CE 120 – Spring 2023
Instructor: M.J. DeJong

Name:_______________________________

CE 120 – Structural Engineering

Mid-Term Examination No. 2

Instructions:

- Do not open the exam until instructed to do so.
- You may use a calculator and watch, but no other electronic devices are permitted.
- Do all problems. Show all relevant work.
- Start solutions alongside or immediately following problem statements. If additional space is required, insert additional sheets.
- Organize and write solutions neatly. Points may be taken off for messy solutions.
- Indicate units in final solutions. Points will be taken off if units are missing or signs are unclear.
- If you have any questions, or need any paper or other materials, walk to the front of the classroom and ask the instructor. Do not raise your hand to get the instructor's attention, and do not call out questions from your seat.

Please sign the following Honor Pledge before submitting your exam:

"I have neither given nor received aid during this examination. I have not concealed any violation of the Honor Code. I did not use any unapproved notes or electronic devices during the examination."

Signature: ____

Some potentially useful equations:

elongation, $e = TL/AE$
curvature, $\kappa = M/EI$

Internal work (axial load) = $T \cdot e$
Internal work (bending) = $\int M_x^* \kappa \, dx = \frac{1}{EI} A_m m_{x_m}^*$

$$L = L_0\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right), \text{US customary units}$$

L shall not be less than $0.5L_0$ for members supporting one floor; and
L shall not be less than $0.4L_0$ for members supporting two or more floors.

Possible Points	Score	
Problem 1	20	_____
Problem 2	10	_____
Problem 3	30	_____
Problem 4	40	_____
TOTAL	100	_____

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** The figures below show an elevation view and a plan view of a three-story building which is to be used for Problems 1 and 2. Note that the two braced frames on the north and south walls are identical, and that elevation A-A is similar for both the North and South sides of the building.

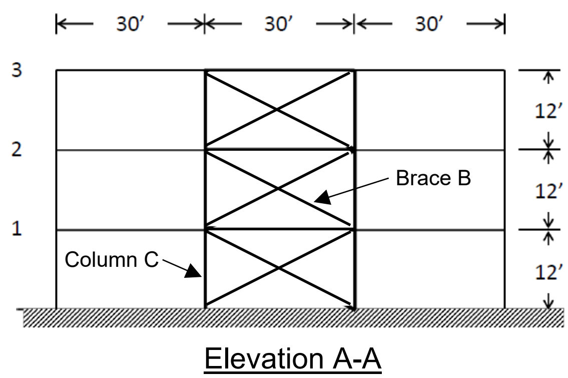

Figure 1

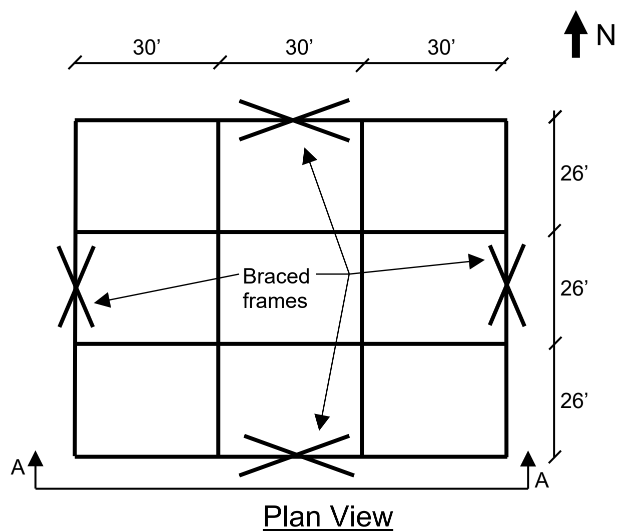

Figure 2

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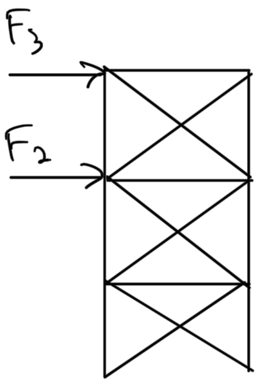
Problem 1 (20 points) – The enclosed building in Figure 1 needs to be designed for wind coming from the west. The design wind pressure on the leeward wall has been calculated to be 10 psf. The wind pressure on the windward wall has been calculated to vary as follows:

- Height = 0 to 12 feet, pressure = 15 psf
- Height = 12 to 24 feet, pressure = 20 psf
- Height = 24 to 36 feet, pressure = 25 psf

Calculate the force in 'Brace B', which is labelled in Figure 1.

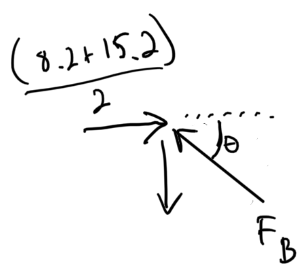
Note: For the X-bracing in Figure 1, assume that both braces are active. One will be in tension and the other in compression.



$$F_3 = \frac{(25+10)(78')(6')}{2} = \frac{16.4^k}{2} = 8.2^k$$

$$F_2 = \frac{(25+10)(78')(6') + (20+10)(78')(6')}{2} = \frac{30.4^k}{2} = 15.2^k$$

Brace force:



$$F_B \cos\theta = \frac{23.4}{2}$$

$$\hookrightarrow \boxed{F_B = 12.6 \text{ kips}}$$

Problem 2 (10 points) – Determine the design force in 'Column C', which is labelled in Figure 1, due to live load only. The design live load is 20 psf at the roof and 50 psf at all floors.

roof → $A_T = 30' \times 13' = 390 \text{ ft}^2$

floors → $A_T = 390 \text{ ft}^2 (2 \text{ floors}) = 780 \text{ ft}^2$

$$L = L_o \left(0.25 + \frac{15}{\sqrt{4 \times 780}}\right) = 0.51(L_o) \geq 0.4(L_o)$$

Design Live Load $= (20 \text{psf} \times 390) + (50 \text{psf} \times 0.51 \times 780)$

$= \boxed{27.8^k}$

Problem 3 (30 points) –The beam shown is subjected to a 2 klf dead load along its entire length. It is also subjected to a single point live load of 10 kips that can be applied anywhere, and a 3 klf live load which can be applied to any span, or to multiple spans. The spans are defined as segments AB, BC, and CD. All loads only act downwards.

(a) Draw the influence line for the shear just to the right of point C.

(b) Draw the influence line for the moment at point A.

(c) Determine the maximum magnitude (either positive or negative) of the moment at point A due to the dead and live loads.

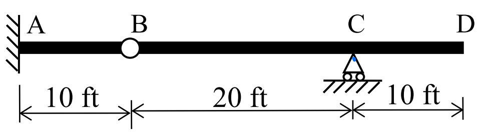
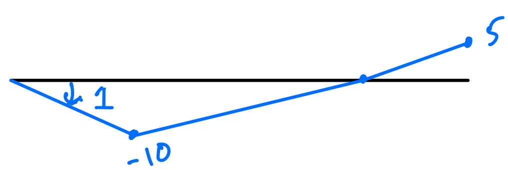


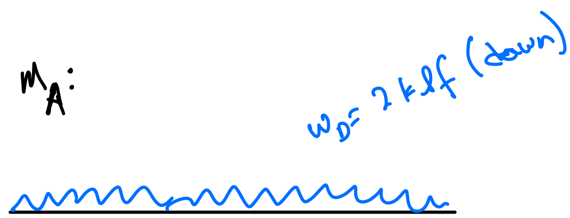
Figure 3

(a)

(b)



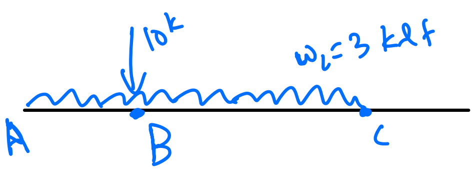
(c) DL for M_A:



$$M_A = 2\text{ klf}\left(-\tfrac{1}{2}\times 10\times 30 + \tfrac{1}{2}\times 5\times 10\right)$$

$$= -250 \text{ k-ft}$$

LL for M_A:
(worst case)



$$M_A = 3\text{ klf}\left(-\tfrac{1}{2}\times 10\times 30\right) - 10(10')$$

$$= -550 \text{ k-ft}$$

$$\left|M_{A_{max}}\right| = 800 \text{ k-ft}$$

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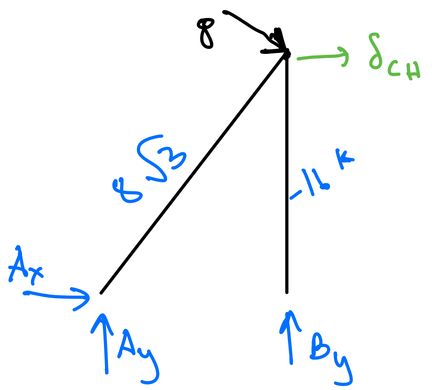
Problem 4 (40 points) – A pin-jointed truss is shown in Figure 4 with a load of 8 kips at point C. The axial stiffness of each member is EA = 10,000 kips.

For the loading shown, determine the horizontal displacement of point C.



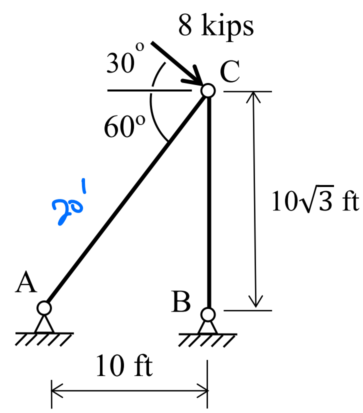


Figure 4

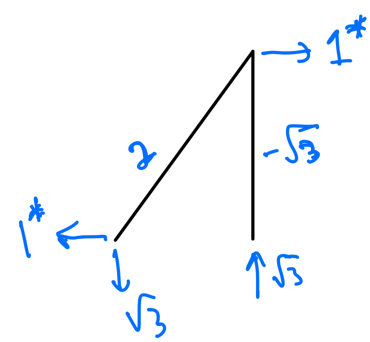
$\Sigma M_A = 0: \quad 8(20') = B_y(10') \rightarrow B_y = 16^k$

$\Sigma F_y = 0: \quad A_y + B_y = 8\sin 30° \rightarrow A_y = -12^k$

$\Sigma F_x = 0: \quad A_x = -8\cos 30° \rightarrow A_x = 6.9^k$

$T_{AC} = \sqrt{(12)^2 + (6.9)^2} = 13.9^k \; (= 8\sqrt{3})$

Virtual:



$$\delta W_{ext} = \delta W_{int}$$

$$1^* \; \delta_{CH} = \frac{(2^*)(13.85^k)(20')}{10{,}000^k} + (-\sqrt{3}^*)\frac{(-16^k)(10\sqrt{3}\,')}{10{,}000^k}$$

$$= 0.055 + 0.048'$$

$$\boxed{\delta_{CH} = 0.103' = 1.24''}$$