6.1.1 Define these terms: a) truss, b) ideal truss, c) bar, d) joint, e) load, f) “bar force”, g) bar tension, h) bar compression, i) reaction, j) roller support and k) pin support.

Question 6.1.1: Define these terms: a) truss, b) ideal truss, c) bar, d) joint, e) load, f) “bar force”, g) bar tension, h) bar compression, i) reaction, j) roller support and k) pin support.

Solution:

a) Truss: In engineering and architecture, a truss refers to a structure made up of straight members connected at joints. Trusses are designed to provide stability and strength to support loads. They are commonly used in bridges, roofs, and other structures, where a strong and lightweight framework is required.

b) Ideal truss: An ideal truss is a simplified representation of a truss structure that assumes certain conditions for analysis. It is assumed that the members of an ideal truss are perfectly rigid and connected at joints without any friction. Additionally, ideal trusses are assumed to be loaded only at the joints and not along the members.

c) Bar: In the context of trusses, a bar refers to a straight structural member that forms part of the truss framework. Bars, also known as truss members or truss elements, can be made of materials such as steel, wood, or concrete.

d) Joint: A joint, in the context of trusses, is a point where two or more truss members are connected together. Joints are crucial as they provide the necessary support and transfer forces between the truss members. Common types of joints used in trusses include pin joints and welded joints.

e) Load: A load refers to the external forces and/or moments applied to a structure. These forces can include dead loads (the weight of the structure itself), live loads (e.g., people, furniture), environmental loads (e.g., wind, snow), and other types of loads.

f) ”Bar force”: The term ”bar force” generally refers to the internal force acting within a truss member. It represents the amount of tension or compression experienced by the bar due to the applied loads and the overall equilibrium of the truss structure.

g) Bar tension: Bar tension refers to the internal force experienced by a truss member when it is being stretched or elongated. Tension forces act along the axis of the member, pulling the ends of the bar away from each other. The magnitude of tension force depends on the applied loads and the characteristics of the truss geometry and materials.

h) Bar compression: Bar compression refers to the internal force experienced by a truss member when it is being compressed or shortened. Compression forces act along the axis of the member, pushing the ends of the bar towards each other. The magnitude of compression force depends on the applied loads and the truss's characteristics.

i) Reaction: In the context of trusses, reactions refer to the forces exerted on the supports or connections that hold the truss in place. These forces are a result of the equilibrium conditions required for a stable truss structure. Reaction forces can be either vertical or horizontal and are essential for calculating the internal forces within the truss members.

j) Roller supports are designed to allow unrestricted rotation and translation along the surface on which they are placed. The surface can be positioned horizontally, vertically, or at any inclined angle. As a result, the reaction force exerted by a roller support is a single force that is perpendicular to the surface and directed away from it. Roller supports are frequently employed at one end of extended bridges to facilitate smooth movement and accommodate the structural requirements.

k) A pin support is capable of withstanding both vertical and horizontal forces; however, it does not resist moments. It permits rotational movement of the structural member while preventing translation in any direction. Although in reality, some small amount of moment resistance may be present

6.1.2 Name as many positive attributes of trusses as you can.

Question 6.1.2: Name as many positive attributes of trusses as you can.

Solution:

1. Strength-to-Weight Ratio: Trusses offer excellent strength-to-weight ratios, meaning they provide high strength and load-bearing capacity while being relatively lightweight. This characteristic allows for the efficient use of materials in construction.

2. Structural Stability: Trusses provide exceptional structural stability. The triangular configuration resists deformation and minimizes the risk of buckling or failure under applied loads. This stability ensures the integrity and safety of the overall structure

3. Flexibility in Design: Trusses offer great design flexibility. They can be tailored to various span lengths, load conditions, and architectural requirements. Trusses can be customized to accommodate different building shapes, sizes, and aesthetic preferences.

4. Structural Efficiency: The triangular arrangement of members in a truss helps distribute loads evenly and minimizes the amount of material required to support those loads.

5. Clear Spans: Trusses enable the construction of large clear spans, which are uninterrupted spaces without the need for intermediate supports or columns. Clear spans are particularly advantageous in applications such as long-span bridges, exhibition halls, and sports arenas, as they provide open and flexible interior spaces.

6. Aesthetics: Trusses can contribute to architectural aesthetics by incorporating visually appealing designs and forms

6.1.3 Name as many negative attributes of trusses as you can.

5.1.3 Trusses have a few disadvantages which need to be kept into consideration when designing a system. They are:

a) They are relatively difficult to build as they comprise of many small parts and hence require time to assemble. Also, joining members at odd angles can some-times be difficult.

b) Trusses can be sensitive to damage when forces are not applied at the anticipated joints - especially if the load acts on the middle of the bar.

c) Trusses depend on the tension strength in some bars. Common building materials (concrete, stone, clay, etc.) crack easily when pulled.

d) They have little or no redundancy - failure in one part often leads to a catastrophic failure of the whole truss system.

e) Trusses are typically very stiff and do not flex under loads, making them unsuitable for applications where some flexure may be required - eg. vehicle frames.

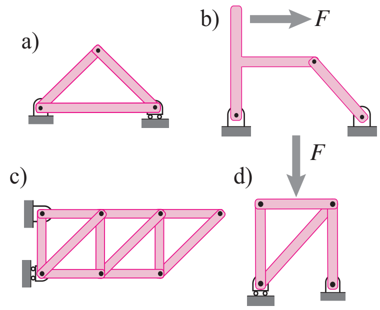
f) Trusses require diagonal members to make triangles. This often blocks clear space through the structure.

Question 6.1.3: Name as many negative attributes of trusses as you can.

Solution:

1. Trusses are relatively difficult to build, involving many small parts and thus requiring much time and effort to assemble.
2. Trusses can be sensitive to damage when forces are not applied at the anticipated joints. They are especially sensitive to loads on the middle of the bars.
3. Trusses inevitably depend on the tension strength in some bars. Some common building materials (e.g., concrete, stone, and clay) crack easily when pulled.
4. Trusses often have little or no redundancy, so failure in one part can lead to total structural failure.
5. The triangulation that trusses require can use space that is needed for other purposes (e.g., doorways, rooms).
6. Trusses tend to be stiff, and sometimes more flexibility is desirable (e.g., diving boards, car suspensions).
7. In some places, some people consider trusses unaesthetic. (e.g., the Washington Monument is not supposed to look like the Eiffel Tower).

6.1.4 Which of the structures below are trusses and which are not? Why not?

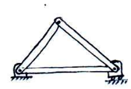


Problem 6.4

5.1.4

Which of the structures below are trusses?

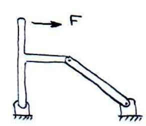
a)



A truss is a structure made from long narrow bars connected at their ends. Loads are applied at the joints.

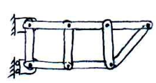
∴ Given structure in (a) is a truss if the loads are only applied at the pin joints.

b)



An ideal truss is an assembly of two-force members. Given structure has force 'F' applied at the tip of a member, which does not result in two-force members. Hence, the structure is not a truss.

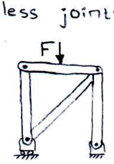
c)



A truss is a collection of bars connected at frictionless joints at which loads are applied.

∴ Given structure is a truss if the loads are applied at the frictionless joints.

d)



The force, in the given structure, is acting on a member but not at a joint, which would not result in two-force members.

∴ The given structure is not a truss.

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6.1.5 Consider this formula

$$b + r = 2j$$

a) What do b, r, and j stand for?
b) What is the use of this formula?
c) What is the source of this formula?

Question 6.1.5: Consider this formula:

$$b + r = 2j$$

a) What do b, r, and j stand for?

b) What is the use of this formula?

c) What is the source of this formula?

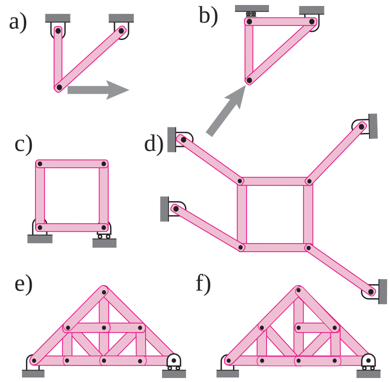
Solution:

a) j is the number of joints, including joints at reaction points. b is the number of bars, and r is the number of reaction components that appear on a free-body diagram of the whole structure. Specifically, there are 2 reaction components from pin joints and 1 from a pin on a roller.

b) The use of this formula is to determine whether the truss is statically determinate or not. If $2j > b + r$, the structure is necessarily not rigid (over-determinate) because there are more equations than unknowns. If $2j < b + r$, the structure is redundant because there are not as many equations as unknowns. In this case, if the equations can be solved, there is more than one combination of forces that solves them. A structure that is both rigid and redundant always has $2j < b + r$. Nonrigid redundant structures can have $2j < b + r$, $2j = b + r$, or $2j > b + r$. A structure which has $2j = b + r$ is statically determinate, where it is rigid and non-redundant.

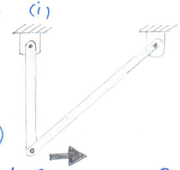
c) The source of this formula is by counting the total number of joint equations, which is two for each joint. By comparing this count to the number of unknown bar forces and reactions.

6.1.6 For each of the trusses below: **i)** What are b, j, and r? **ii)** What does the formula $b + r = 2j$ tell you ?



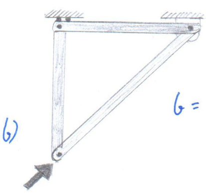
Problem 6.6

5.1.6 (i)



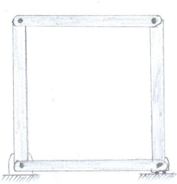
a)

$b=2;\ r=4;\ j=3$



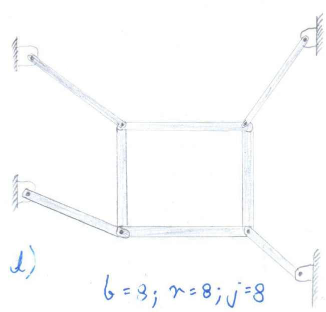
b)

$b=3;\ r=3;\ j=3$



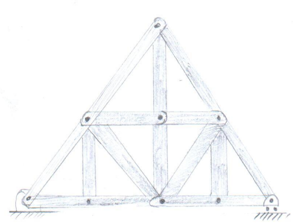
c)

$b=4;\ r=3\ ;\ j=4$



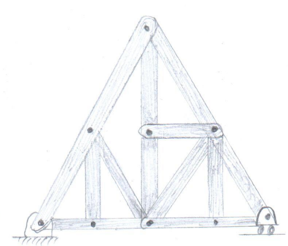
d)

$b=8;\ r=8;\ j=8$



e)

$b=16;\ r=3;\ j=9$



f)

$b=15;\ r=3;\ j=9$

(ii) The relation $b+r=2j$ tells us if the system is statically determinate or not. If the relation satisfies, then the system is determinate; if not, it isn't.

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Question 6.1.6: For each of the trusses below:

i) What are b, j, and r?

ii) What does the formula b + r = 2j tell you?

Solution:

a) i)

b	2
j	3
r	4

ii)

$$2j = b + r$$

$$2(3) = 4 + 2$$

Hence, the truss is Statically determinate, since 2j= b + r and the Truss is Rigid and Non-redundant.

b) i)

b	3
j	3
r	3

ii)

$$2j = b + r$$

$$2(3) = 3 + 3$$

Hence, the truss is Statically determinate, since 2j= b + r and the Truss is Rigid and Non-redundant.

c i)

b	4
j	4
r	3

ii)

$$2j = b + r$$

$$2(4) \neq 4 + 3$$

Hence, the truss is not statically determinate, since $2j \neq b + r$ and the truss is non-rigid.

d i)

b	8
j	8
r	8

ii)

$$2j = b + r$$

$$2(8) = 8 + 8$$

Although $2j = b + r$ but the truss is non-rigid and redundant hence it is not statically determinate.

e i)

b	16
j	9
r	3

ii)

$$2j = b + r$$

$$2(9) \neq 16 + 3$$

Hence, the truss is not statically determinate, since $2j \neq b + r$ and the truss is Redundant.

f i)

b	15
j	9
r	3

ii)

$$2j = b + r$$

$$2(9) = 15 + 3$$

Hence, the truss is Statically determinate, since 2j= b + r and the Truss is Rigid and Non-redundant.

6.1.7 For a given truss you are told values for b, j, and r.

a) When solving the truss how many unknowns are you trying to solve for?

b) How many independent scalar equations do you have from using the method of joints on the whole structure?

Question 6.1.7: For a given truss you are told values for b, j, and r.

a) When solving the truss how many unknowns are you trying to solve for?

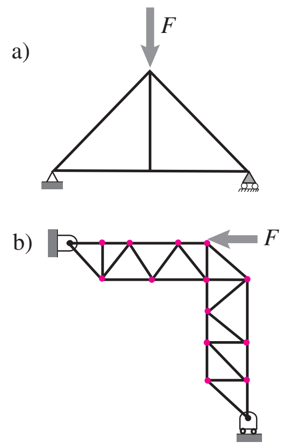
b) How many independent scalar equations do you have from using the method of joints on the whole structure?

Solution:

a) When solving a truss, the tensions in bars and the reaction forces are unknown. Hence the no of unknowns you are trying to solve for is b+r.

b) Each joint yields two equations in a 2D truss, one for the x-component and one for the y-component. Hence, there are 2j independent scalar equations from using the method of joints on the whole structure.

6.1.8 Find the zero-force members in the trusses below.

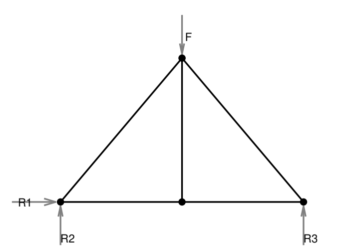


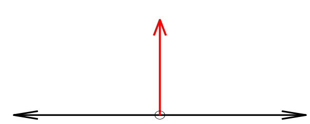
Problem 6.8

Question 6.1.8: Find the zero-force members in the trusses below

Solution:

a) The bar in red colour is a zero-force member since it's the only bar contributing a force in the y-direction.





b) The red-coloured members in the given truss represent zero-force members, and all the conditions for zero-force members apply to this truss.

1

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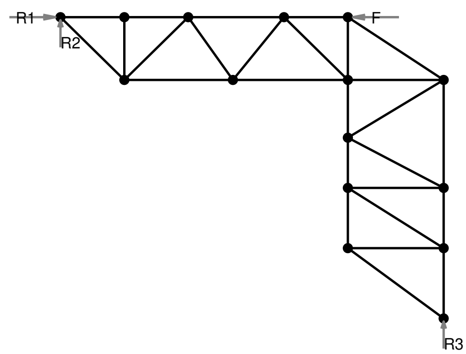

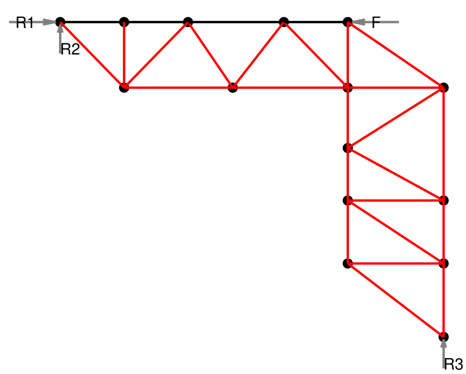

2

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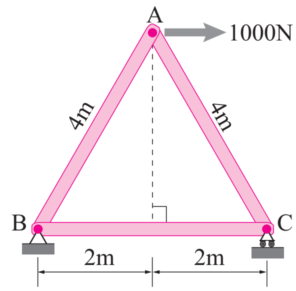
6.1.9 What is the tension in bar AC.

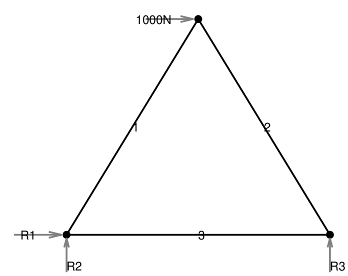


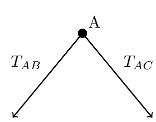
Problem 6.9

Answer:
$T_{AC} = -1000\,\mathrm{N}$, (AC is in compression)

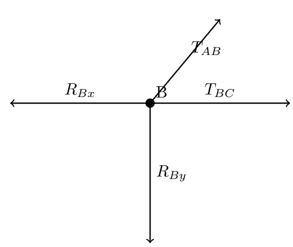
Question 6.1.9: Find T_{AC}

Solution:



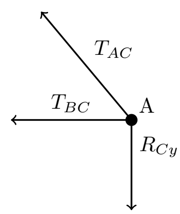


$$-0.5T_{AB} + 0.5T_{AC} + 1000N = 0$$
$$-0.8660T_{AB} - 0.8660T_{AC} = 0$$



$$0.5T_{AB} + T_{BC} + R_{Bx} = 0$$
$$0.8660T_{AB} + R_{By} = 0$$

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*



$$-0.5T_{AC} - T_{BC} = 0$$
$$0.8660T_{AC} + R_{Cy} = 0$$

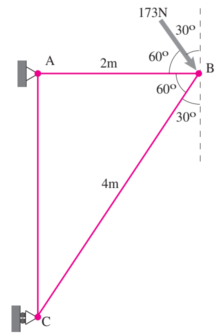
$$\begin{bmatrix} -0.5 & 0.5 & 0 & 0 & 0 & 0 \\ -0.866 & -0.866 & 0 & 0 & 0 & 0 \\ 0.5 & 0 & 1 & 1 & 0 & 0 \\ 0.866 & 0 & 0 & 0 & 1 & 0 \\ 0 & -0.5 & -1 & 0 & 0 & 0 \\ 0 & 0.866 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} T_{AB} \\ T_{AC} \\ T_{BC} \\ R_{Bx} \\ R_{By} \\ R_{Cy} \end{bmatrix} = \begin{bmatrix} 1000N \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

The reduced row echelon form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} T_{AB} \\ T_{AC} \\ T_{BC} \\ R_{Bx} \\ R_{By} \\ R_{Cy} \end{bmatrix} = \begin{bmatrix} 1000 \\ -1000 \\ 500 \\ -1000 \\ -866.025403784439 \\ 866.025403784439 \end{bmatrix}$$

T_{AC} represents the tension in Bar AC, which is -1000N, implying that the bar is under compression and the tension is -1000N.

6.1.10 The only force acting on the negligible-weight truss ABC is the 173 N force shown. Find the tension in the bar AB.



Problem 6.10

Answer:
$T_{AB} = 173\,\mathrm{N}$

Question 6.1.10: Find the tension in the bar AB.

Solution:

Since there are 3 Joints, the truss will have 6 equations, and 6 unknowns (3 bar tensions, 3 reaction forces).

We will form a 6*6 matrix to find the tension in Bar AB, using the 6 equations.
The equations are formed by summing all the components in one direction and equating them to zero at a joint.

The x-component of the external force is $173\cos(60°)$, and the y-component is $-173\sin(60°)$.
The first 2 Equations will be from Joint A, the next 2 from Joint B and the last 2 from Joint C.

$$T_1 + R_1 = 0 \tag{1}$$
$$-T_3 + R_2 = 0 \tag{2}$$
$$-T_1 - 0.9187 \cdot T_2 + 86.5N = 0 \tag{3}$$
$$-0.395 \cdot T_2 - 149.82N = 0 \tag{4}$$
$$0.9187 \cdot T_2 + R_3 = 0 \tag{5}$$
$$0.395 \cdot T_2 + T_3 = 0 \tag{6}$$

Now we will create a 6 by 6 by using these equations.

$$\begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 1 & 0 \\ -1 & -0.9187 & 0 & 0 & 0 & 0 \\ 0 & -0.395 & 0 & 0 & 0 & 0 \\ 0 & 0.9187 & 0 & 0 & 0 & 1 \\ 0 & 0.395 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ R_1 \\ R_2 \\ R_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -86.50N \\ 149.82N \\ 0 \\ 0 \end{bmatrix}$$

Now by finding the reduced row echelon form (RREF), we can obtain the values of the 6 unknowns.

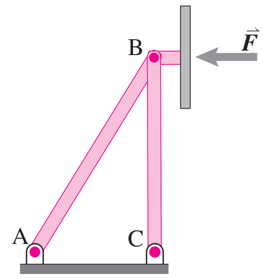
$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ R_1 \\ R_2 \\ R_3 \end{bmatrix} = \begin{bmatrix} 434.92N \\ -379.27N \\ 149.82N \\ -434.92N \\ 149.82N \\ 348.42N \end{bmatrix}$$

T_1 represents the tension in Bar AB, which is 435N, implying that the bar is under tension and the tension is 435N.

1

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

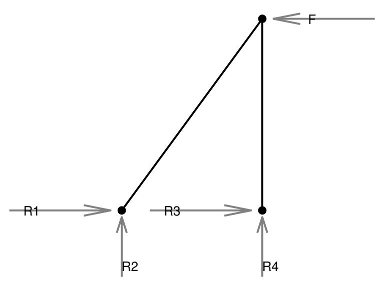
6.1.11 A billboard is supported by a two bar truss as shown in the figure. The two bars have pin joints at A, B, and C. Angle ABC is 30°. The total wind load on the board is estimated to be 300 N, find the forces in bars AB and BC.



Problem 6.11

Question 6.1.11: A billboard is supported by a two bar truss as shown in the figure. The two bars have pin joints at A, B, and C. Angle ABC is 30. The total wind load on the board is estimated to be 300 N, find the forces in bars AB and BC

Solution:



$$0.5T_1 + R_1 = 0 \quad (1)$$
$$0.8660T_1 + R_2 = 0 \quad (2)$$
$$-0.5T_1 - 300N = 0 \quad (3)$$
$$-0.8660T_1 - T_2 = 0 \quad (4)$$
$$R_5 = 0 \quad (5)$$
$$T_2 + R_6 = 0 \quad (6)$$

In the following equations, Bar AB is T_1 and BAR BC is T_2

1

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The matrix representation of the equations is:

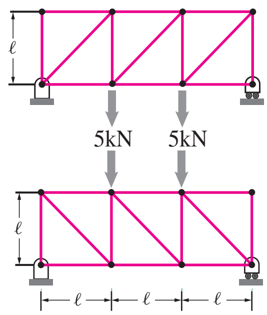
$$\begin{bmatrix} 0.5 & 0 & 1 & 0 & 0 & 0 \\ 0.8660 & 0 & 0 & 1 & 0 & 0 \\ -0.5 & 0 & 0 & 0 & 0 & 0 \\ -0.8660 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ R_1 \\ R_2 \\ R_3 \\ R_4 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 300N \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Now by finding the reduced row echelon form (RREF), we can obtain the values of the 6 unknowns.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ R_1 \\ R_2 \\ R_3 \\ R_4 \end{bmatrix} = \begin{bmatrix} -600N \\ 519.62N \\ 300N \\ 519.62N \\ 0N \\ -519.62N \end{bmatrix}$$

The tension in rod AB is: 600N and the Rod is under compression
The tension in rod BC is: 519.62N and the Rod is under tension

6.1.12 Find the support reactions for the two trusses without any (written) calculations. Should the support reactions be different? Why?



Problem 6.12

Question 6.1.12: Find the support reactions for the two trusses without any (written) calculations. Should the support reactions be different? Why?

Solution:

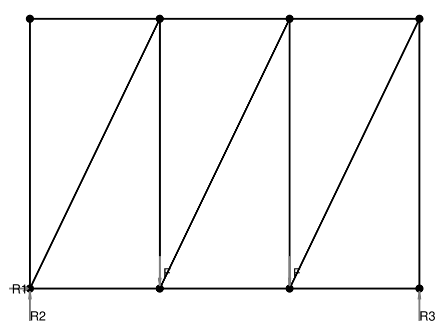


Figure 1: Truss system 1

In the truss system shown in Figure 1, the support tensions at points R2 and R3 will both be 5 kN. This is because the entire truss structure is in equilibrium, meaning that the bar tension balances out the internal forces. The reaction force balances out the external forces applied to the truss. Since the external force is 10 kN, each support will experience half of that force, resulting in a tension of 5 kN at each support point.

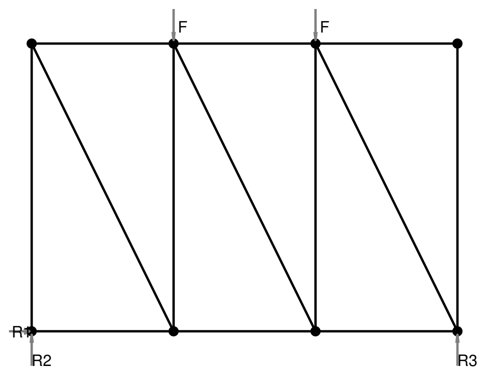
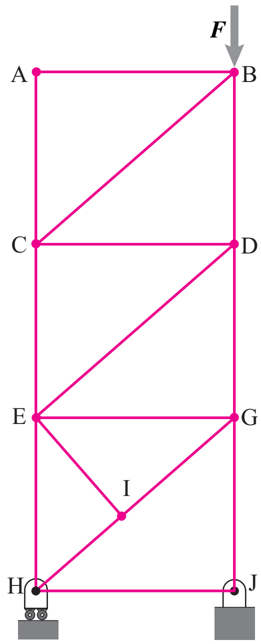


Figure 2: Truss system 2

In Figure 2, the same logic applies, and the reaction forces will still be 5 kN only. Hence, the support reactions should not be different.

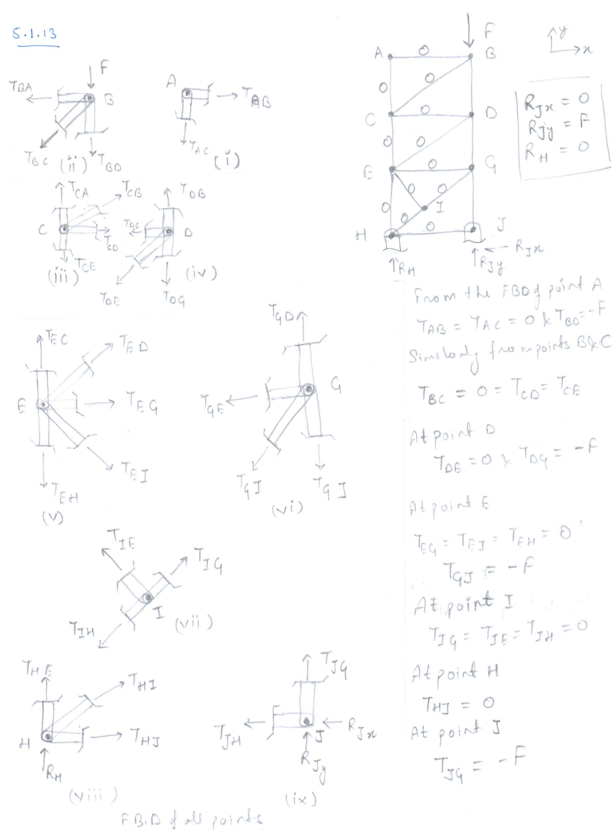
Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

6.1.13 Sketch the truss below. Write a big clear zero on top of each of the zero-force members.



Problem 6.13

Answer:
12 of the 15 bars are zero-force members; all but BD, DG, and GJ. The others carry no load but are needed for stability.



Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

Question 6.1.13: Sketch the truss below. Write a big clear zero on top of each of the zero-force members.

Solution:

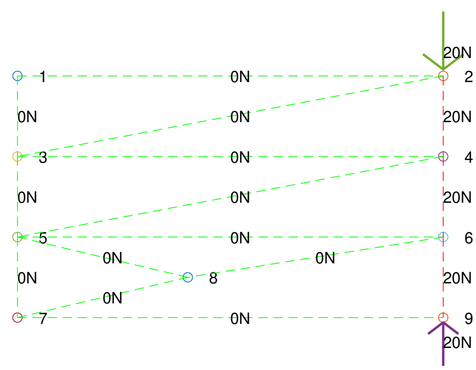


Figure 1: Truss system

The green-coloured members in the given truss represent zero-force members.

Zero-Force Members:

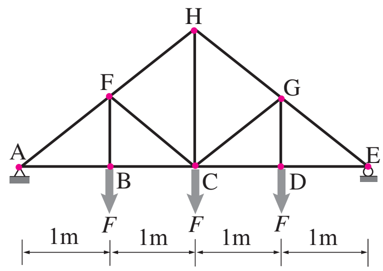
- At any joint where
  - there are no loads, and
  - where there are only two unknown non-parallel bar forces, and
  - where all known bar tensions are zero,

  then the two new bar tensions are both zero
- At any joint where all bars but one are in the same direction as the applied load (if any), the one bar is a zero-force member.

In the given structure, a single force of 20N acts downward on the entire truss. As a result, the vertical line of the truss experiences a 20N force, while the other members of the truss experience no force.

Although zero-force members carry no load they prevent structural collapse. A common use of zero-force members is to brace long bars that are in compression and which would otherwise buckle (pop out to one side).

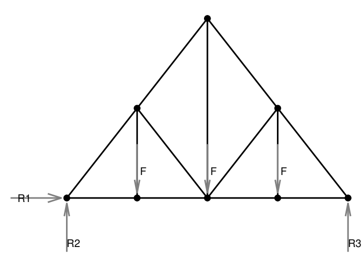
6.1.14 Find the support reactions on the truss shown in the figure taking $F = 5\,\text{kN}$.



Problem 6.14

Question 6.1.14: Find the support reactions on the truss shown in the figure taking F = 5 kN

Solution:

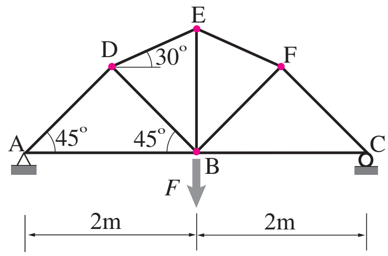


The total external force acting on the truss in the y-direction is 15 kN, and there is no external force acting in the x-direction. Therefore, the value of R_1 will be 0 N. The 15 kN external force will be balanced by the support reactions R_2 and R_3. Consequently, both R_2 and R_3 will be 7.5 kN each.

Furthermore, it is crucial to note that the internal bar tension forces within the truss will equilibrate internally, ensuring a state of balance within the structure.

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

6.1.16 How do the support reactions on the truss shown in the figure change if the load at point B is replaced by three equal loads, $F/3$ each, acting at points D, E, and F?



Problem 6.16

Question 6.1.16: How do the support reactions on the truss shown in the figure change if the load at point B is replaced by three equal loads, F/3 each, acting at points D, E, and F?

Solution:

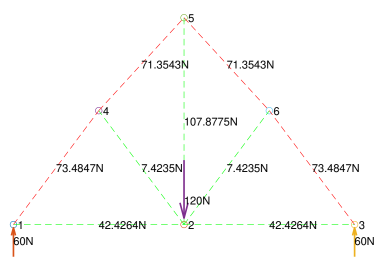


Figure 1: Truss system 1

In the truss system shown in Figure 1, the tension forces at joints A and C will act in the positive Y-direction and have magnitudes of F/2 N each. Additionally, at joint A, there will be a support reaction force of 0N in the X-direction. This is because the entire truss structure is in equilibrium, meaning that the bar tension balances out the internal forces. The reaction force balances out the external forces applied to the truss. Since the external force is 120 N (taken for example), each support will experience half of that force, resulting in a tension of 60 kN at each support point.

1

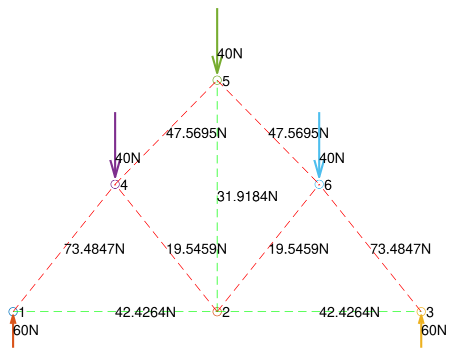
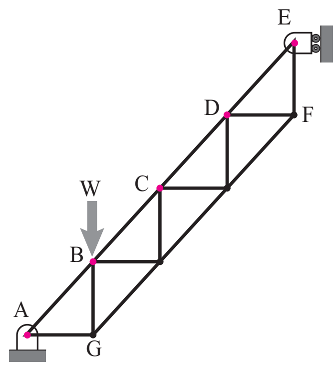


Figure 2: Truss system 2

In Figure 2, the same logic applies, and the reaction forces will still be F/2 N (60N) only. Hence, the support reactions should not be different.

Hence Proved, Replacing the load at point B with three equal loads (F/3 each) at points D, E, and F does not alter the support reactions in the truss.

6.1.17 The stairstep truss shown in the figure has 500 mm long horizontal and vertical bars. Find the support reactions at A and E when a load $W = 1\,\mathrm{kN}$ is applied at (a) point B, (b) point C, and (c) point D, respectively.



Problem 6.17

Question 6.1.17: The stairstep truss shown in the figure has 500 mm long horizontal and vertical bars. Find the support reactions at A and E when a load W = 1 kN is applied at (a) point B, (b) Point C, and (c) point D, respectively

Solution:

Below are visual solutions for all three scenarios:

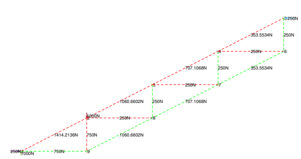


Figure 1: a

Part a:
When the external force acts on point B, the truss experiences reaction forces. The reaction force at point A is directed in the positive x-direction and has a magnitude of 250N. Additionally, there is a reaction force in the positive y-direction at point A with a magnitude of 1000N. At point E, there is a reaction force in the negative x-direction with a magnitude of 250N.

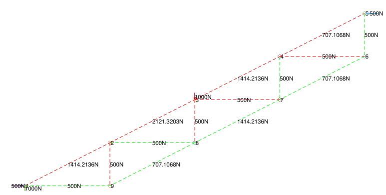


Figure 2: b

Part b:
When the external force acts on point C, the truss experiences reaction forces. The reaction force at point A is directed in the positive x-direction and has a magnitude of 500N. The truss also has a reaction force in the positive y-direction at point A with a magnitude of 1000N. At point E, there is a reaction force in the negative x-direction with a magnitude of 500N.

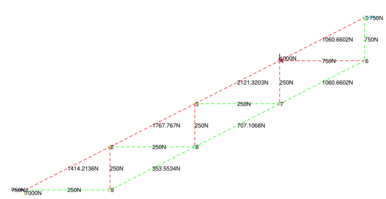


Figure 3: c

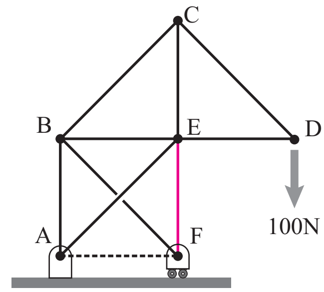
Part c:
When the external force acts on point D, the truss experiences reaction forces. The reaction force at point A is directed in the positive x-direction and has a magnitude of 750N. The truss also has a reaction force in the positive y-direction at point A with a magnitude of 1000N. At point E, there is a reaction force in the negative x-direction with a magnitude of 750N.

Here is a table summarizing the reaction forces:

	Reaction Force at A, x direction	**Reaction Force at E, direction**
Part a	250 N	−250 N
Part b	500 N	−500 N
Part c	750 N	−750 N

In all three scenarios, the reaction force in the y-direction at point A remains constant. Additionally, it is evident that the reaction force at point A in the x-direction balances out the reaction force at point E, while the external force is balanced by the reaction force at point A in the y-direction.

6.1.18 In the truss shown in the figure, how does the force in bar EF change if the diagonal bar BF is removed and another bar AF (shown by dotted line) is introduced instead? You can assume any reasonable dimensions for the bars if needed.



Problem 6.18

5.1.18

To find reaction at joint F

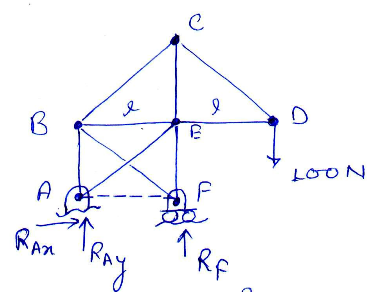


fig 1.

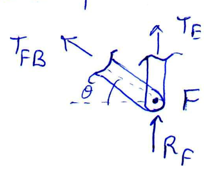
$$\left[\sum \vec{F} = \vec{0}\right] \cdot \hat{\imath}$$

$$\Rightarrow R_{Ax} = 0$$

$$\left[\sum \vec{M}_A = \vec{0}\right] \cdot \hat{k} \Rightarrow \left[R_F l - 2l \times 100\right] = 0$$

$$\Rightarrow \boxed{R_F = 200N}$$

Now bar AF is not present then at point F



$$\left[\sum \vec{F} = \vec{0}\right] \cdot \hat{\imath}$$

$$\Rightarrow T_{FB} \cos\theta = 0$$

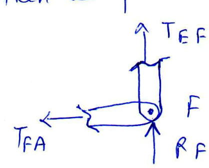
$$\Rightarrow T_{FB} = 0$$

$$\left[\sum \vec{F} = \vec{0}\right] \cdot \hat{\jmath}$$

$$\Rightarrow T_{EF} + R_F + \cancel{T_{FB}}^{\,0} \sin\theta = 0$$

$$\Rightarrow \boxed{T_{EF} = -R_F = -200N}$$

Now bar AF is present and bar BF is removed then at point F



$$\left[\sum \vec{F} = \vec{0}\right] \cdot \hat{\imath}$$

$$\Rightarrow T_{FA} = 0$$

$$\left[\sum \vec{F} = \vec{0}\right] \cdot \hat{\jmath}$$

$$\Rightarrow T_{EF} + R_F = 0$$

$$\boxed{T_{EF} = -R_F = -200N}$$

∴ Force in bar EF does not change if AF is introduced instead of BF.

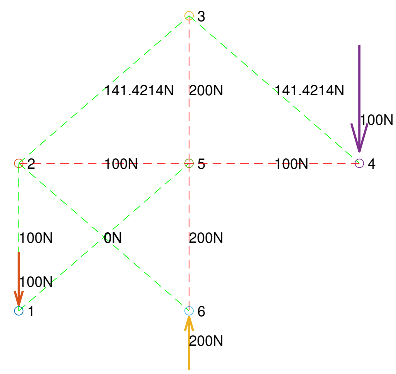
Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

Question 6.1.18: In the truss shown in the figure, how does the force in bar EF change if the diagonal bar BF is removed and another bar AF (shown by dotted line) is introduced instead? You can assume any reasonable dimensions for the bars if needed.

Solution: The problem was solved by creating 12 equations: 2 equations at each joint. These equations equated all the forces in the x direction to zero and all the forces in the y direction to zero.

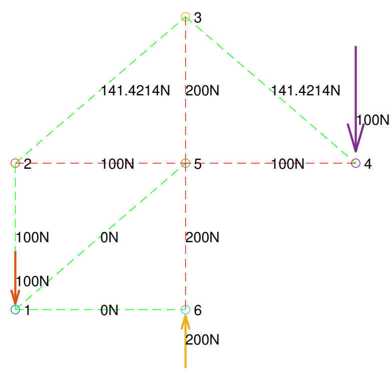
$$0.7071T_2 + R_1 = 0 \quad (1)$$
$$T_1 + 0.7071T_2 + R_2 = 0 \quad (2)$$
$$T_3 + 0.7071T_4 + 0.7071T_5 = 0 \quad (3)$$
$$-T_1 + 0.7071T_4 - 0.7071T_5 = 0 \quad (4)$$
$$-0.7071T_4 + 0.7071T_7 = 0 \quad (5)$$
$$-0.7071T_4 - T_6 - 0.7071T_7 = 0 \quad (6)$$
$$-0.7071T_7 - T_8 = 0 \quad (7)$$
$$T_7 = 100, \mathrm{N} \quad (8)$$
$$-0.7071T_2 - T_3 + T_8 = 0 \quad (9)$$
$$-0.7071T_2 + T_6 - T_9 = 0 \quad (10)$$
$$-0.7071T_5 - 0.7071T_{12} = 0 \quad (11)$$
$$0.7071T_5 + T_9 + R_3 = 0 \quad (12)$$
$$(1)$$

By combining these equations into a matrix and reducing it to row-echelon form, we were able to determine the magnitudes of the tension and reaction forces.



The force in Bar EF is 200N

Now after the diagonal bar BF is removed and another bar AF is introduced instead:



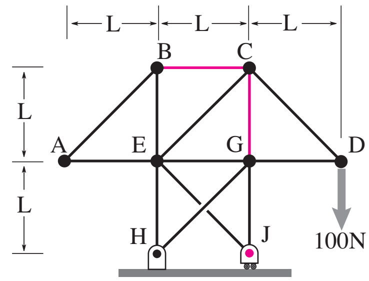
In the figure above, it can be observed that the force in Bar EF remains constant at 200N. This is due to the fact that both Bar AF and Bar BF are zero-force members. Consequently, the force acting on Bar EF is unaffected and remains at 200N.

6.1.19 For the truss shown, find:

a) The reaction at J.

b) The bar force in BC (tension or compression).

c) The force in bar CG (tension or compression).



Problem 6.19

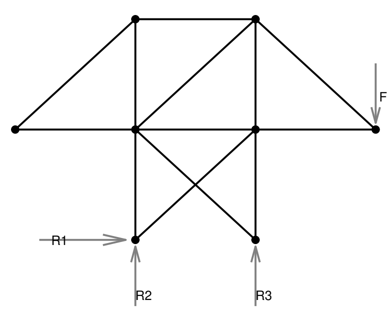
Question 6.1.19: For the truss shown, find:

a) The reaction at J.

b) The bar force in BC (tension or compression).

c) The force in bar CG (tension or compression).

Solution:

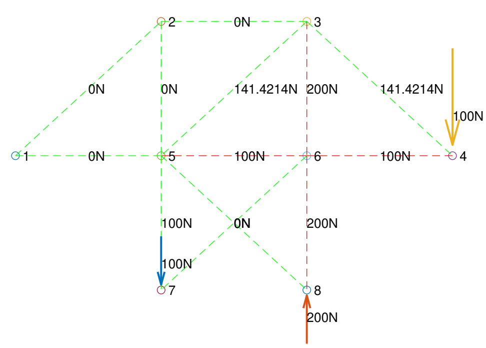


The problem was solved by creating 16 equations: 2 equations at each joint. These equations equated all the forces in the x direction to zero and all the forces in the y direction to zero.

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

$$0.7071T_1 + T_2 = 0 \tag{1}$$
$$0.7071T_1 = 0 \tag{2}$$
$$-0.7071T_1 + T_4 = 0 \tag{3}$$
$$-0.7071T_1 - T_3 = 0 \tag{4}$$
$$-T_4 - 0.7071T_5 + 0.7071T_7 = 0 \tag{5}$$
$$-0.7071T_5 - T_6 - 0.7071T_7 = 0 \tag{6}$$
$$-0.7071T_7 - T_8 = 0 \tag{7}$$
$$0.7071T_7 - 100 = 0 \tag{8}$$
$$-T_2 + 0.7071T_5 + T_{11} + 0.7071T_{12} = 0 \tag{9}$$
$$T_3 + 0.7071T_5 - 0.7071T_{12} - T_{13} = 0 \tag{10}$$
$$T_8 - 0.7071T_{10} - T_{11} = 0 \tag{11}$$
$$T_6 - T_9 - 0.7071T_{10} = 0 \tag{12}$$
$$0.7071T_{10} + R_1 = 0 \tag{13}$$
$$0.7071T_{10} + T_{13} + R_2 = 0 \tag{14}$$
$$-0.7071T_{12} = 0 \tag{15}$$
$$T_9 + 0.7071T_{12} + R_3 = 0 \tag{16}$$

By combining these equations into a matrix and reducing it to row-echelon form, we were able to determine the magnitudes of the tension and reaction forces.
A Visual solution to the problem :



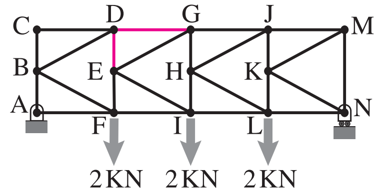
Hence the answers are:

a) 200N

b) 0N

c) 200N, compression

6.1.20 The truss shown in the figure consists of 4 square bays of a 'K' structure. Each bay has two 2 m long horizontal, two 1 m long vertical bars, and two diagonal bars. Find the tensions in rods DE and DG.

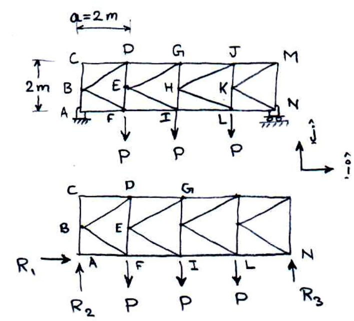


Problem 6.20

5.1.20

Given truss consists of 4 bays of 'K' structures.

Find the tensions in rods DE & DG.



FBD of the complete structure is shown in the adjacent figure. Let the force applied at the joints F, I and L be denoted by P.

Given that P = 2KN

Applying force balance, $\Sigma \underline{F} = \underline{0}$

$$\Rightarrow \{R_1\hat{\underline{i}} + R_2\hat{\underline{j}} - P\hat{\underline{j}} - P\hat{\underline{j}} - P\hat{\underline{j}} + R_3\hat{\underline{j}} = \underline{0}\}$$

$\{\}\cdot\hat{\underline{i}} \Rightarrow R_1 = 0$ — (1)

$\{\}\cdot\hat{\underline{j}} \Rightarrow R_2 + R_3 = 3P$ — (2)

Applying Moment balance about A, $\Sigma \underline{M}_{/A} = \underline{0}$

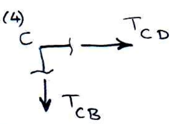
$$\Rightarrow a\hat{\underline{i}} \times -P\hat{\underline{j}} + 2a\hat{\underline{i}} \times -P\hat{\underline{j}} + 3a\hat{\underline{i}} \times -P\hat{\underline{j}} + 4a\hat{\underline{i}} \times R_3\hat{\underline{j}} = \underline{0}$$

$$\Rightarrow \{-aP\hat{\underline{k}} - 2aP\hat{\underline{k}} - 3aP\hat{\underline{k}} + 4aR_3\hat{\underline{k}} = \underline{0}\}$$

$\{\}\cdot\hat{\underline{k}} \Rightarrow -6aP + 4aR_3 = 0 \Rightarrow R_3 = \frac{3}{2}P$ — (3)

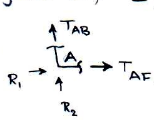
From (2) and (3) $R_2 + \frac{3}{2}P = 3P \Rightarrow R_2 = \frac{3}{2}P$ — (4)

FBD of BCD portion of the truss is



Applying force balance at joint C, $\Sigma \underline{F} = \underline{0} \Rightarrow T_{CD} = T_{CB} = 0.$ — (5)

FBD of joint A is



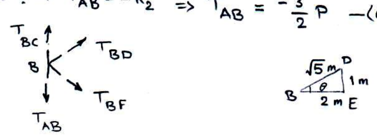
Applying force balance, $\Sigma \underline{F} = \underline{0}$

$\Rightarrow \{R_1\hat{\underline{i}} + T_{AF}\hat{\underline{i}} + R_2\hat{\underline{j}} + T_{AB}\hat{\underline{j}} = \underline{0}\}$

$\{\}\cdot\hat{\underline{j}} \Rightarrow T_{AB} = -R_2 \Rightarrow T_{AB} = -\frac{3}{2}P$ — (6)

To find T_{DE} & T_{DG}, T_{BD} is needed.

$\therefore$ Consider the FBD of joint B,

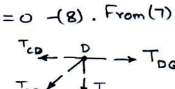


$\{\Sigma \underline{F} = \underline{0}\} \Rightarrow \{\}\cdot\hat{\underline{i}} \Rightarrow T_{BD}\cos\theta + T_{BF}\cos\theta = 0$

$\Rightarrow T_{BD} = -T_{BF}$ — (7)

$\{\}\cdot\hat{\underline{j}} \Rightarrow T_{CB} - T_{AB} + T_{BD}\sin\theta - T_{BF}\sin\theta = 0$ — (8). From (7) & (8), $T_{BD} = \frac{-\sqrt{5}}{4}3P$ — (9)

Consider the FBD of joint D,



Applying force balance at D, $\Sigma \underline{F} = \underline{0}$

$\Rightarrow \{-T_{CD}\hat{\underline{j}} + T_{DG}\hat{\underline{i}} - T_{DB}\cos\theta\hat{\underline{i}} - T_{DE}\hat{\underline{j}} - T_{DB}\sin\theta\hat{\underline{j}} = \underline{0}\}$

$\{\}\cdot\hat{\underline{i}} \Rightarrow T_{DG} = -\frac{\sqrt{5}}{4}3P\cos\theta \Rightarrow T_{DG} = -\frac{3P}{2}$ (or) $\boxed{T_{DG} = -3KN}$

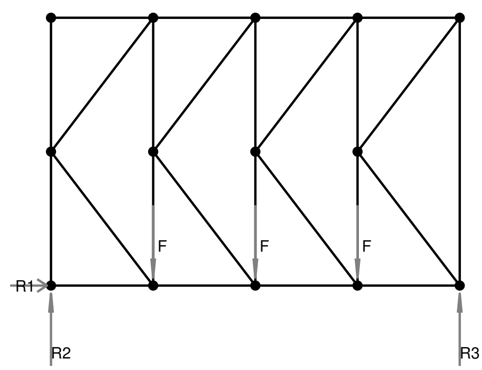
$\{\}\cdot\hat{\underline{j}} \Rightarrow T_{DE} = -T_{BD}\sin\theta = +\frac{\sqrt{5}}{2}\frac{3P}{2}\frac{1}{\sqrt{5}}$

$\Rightarrow T_{DE} = \frac{3P}{4}$ (or) $\boxed{T_{DE} = 1.5KN}$

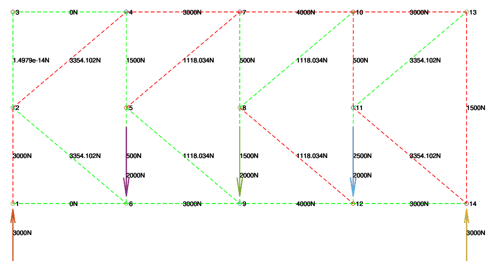
Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

Question 6.1.20: The truss shown in the figure consists of 4 square bays of a 'K' structure. Each bay has two 2 m long horizontal, two 1 m long vertical bars, and two diagonal bars. Find the tensions in rods DE and DG.

Solution:



The truss has 14 joints and 28 unknowns. Additionally, it has 25 bar tensions and 3 reaction forces. Therefore, manually solving this truss using the method of joints would be very tedious. Instead, a computer program has been used to solve this question using the method of joints.



Rod DE is under tension with a force of 1500N.
Rod DG is under compression with a force of 3000N.

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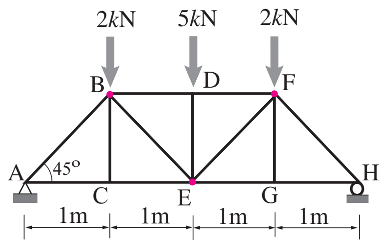
6.1.21 Analyze the truss shown in the figure and find the forces in all the bars.

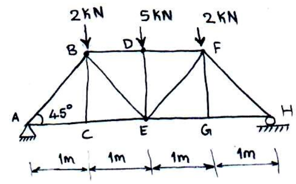


Problem 6.21

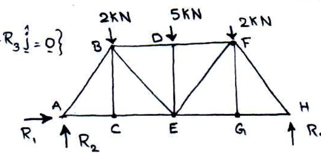
5.1.21.

Find the forces in all the bars.

FBD of the truss is shown in the adjacent figure.



Applying force balance to the truss,



$\sum \underline{F} = \underline{0} \Rightarrow \{R_1\hat{\underline{i}} + R_2\hat{\underline{j}} - 2KN\hat{\underline{j}} - 5KN\hat{\underline{j}} - 2KN\hat{\underline{j}} + R_3\hat{\underline{j}} = \underline{0}\}$

$\{\}\cdot\hat{\underline{i}} \Rightarrow R_1 = 0N$ —(1)

$\{\}\cdot\hat{\underline{j}} \Rightarrow R_2 + R_3 = 9KN$ —(2)

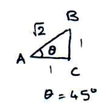
Applying Moment balance about A,

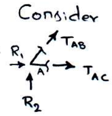
$\sum \underline{M}_{/A} = \underline{0} \Rightarrow (1m\hat{\underline{i}} + 1m\hat{\underline{j}}) \times 2KN(-\hat{\underline{j}}) + (2m\hat{\underline{i}} + 1m\hat{\underline{j}}) \times -5KN\hat{\underline{j}} + (3m\hat{\underline{i}} + 1m\hat{\underline{j}}) \times -2KN\hat{\underline{j}} + 4m\hat{\underline{i}} \times R_3\hat{\underline{j}} = \underline{0}$

$\Rightarrow \{-2KNm\hat{\underline{k}} - 10KNm\hat{\underline{k}} - 6KNm\hat{\underline{k}} + R_3(4m)\hat{\underline{k}} = \underline{0}\}$

$\{\}\cdot\hat{\underline{k}} \Rightarrow R_3 = 4.5KN$ and from (2) $R_2 = 4.5KN$ —(3)

Consider the FBD of the joint A; apply force balance, $\sum \underline{F} = \underline{0}$





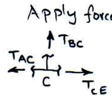
$\Rightarrow \{R_1\hat{\underline{i}} + T_{AC}\hat{\underline{i}} + T_{AB}\cos\theta\,\hat{\underline{i}} + T_{AB}\sin\theta\,\hat{\underline{j}} + R_2\hat{\underline{j}} = \underline{0}\}$

$\{\}\cdot\hat{\underline{i}} \Rightarrow T_{AC} + T_{AB}\frac{1}{\sqrt{2}} = 0$ —(4)

$\{\}\cdot\hat{\underline{j}} \Rightarrow T_{AB}\frac{1}{\sqrt{2}} + R_2 = 0$ —(5)

From (3), (4) and (5), $\boxed{T_{AB} = -6.36KN}$ and $\boxed{T_{AC} = 4.5KN}$ —(6)

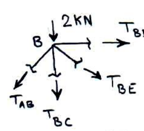
Apply force balance to joint C, $\sum \underline{F} = \underline{0}$



$\Rightarrow \{T_{BC}\hat{\underline{j}} + T_{CE}\hat{\underline{i}} + T_{AC}(-\hat{\underline{i}}) = \underline{0}\}$

$\{\}\cdot\hat{\underline{i}} \Rightarrow \boxed{T_{CE} = T_{AC} = 4.5KN}$ and $\{\}\cdot\hat{\underline{j}} \Rightarrow \boxed{T_{BC} = 0N}$ —(7)

Consider the FBD of the joint B. Apply force balance to joint B, $\sum \underline{F} = \underline{0}$

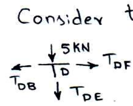


$\Rightarrow \{T_{AB}\cos\theta(-\hat{\underline{j}}) - T_{AB}\sin\theta\,\hat{\underline{i}} - T_{BC}\hat{\underline{j}} + T_{BE}\cos\theta(-\hat{\underline{j}}) + T_{BE}\sin\theta\,\hat{\underline{i}} + T_{BD}\hat{\underline{i}} - 2KN\hat{\underline{j}} = \underline{0}\}$

$\{\}\cdot\hat{\underline{j}} \Rightarrow -\frac{T_{AB}}{\sqrt{2}} - \frac{T_{BE}}{\sqrt{2}} - 2KN - 0N = 0 \Rightarrow \boxed{T_{BE} = 3.53KN}$

$\{\}\cdot\hat{\underline{i}} \Rightarrow -\frac{T_{AB}}{\sqrt{2}} + \frac{T_{BE}}{\sqrt{2}} + T_{BD} = 0 \Rightarrow \boxed{T_{BD} = -7KN}$

Consider the FBD of the joint D. Apply force balance to joint D, $\sum \underline{F} = \underline{0}$



$\Rightarrow \{-5KN\hat{\underline{j}} - T_{DE}\hat{\underline{j}} + T_{DF}\hat{\underline{i}} - T_{DB}\hat{\underline{i}} = 0\}$

$\{\}\cdot\hat{\underline{j}} \Rightarrow \boxed{T_{DE} = -5KN}$

$\{\}\cdot\hat{\underline{i}} \Rightarrow \boxed{T_{DF} = -7KN}$

As the given truss and loading is symmetric about DE, the forces in the remaining members are.

$\boxed{T_{CE} = T_{EG} = 4.5KN}$, $\boxed{T_{EF} = T_{BE} = 3.53KN}$; $\boxed{T_{FG} = T_{BC} = 0N}$; $\boxed{T_{GH} = T_{AC} = 4.5KN}$

and $\boxed{T_{FH} = T_{AB} = -6.36KN}$

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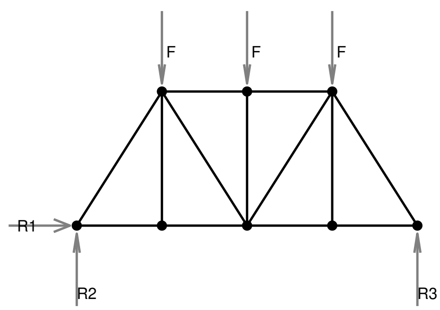
Question 6.1.21: Analyze the truss shown in the figure and find the forces in all the bars.

Solution:



The problem was solved by creating 16 equations: 2 equations at each joint. These equations equated all the forces in the x direction to zero and all the forces in the y direction to zero.

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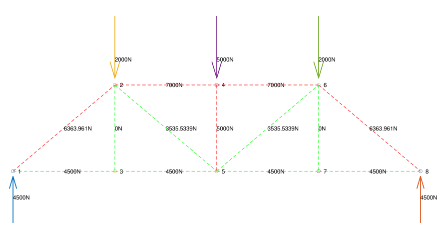
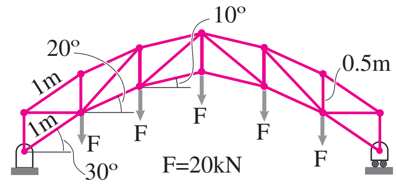
$$0.7071T_1 + T_8 + R_1 = 0 \quad (1)$$
$$0.7071T_1 + R_2 = 0 \quad (2)$$
$$-0.7071T_1 + T_2 + 0.7071T_{10} = 0 \quad (3)$$
$$-0.7071T_1 - T_9 - 0.7071T_{10} = 2000, \mathrm{N} \quad (4)$$
$$T_7 - T_8 = 0 \quad (5)$$
$$T_9 = 0 \quad (6)$$
$$-T_2 + T_3 = 0 \quad (7)$$
$$-T_{11} = 5000, \mathrm{N} \quad (8)$$
$$T_6 - T_7 - 0.7071T_{10} + 0.7071T_{12} = 0 \quad (9)$$
$$0.7071T_{10} + T_{11} + 0.7071T_{12} = 0 \quad (10)$$
$$-T_3 + 0.7071T_4 - 0.7071T_{12} = 0 \quad (11)$$
$$-0.7071T_4 - 0.7071T_{12} - T_{13} = 2000, \mathrm{N} \quad (12)$$
$$T_5 - T_6 = 0 \quad (13)$$
$$T_{13} = 0 \quad (14)$$
$$-0.7071T_4 - T_5 = 0 \quad (15)$$
$$0.7071T_4 + R_3 = 0 \quad (16)$$

By combining these equations into a matrix and reducing it to row-echelon form, we were able to determine the magnitudes of the tension and reaction forces.
A Visual solution to the problem :



2

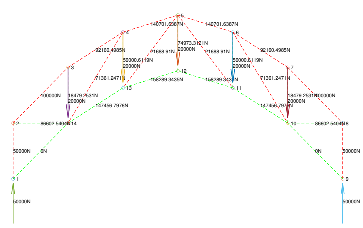
6.1.22 Analyze the truss shown in the figure and find out forces in all bars. Use symmetry to reduce the number of equations you need to solve.



Problem 6.22

Question 6.1.22: Analyze the truss shown in the figure and find out forces in all bars. Use symmetry to reduce the number of equations you need to solve

Solution:



In the diagram, it is evident that the tension forces exhibit symmetry. Therefore, by determining the tension forces on the left side of the truss, one can simply mirror those values on the right side. This allows for a simplified analysis of the tension forces in the entire truss structure.