Department of Civil and Environmental Engineering, Fall Semester, 2024

ENCE 353 Midterm 1, Open Notes and Open Book

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Exam Format and Grading. This take home midterm exam is open notes and open book. You need to comply with the university regulations for academic integrity.

There are two questions. Partial credit will be given for partially correct answers, so please show all your working.

Please see the **class web page for instructions on how to submit your exam paper**.

Question	Points	Score
1	20	
2	20	
Total	40	

Question 1 (20 points): Support Reactions and Bending Moments in a Combined Beam/Truss Structure.

Consider the combined multi-span beam/truss structure shown in Figure 1.

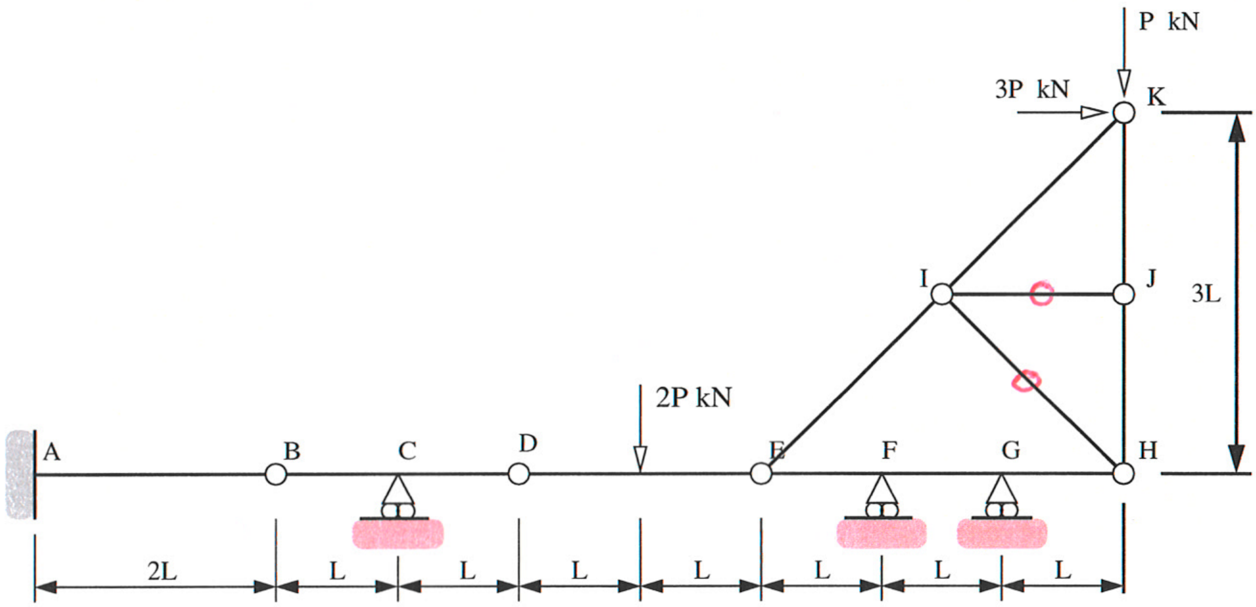


Figure 1. Front elevation view of multi-span beam structure.

The cantilever is fully-fixed to the wall at Point A. Points B, D and E are hinges. Horizontal and vertical point loads **3P** (kN) and **P** (kN) are applied to the truss as shown in Figure 1.

[1a] (2 pts). Compute the degree of indeterminacy for the articulated beam structure (A-B-C-D-E-F-G-H).

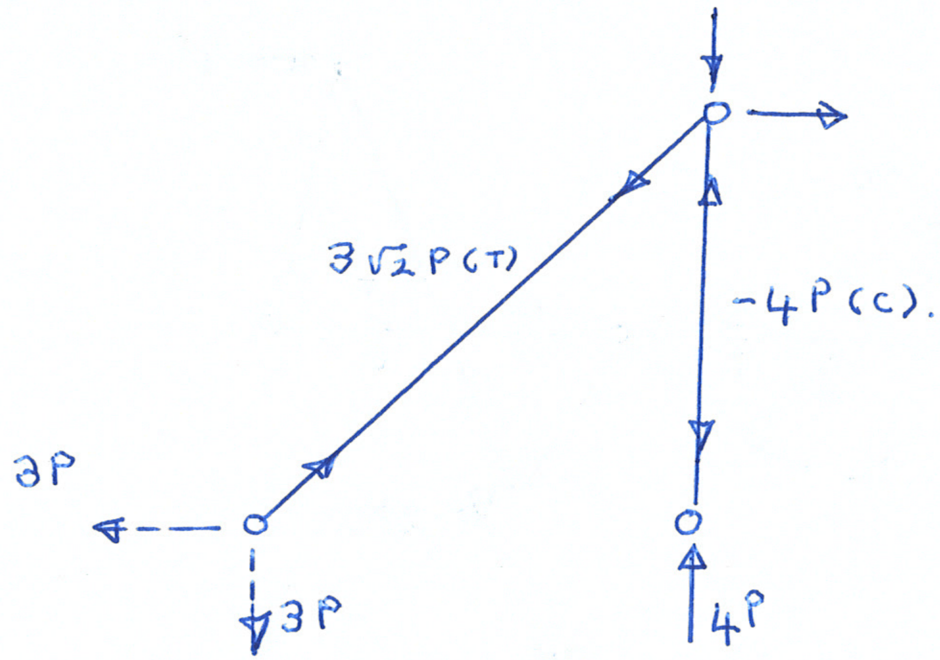
$\hat{i} = f - 3 - r$; $f = 6$, $r = 3$

$= 6 - 3 - 3 = 0$ ← statically determinate.

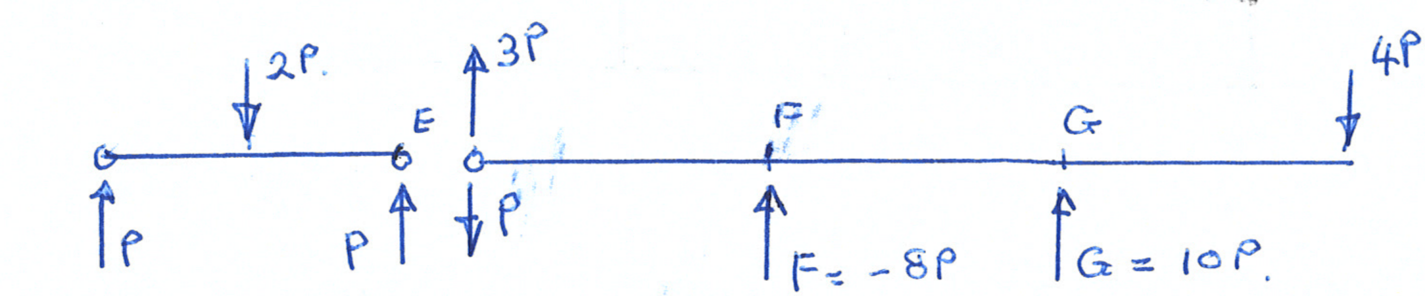
[1b] (3 pts). Identify the zero-force members in the truss structure. You can simply mark them up on Figure 1.

See red dots on Fig. 1.

[1c] (4 pts). Compute the distribution of forces throughout the truss structure. Draw a diagram summarizing your results.



[1d] (4 pts). Compute the vertical reaction forces at nodes F and G.



$\sum M_E = 0, \quad FL + G(2L) = (4P)3L$

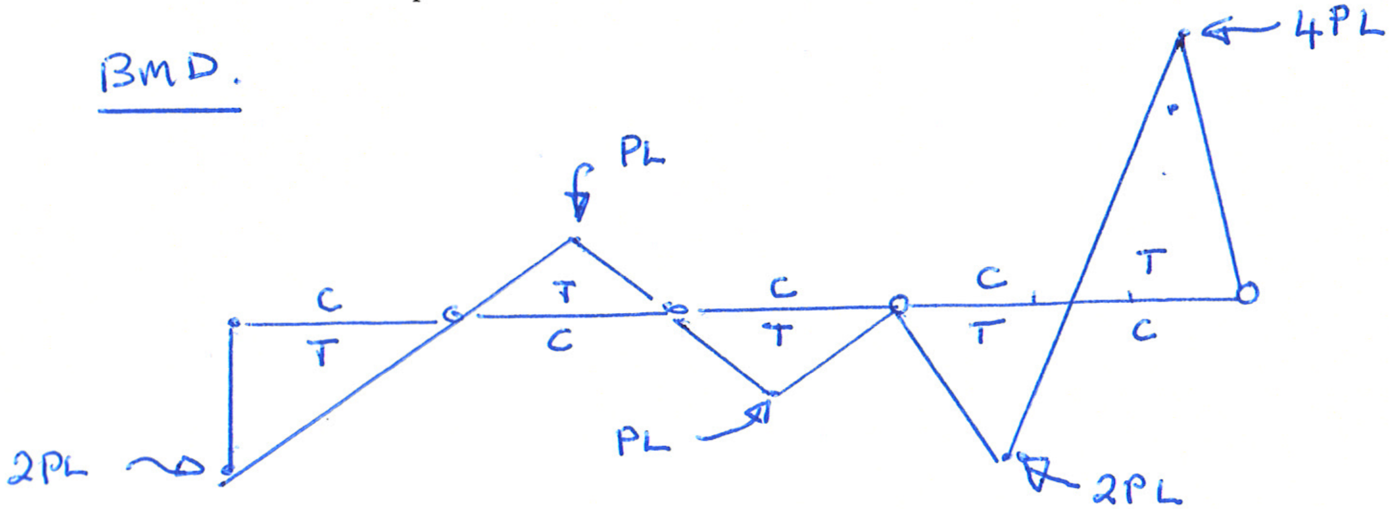
$\Rightarrow F + 2G = 12P$ ——— (A)

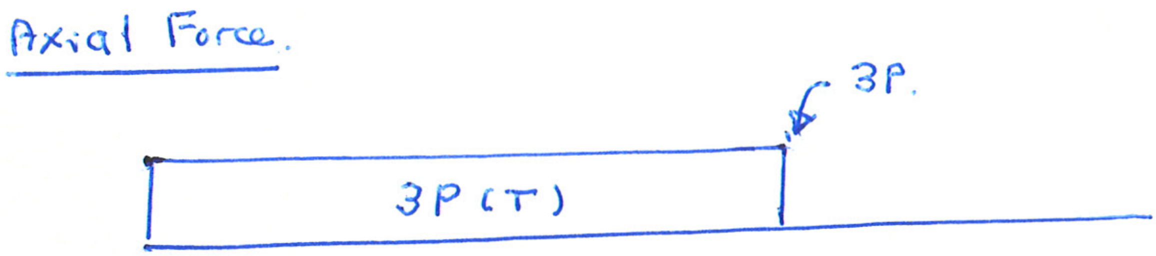
$\sum V = 0, \quad F + G + 2P = 4P$

$\Rightarrow F + G = 2P$ ——— (B)

From equations (A) & (B) $G = 10P, \; F = -8P.$

[1e] (7 pts). Draw and label diagrams showing how the **bending moment** and **axial force** vary along the beam, nodes A through H. Clearly indicate on your bending moment diagram, regions that are in tension/compression.





Question 2 (20 points): Analysis of a Leaning Tower Structure

Consider the leaning tower structure shown in Figure 2.

No joints = 7
No members = 11
No reactions = 3

m + r = 2j => Statically determinate.

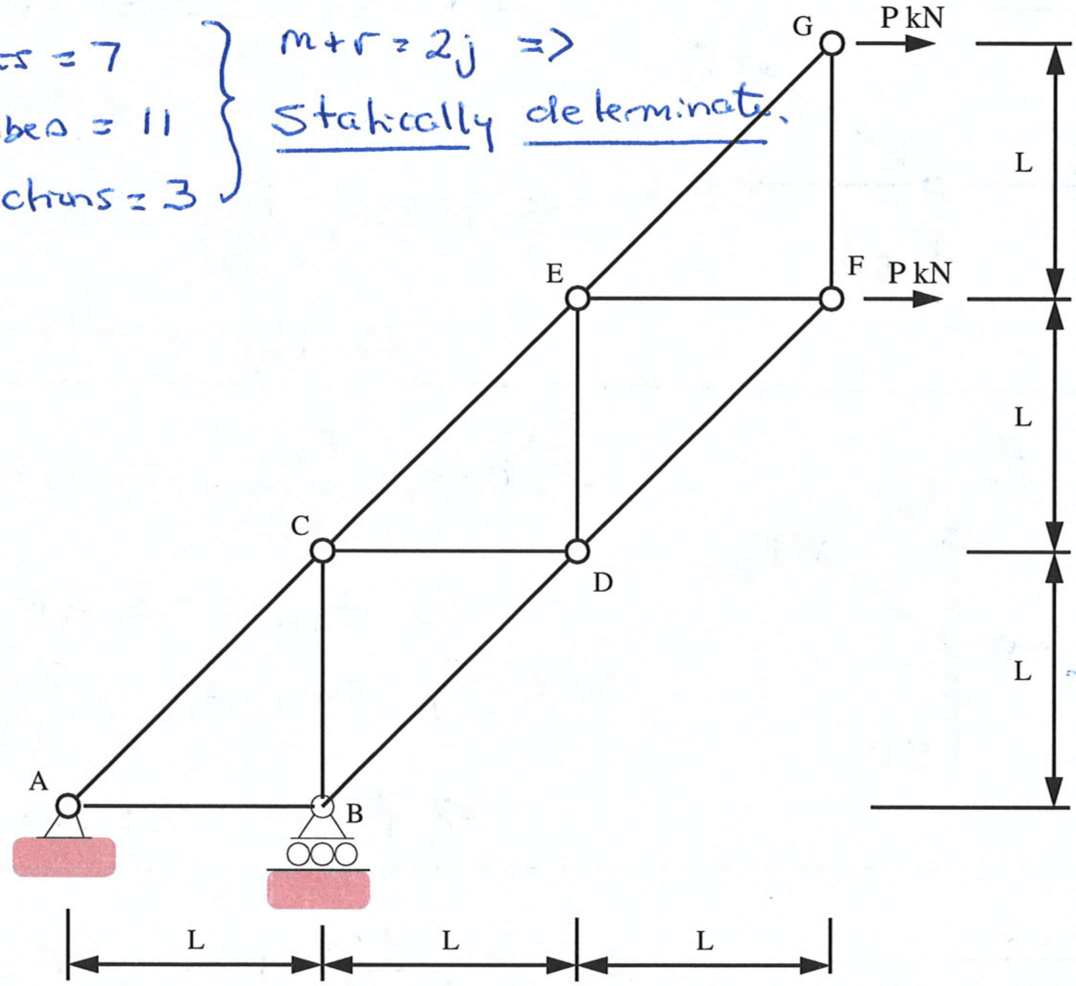


Figure 2. Elevation view of a leaning tower structure.

Horizontal loads **P** (kN) are applied at nodes F and G as shown in the figure.

[2a] (5 pts). Compute the **total support reactions** at A and B.

$\sum M_A = 0$ $\quad V_B \cdot L = 2PL + 3PL = 5PL$

$\Rightarrow V_B = 5P$

Total support reaction at A, $[2^2 + 5^2]^{1/2} P = \sqrt{29}$

Support (A)

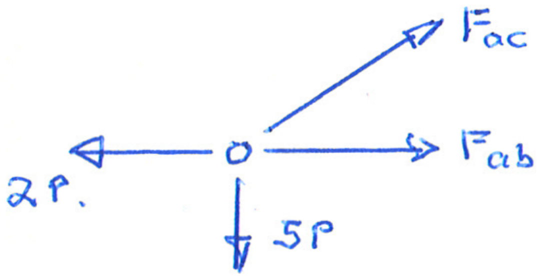
2P ← ; ↓ 5P

Support (B)

↑ 5P

[2b] (10 pts). Using the method of joints (or otherwise) compute the distribution of tension and compression forces throughout the structure. Show all of your working.

Node A.



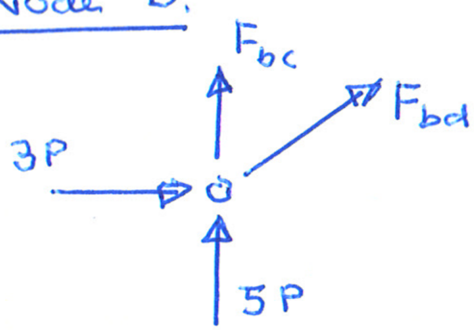
$\Sigma' V = 0, \quad \frac{F_{ac}}{\sqrt{2}} = 5P$

$\Rightarrow F_{ac} = 5\sqrt{2}\,P \text{ (T)}.$

$\Sigma' H = 0, \quad \frac{F_{ac}}{\sqrt{2}} + F_{ab} = 2$

$\Rightarrow F_{ab} = -3P \text{ (C)}.$

Node B.



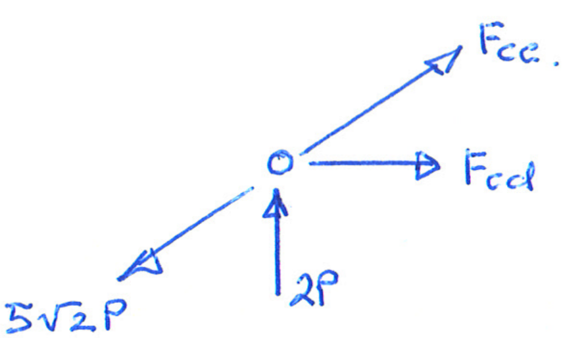
$\Sigma' H = 0, \quad \frac{F_{bd}}{\sqrt{2}} + 3P = 0$

$\Rightarrow F_{bd} = -3\sqrt{2}\,P \text{ (C)}.$

$\Sigma' V = 0, \quad 5P + F_{bc} - \frac{3\sqrt{2}}{\sqrt{2}}P = 0$

$\Rightarrow F_{bc} = -2P \text{ (C)}.$

Node C.



$\Sigma' V = 0, \quad \frac{F_{ce}}{\sqrt{2}} + 2P - 5P = 0$

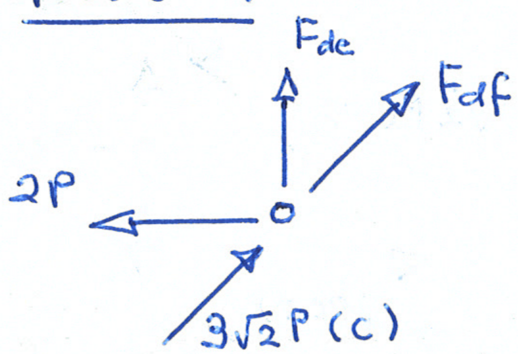
$\Rightarrow F_{ce} = 3\sqrt{2}\,P \text{ (T)}.$

$\Sigma' H = 0, \quad \frac{F_{ce}}{\sqrt{2}} + F_{cd} = \frac{5\sqrt{2}\,P}{\sqrt{2}}$

$\Rightarrow F_{cd} = 2P \text{ (T)}.$

Question 2b continued ...

Node D:



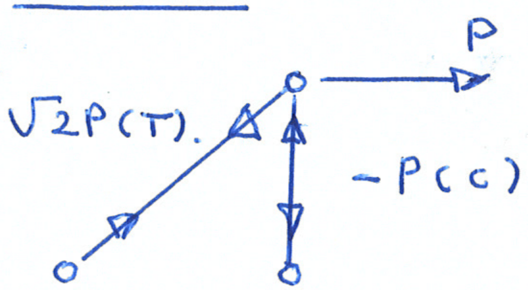
$\sum H = 0$ $\quad \frac{F_{df}}{\sqrt{2}} = 2P - \frac{3\sqrt{2}}{\sqrt{2}}P$

$\rightarrow$ $F_{df} = -\sqrt{2}P$(C).

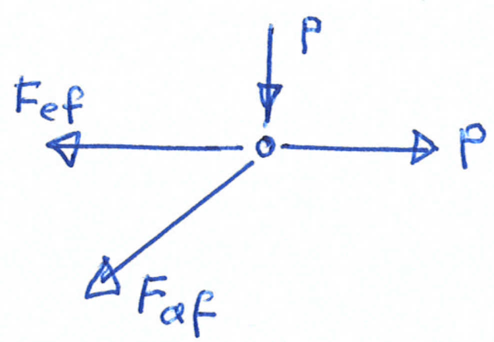
$\sum V = 0.$ $\quad F_{de} + \frac{F_{df}}{\sqrt{2}} + \frac{3\sqrt{2}}{\sqrt{2}}P = 0$

$\rightarrow$ $F_{de} = -2P$ (c).

Node G:



Node F:



$\sum V = 0$ $\quad P + \frac{F_{af}}{\sqrt{2}} = 0$

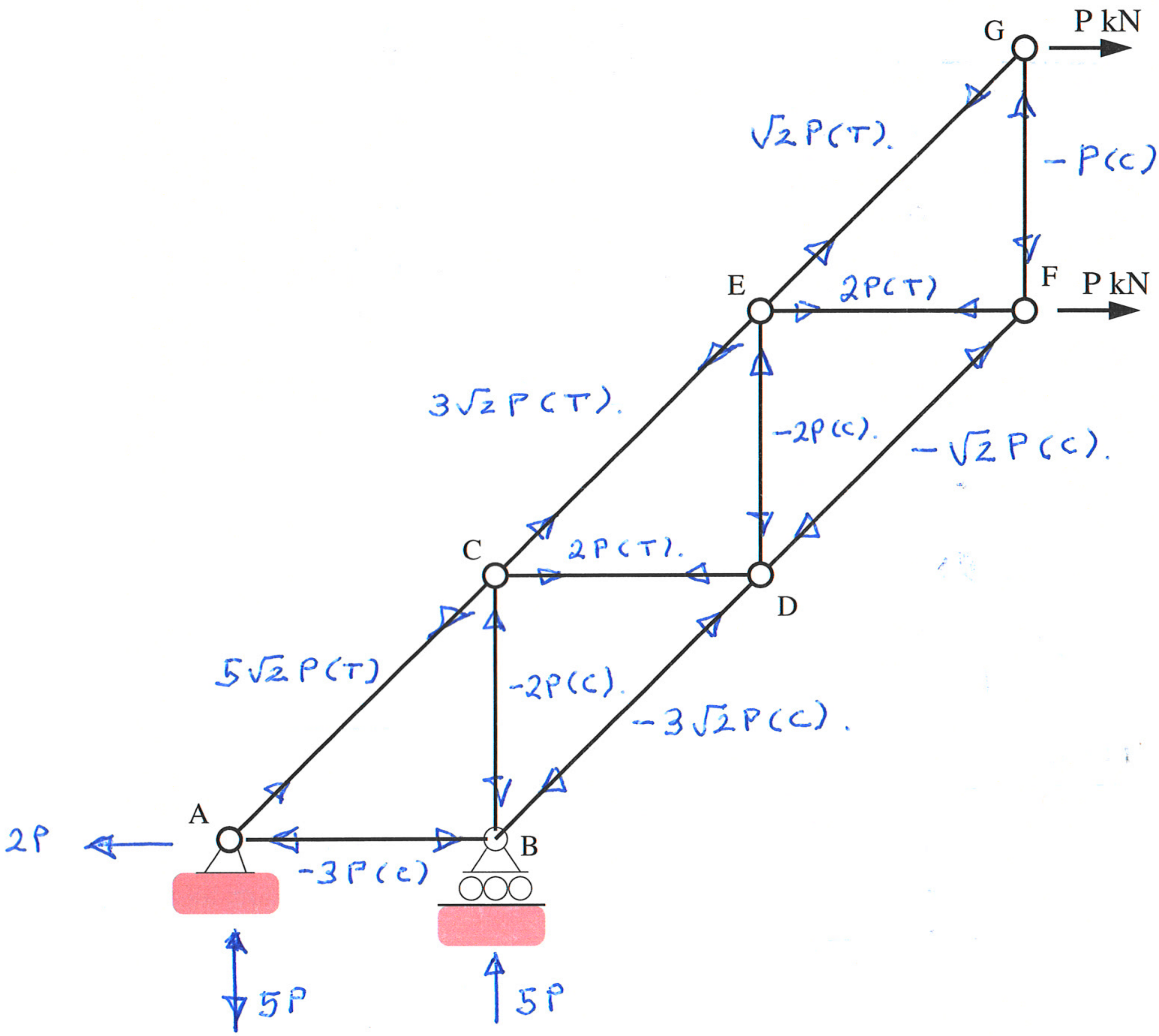
$\Rightarrow$ $F_{af} = -\sqrt{2}P$ (c).

$\sum H = 0$ $\quad F_{ef} + \frac{F_{af}}{\sqrt{2}} = P$

$\Rightarrow$ $F_{ef} = 2P$ (T).

Node E. $\sum V = 0$, $\sum H = 0$ $\rightarrow$ validate equilibrium.

To summarize, draw the distribution of tensile/compressive forces on this diagram:



[2c] (5 pts). Now suppose that the maximum tensile force any member can support is 10 kN, and that the maximum allowable compressive force is:

$$P_{ci} = 8\left(\frac{L}{L_i}\right)^2 kN, \tag{1}$$

where L_i is the length of the i-th element, and P_{ci} is the maximum allowable compressive force of the i-th element before buckling.

Determine the maximum value of P (kN) that the leaning tower can safely carry.

Maximum tensile force $= 5\sqrt{2}\,P$

" compressive force $= -3\sqrt{2}\,P$ in $\overline{BD}$

Limiting constraints:

Tension: $5\sqrt{2}P \leq 10$ kN. $\rightarrow P \leq \sqrt{2}P$. — (A)

Compression $3\sqrt{2}P \leq 8/2 = 4$ kN

$\rightarrow P \leq \dfrac{4}{3\sqrt{2}}$ kN. ——— (B)

Note: $\dfrac{4}{3\sqrt{2}} = \dfrac{4}{6}\sqrt{2} < \sqrt{2} \rightarrow$ compression case limits allowable load