস্থানের load

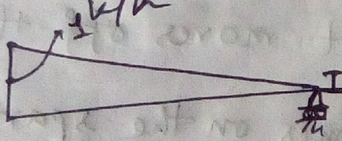
⇓

But it is very troublesome.

* best way ⇒ which wheel will give you max^m shear at quarter point?

Q. What is the max^m reaction at left support ~~for~~ this load of problem (2).



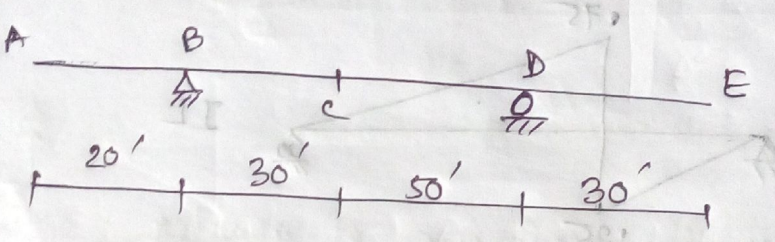


IL for left support reaction.

18.10.2015

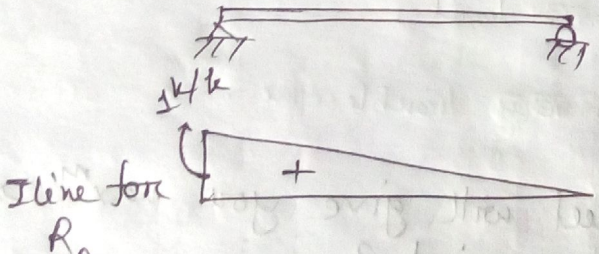
Asg # 22

Find max^m shear and moment at section C for an uniform moving load of 7 k/ft combined with a moving concentration of 90^k.



Art # 60 (Shedd Vowter)

- Position of wheel for max^m reaction of a simple beam :—



Due to a movement d_1 for a locomotive with series of loads,

Change in reaction

$$\Delta R = \frac{\Sigma P d_1}{L} - P_1 + \frac{P' e}{L}$$

where, ΣP = loads that stay on the span before & after ~~moment~~ movement

d_1 = distance travelled by ΣP

P_1 = load that moves off the span

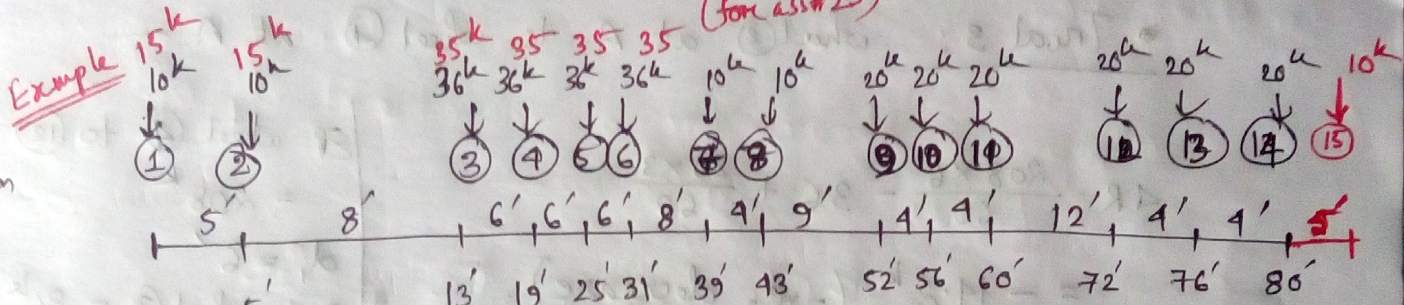
P' = load that comes on the span

e = distance travelled by P' on the span.

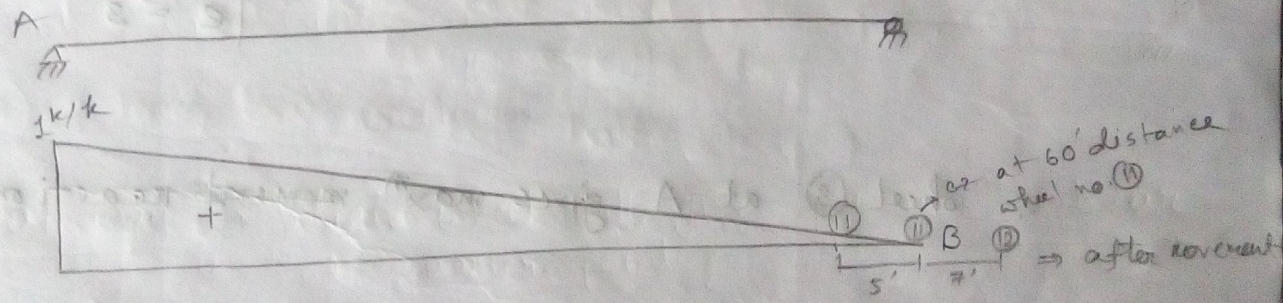
- Procedure :—

1. Place wheel (1) at A
2. Move wheel until wheel (2) at A and calculate ΔR.
3. If ΔR = −ve, then wheel (1) at A give max^m reaction.
4. If ΔR = +ve, move wheel (3) at A and calculate ΔR and repeat until ΔR = −ve.

Example (for assi#23)



Find max^m react^n for a simple span beam of 60'



- Trial no 1 :— wheel ① at A to wheel ② at A :—

$$\Delta R = \frac{\Sigma P d_1}{L} - P_1 + \frac{P' e}{L}$$

$$= \frac{234 \times 5}{60} - 10 + 0 = 9.5^k \text{ (+ve, increase)}$$

ΣP = wheel ② to wheel ⑪ = 234^k

$d_1 = 5'$

P_1 = wheel ① = 10^k

$P' = 0$

• Trial 2 : wheel ② at A to wheel ③ at A —

$$\Delta R = \frac{224 \times 8}{60} - 10 + \frac{20 \times 1}{60}$$

$$= 20.2^k \text{ (+ve, increase)}$$

ΣP = wheel ② to wheel ⑪

$= 224^k$

$d_1 = 8'$

P_1 = wheel ② $= 10^k$

P' = wheel ⑫ $= 20^k$

$e = 1'$

• Trial 3 : wheel ③ at A to wheel ④ at A —

$$\Delta R = \frac{208 \times 6}{60} - 36 + \frac{20 \times 3}{60}$$

$$= -14.2^k \text{ (-ve, decrease).}$$

ΣP = wheel ④ to ⑫

$= 208^k$

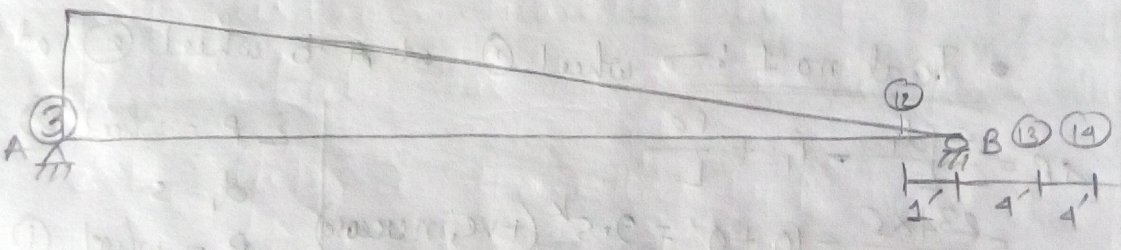
$d_1 = 6'$

P_1 = wheel ③ $= 36^k$

P' = wheel ⑫ $= 20^k$

$e = 3'$

∴ wheel ③ at A gives max^m ~~moment~~ reaction. Hence,



$$\therefore \text{Max}^{m} \text{ reaction} = \frac{1}{60}\left[60 \times 36^{k} + 54 \times 36^{k} + \cdots + 1 \times 20^{k}\right]$$

$$= 150.4^{k}$$

Assgn #23

Find max^{m} reaction of a simple beam of 70' span.

(Previous figure)