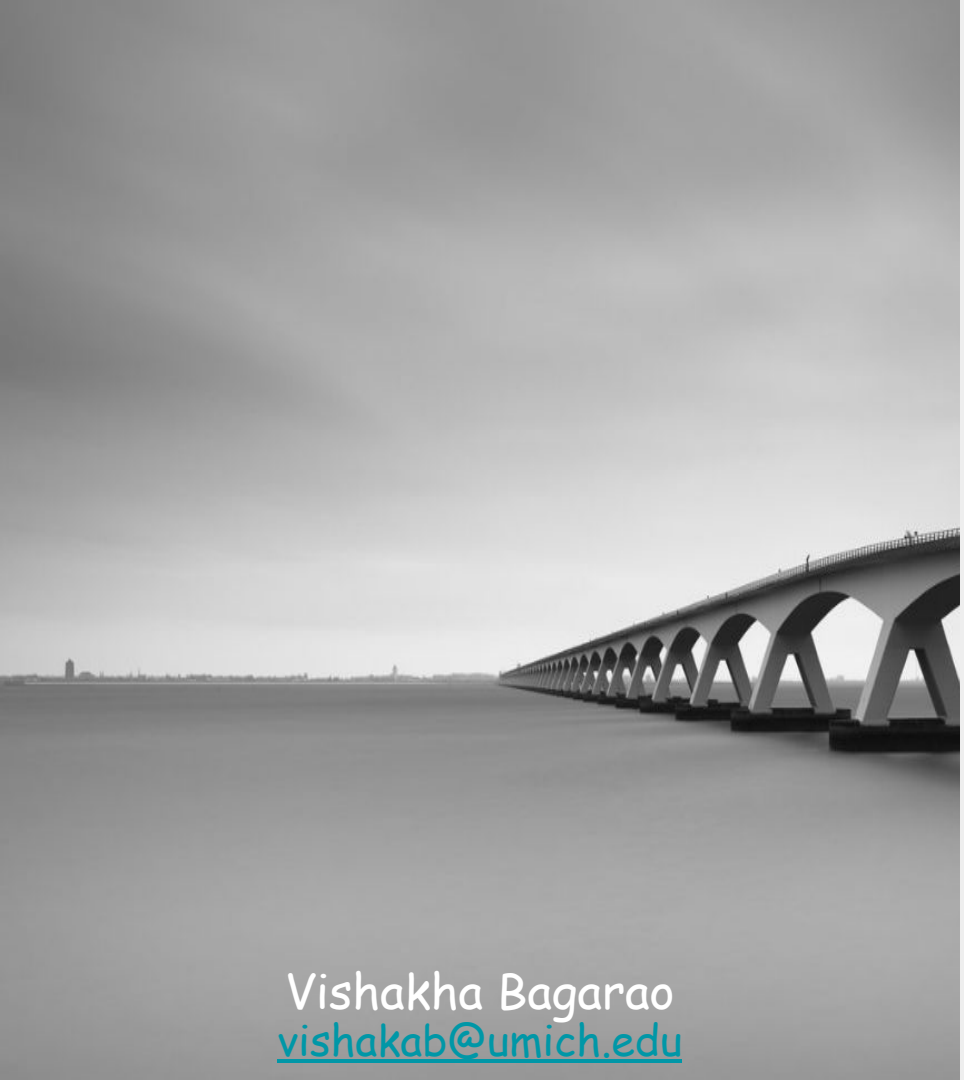
Arch 314- Structures I

Recitation 006

Vishakha Bagarao

11th Oct 2024



Contents

- Bridge Report
- Quick Recap
  - Pinned frames
- Plane trusses by Graphic Statics
  - Lab 05- Graphic Statics

Vishakha Bagarao
vishakab@umich.edu

Bridge Report Rubrics

- Ranking is based on the **load-to-weight ratio** of the bridge.
- Make it pretty!

  10 Bonus Points for Aesthetics!
- Review the **rubrics** for a clear understanding of the point system and grading criteria.

4th Oct

Good Job!!!

4th Nov

25th Nov

PRELIMINARY REPORT (re-submit original)	**40**	
Explanation	5	
Illustrations: section (5), elevation (5), 3d view (5)	15	
Analysis: forces (5), sizing (5), weight estimate (5), load capacity (5)	20	
TESTING	**60**	
Bridge < 4 oz is 8 pts and holds at least 50 lbs is 8 pts (else pts scaled down)	16	
Correct materials – wood and glue – solid deck (no holes)	14	
Points awarded (out of 30) based on class rank using formula: [(4/weight OZ)*50 + (load in LBS/50)*9]	30	
FINAL REPORT REQUIREMENTS	**150**	
Preliminary Design Development	**20**	
How initial (preliminary) bridge design was developed	4	
How initial (preliminary) member sizes were chosen	4	
Why bridge design was or was not adjusted from preliminary design	4	
Why member sizes were or were not adjusted from preliminary design	4	
Discussion of how pre-analysis of initial bridge impacted the final design	4	
Revised Bridge Design Analysis	**50**	
Internal axial force calculations/modeling (with proper design loading indicated) (Dr. Frame acceptable)	10	
Derivation of member cross-sectional areas from axial forces	10	
Member size selection from available stock	4	
Est. weight calculation of bridge - including members, glue & fasteners	6	
Method of joints/sections calculation for at least 1 joint (@ reaction is usually easiest based on truss geometry, but could be done elsewhere)	10	
Member crushing calculations/check (show work) using $F'_c=P/A$	4	
Prediction of capacity of bridge and mode of failure	6	
Illustration of Tested (Revised from Preliminary) Design	**20**	
Cross-section of bridge	4	
Elevation(s) of bridge	4	
Dimensions and units labeled in elevation and cross-section	4	
Member sizes labeled (with dimensions)	4	
Member stresses labeled (with units)	4	
Testing Results	**30**	
Weight and height of bridge	5	
Capacity of bridge	5	
Observations of testing	6	
Description of mode of failure	5	
Images of failure	5	
Following the guidelines	4	
Post-Testing Analysis	**30**	
Comparison of testing with predicted capacity and modes of failure	10	
Discussion of discrepancies between results	10	
Suggested improvements for future designs with reasoning discussed	10	
FINAL GRADE	**250**	

Bridge Report

Model:

- **Weigh members** individually before and after gluing to ensure accurate weight (glue adds ~5% weight).
  (Weigh 2 members > Glue them as joint > weigh again > Subtract both weight to get the precise weight of the joint)
- Aim to finish **well before the deadline** to revise if the weight exceeds limits (4 ounce).
- Ensure **strong joints**—glue carefully for optimal strength.
- While designing or placing a joint, consider the **size of the steel bars** used for testing (1 1/2" x 2" x 5 7/8").
- You can use **any wood** but ensure it adheres to the guidelines.

Testing:

- Don't forget to take photographs of your models both **before and after testing**—this is crucial for your final report.
- Keep in mind that **wood can weaken over time under load**, so please be efficient and **load your bridge model as quickly as possible** during testing.

Structures I
Arch 314

Peter von Buelow
Fall 2024

Truss Bridge Project

Description
This project gives students the chance to apply concepts learned in truss analysis to the design of a small road bridge. The project also introduces techniques for design and testing of structural models. Work is to be conducted in groups of up to four people. The project is divided into three parts: 1) initial conceptual design and analysis, 2) design development and testing, 3) post analysis and documentation.

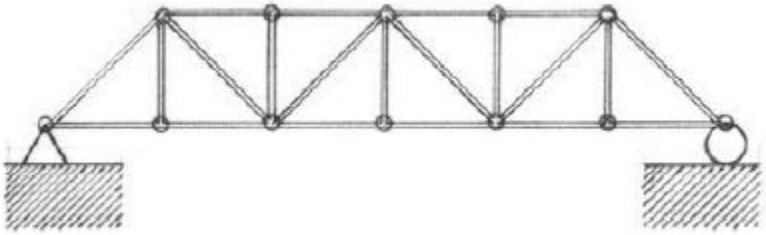
Objectives
- to explore the geometric design parameters of a structural truss through bridge design.
- to perform quantitative analysis as a means of testing and evaluating a design.
- to test a design concept using a 1:64 (3/16" = 1') scale structural model.
- to document the results in a clear, well organized report.

Procedure
1) Develop a structural concept for a 2-lane vehicular bridge meeting the following criteria:
   - Function: accommodate a flat roadway to carry 2-lane traffic (10ft lane width)
   - Loads: each lane to carry 640 PLF (HS20 truck loading)
   - Geometry: 160 ft span, 52 ft maximum depth (below supports), unlimited height
   - Materials: wood, glue (no strength modifying of wood, i.e., coating in glue or other material)
   - Efficiency: maximize the load capacity to bridge weight ratio.
2) Analyze the design concept using either manual calculations or computer software:
   - Determine the magnitude and sign (tension or compression) of the force within each truss member.
   - Determine the cross-sectional sizing for each member based on the force calculations and the allowable material stress (**F = P/A** or **A = P/F**). See attached table for material properties of basswood.
3) Document initial design concept and quantitative analysis in a preliminary report.
4) Construct a structural test model (scale: 3/16" = 1'-0"). The model will be tested in class to determine its maximum load capacity. Load is applied with 5 lb. steel bars measuring 1 ½" x 2" x 5 7/8".
5) Produce a final report (see scoring rubric for more details) to include:
   - Explanation of the structural concept
   - Design and analysis with drawings
   - Test documentation and results
   - Discussion of results and possible improvements

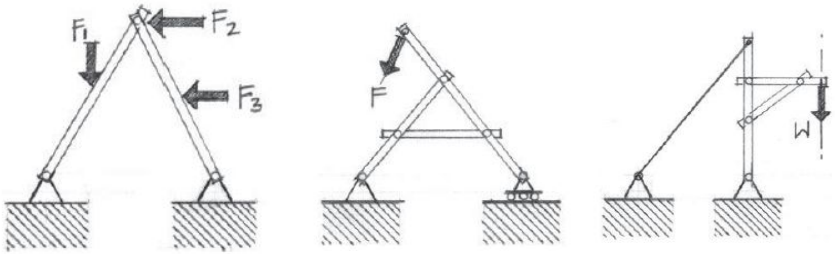
Model Criteria
- Models are to be made entirely of basswood and glue. Additional basswood gusset plates at member connections are allowed. No steel pins or fasteners are allowed for the joining of members.
- Trusses must be constructed of individual members. That is, you may not laser cut a truss from a flat sheet of basswood. Based on the grain of wood, this would be counterproductive anyway.
- Maximum member cross-sectional dimension = ¼". If two pieces of wood are laminated together, the maximum thickness may not exceed ¼".
- Strength modifying of basswood (coating in glue or other material) is not allowed.
- Models must span a 30" gap (an exactly 30" long bridge will fall through), hang no further than 10" below the supports, and have a 1/8" maximum deck thickness.
- Models may bear only on the top surfaces of the support frame.
- Models must have a **FLAT,** continuous deck with a minimum of 4" width. It cannot be perforated.
- The models will be loaded on the roadway deck using 1 ½" x 2" x 5 7/8" steel bars.
- Bridge decks must be loadable, and able to accommodate the placement of steel weights.
- Models (wood + glue) may not weigh more than **4 ounces.**
- Models must carry a **minimum load of 50 lbs**. (10 steel bars)
- Ranking score is based on the ratio of load capacity to the weight of the bridge.
- Some points will be awarded based on class ranking of load-to-weight ratio.

Part	Due Dates	points
Preliminary Report	10.04.23	40
Model Testing	11.04.23	60
Final Report	11.25.23	150

Multiforce member



Truss

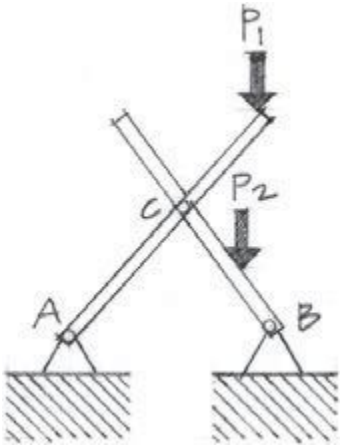


Multiforce Members

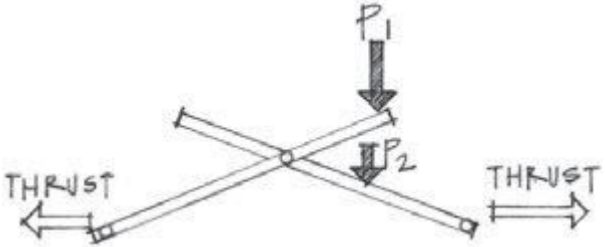
- Trusses are structures consisting entirely of pin joints and of straight two-force members where the resultant force developed was directed along the member's axis.

- Multiforce members are the member acted upon by three or more forces.
- These forces are generally not directed along the member's axis; thus, the resultant member force direction is unknown.
- Bending of the member is typically the outcome.
- Pinned frames are structures containing multiforce members that are usually designed to support an array of load conditions.

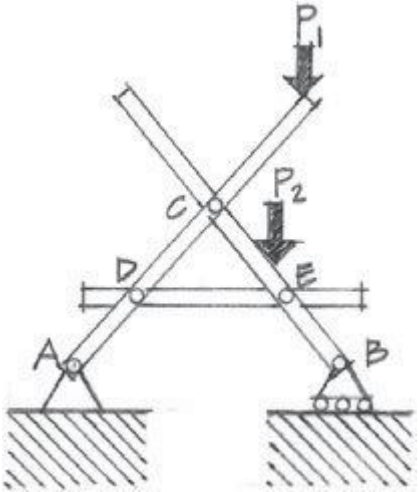
Rigid and Non Rigid Pinned Frames:



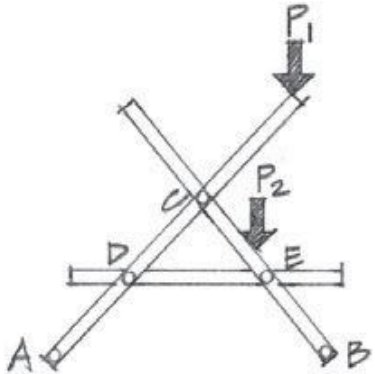
Non-Rigid Pinned frame with Support



Non-Rigid Pinned frame without Support



Rigid Pinned frame with Support



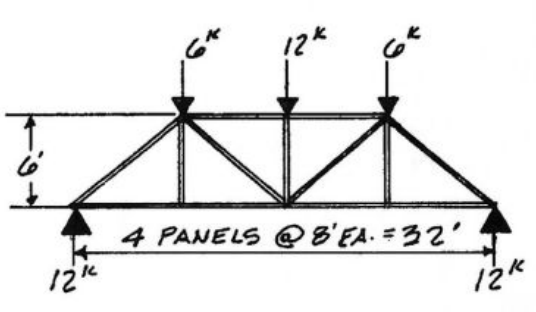
Rigid Pinned frame without Support

Things you should already know:

- Truss
- Types of Loads on truss
- Zero force members- Members that do not carry any load
  (If there is only one member attaching to the joint and no external force acting directly, no diagonal members, the vertical members are zero force members)
- Analysis of truss by method of joints
- Analysis of truss by method of section

Analysis of truss by graphical method

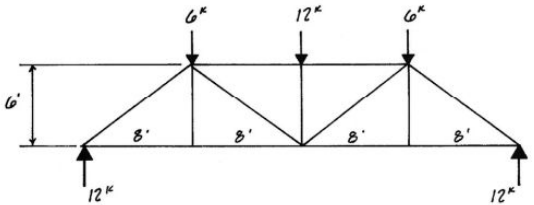
Analysis by graphical method:



Step 01:

Draw the truss to scale

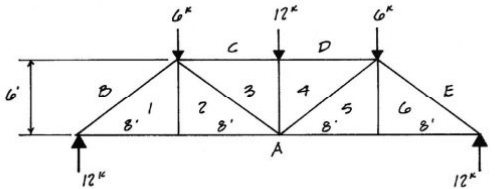
- Solve for all external forces on the truss.
- Make a simple line drawing of your truss.
- Draw it to scale.



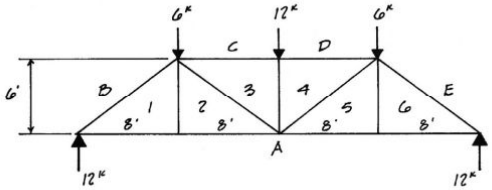
Step 02:

Labelling

- Label each space outside the truss with a letter.
- Number each space inside the truss. (from left to right.)
- Start at bottom center (by convention).
- Continue in a clockwise direction around the outside of the truss.



Analysis by graphical method:



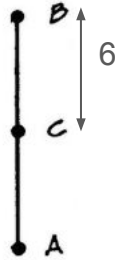
Step 03:

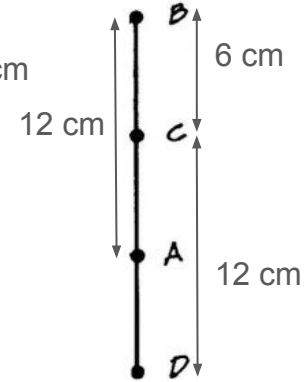
Force diagram

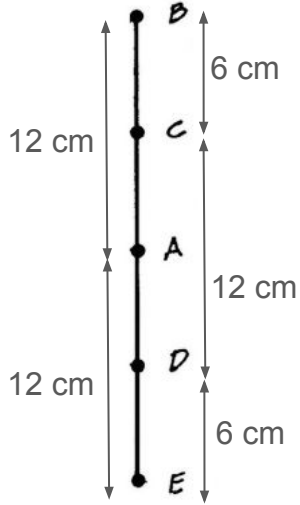
- Start in the external space (A) and move clockwise to the next space (B).
- Note the direction and magnitude of the external force you cross (12k ↑ up).
- Draw this force to scale.
- The force starts with the tail (A) and continues to the head (B).

Continue drawing the force diagram

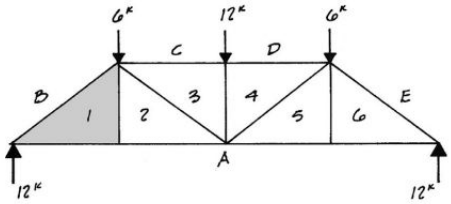
- Continue clockwise around the outside of the truss.
- Draw the force in its actual direction and to scale.







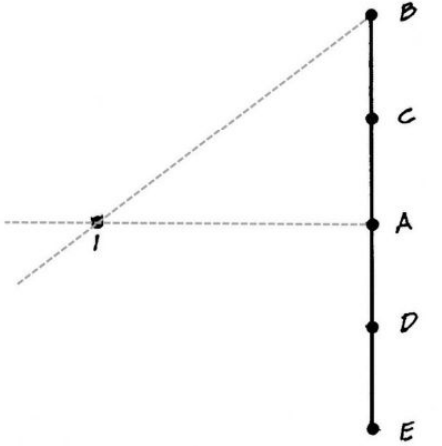
Analysis by graphical method:



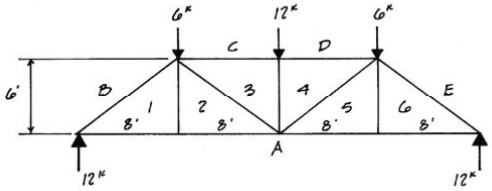
Step 04:

Draw the member forces

- Start in the external space (A) and cross to the first adjacent internal space (1).
- Draw the line you cross starting at the external letter (A).
- Now move to the next external space (B) adjacent to the same internal space (1).
- Draw a line with the same slope as the member crossed starting at the letter of the external space (B).
- These two lines cross at a point (1).
- Note that you needed 2 lines to define the location of the point (1).

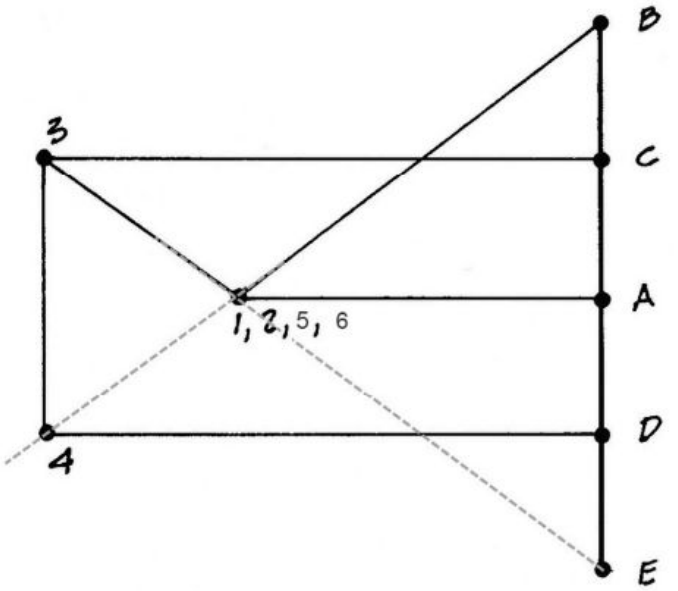


Analysis by graphical method:



Continue drawing the member forces

- Now find the next point (2).
- Now move to the next external space (A) adjacent to this internal space (2).
- Draw a line with the same slope as the member crossed starting at the letter of the external space (A).
- Now observe the member which is between the next two spaces (1 & 2).
- Draw a line with the same slope as the member through the location of the point which labels the adjacent space (1).
- The scaled length of the line equals the force.
- If a line has zero length (like 1-2) then the force in the member is zero.
- Continue drawing for each internal space.

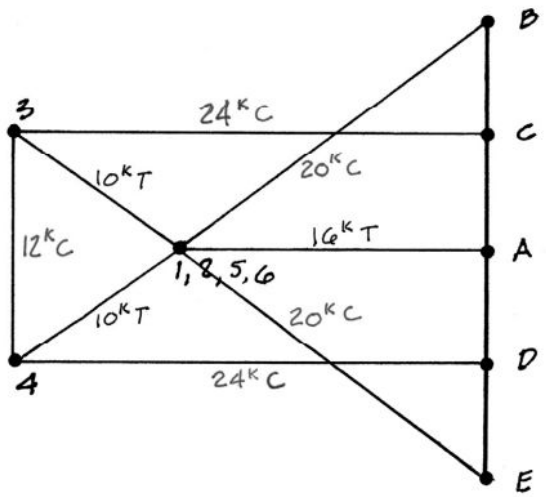


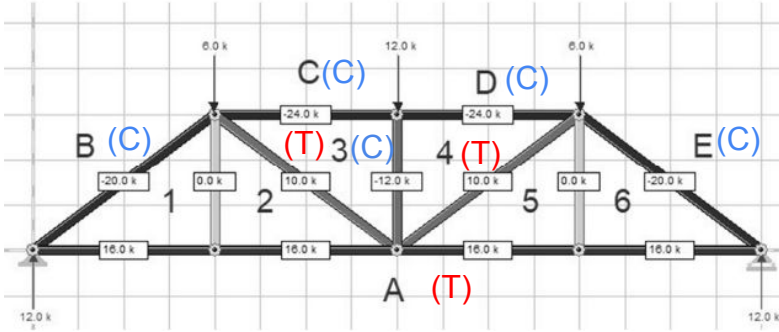
Analysis by graphical method:

Step 05:

Reading the forces:

- Each line on the graph represents the scaled magnitude and direction of the force within it.
- To determine the sign of the force: Choose a member on the truss.
  Then choose a joint connected to that member.
  Moving about the joint in a clockwise direction note the space before and after crossing the member.
  This gives the direction of the force on the graphic diagram. Applying this direction to the FBD of the joint shows the sign: compression pushing and tension pulling.





Analysis of Truss by Graphical Method:

Structures I
Arch 314

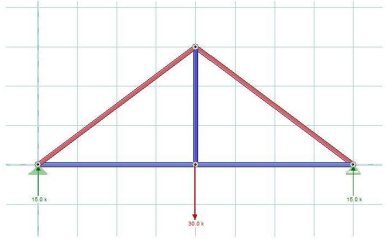
Name 1 _____
Name 2 _____
Name 3 _____

Graphic Statics

Description
This project provides opportunity to explore the graphic method of truss analysis

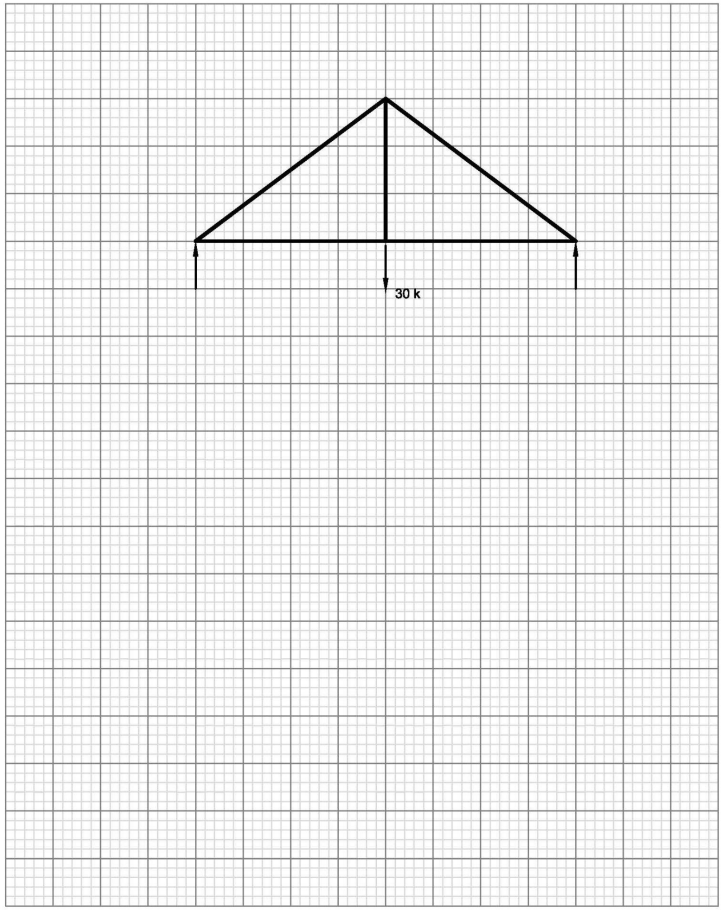
Goals
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure
1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB, BC, CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.

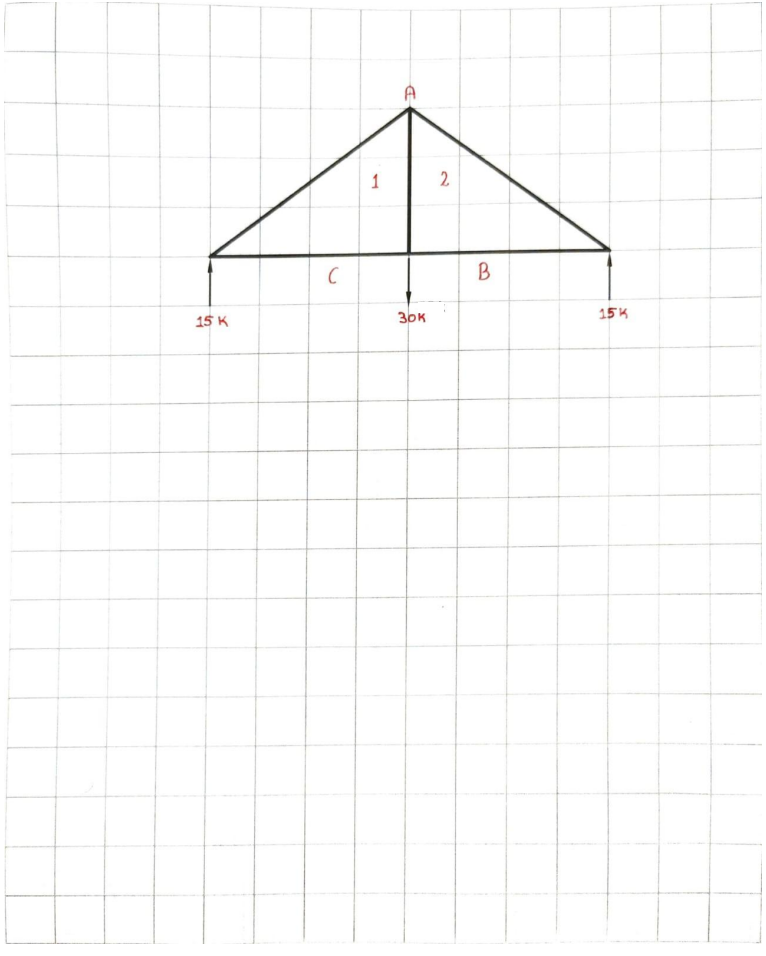


Structures I
Arch 314

Name(s):



Analysis of Truss by Graphical Method:



Graphic Statics

Description

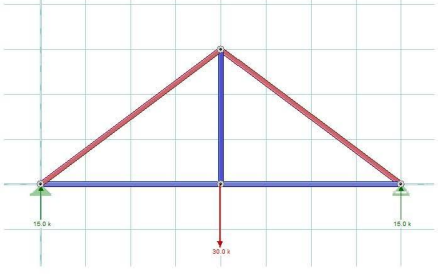
This project provides opportunity to explore the graphic method of truss analysis

Goals

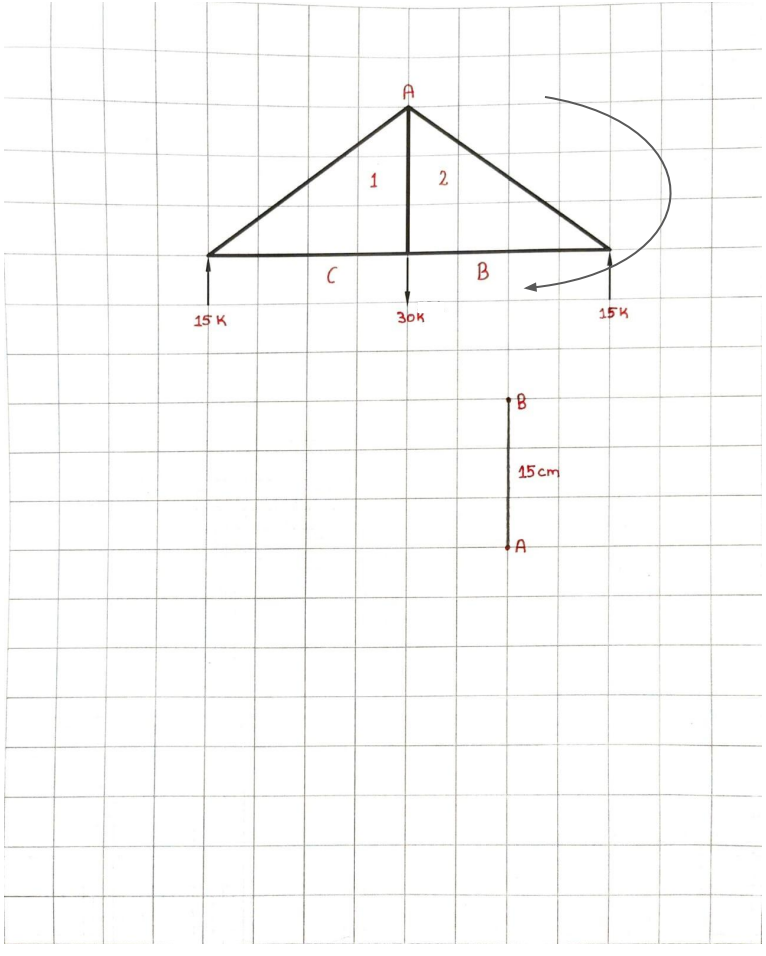
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB, BC, CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

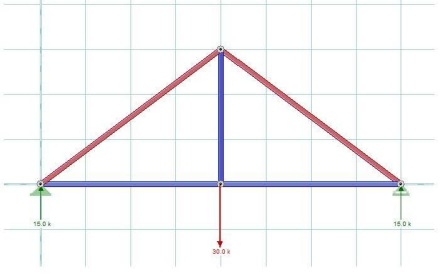
This project provides opportunity to explore the graphic method of truss analysis

Goals

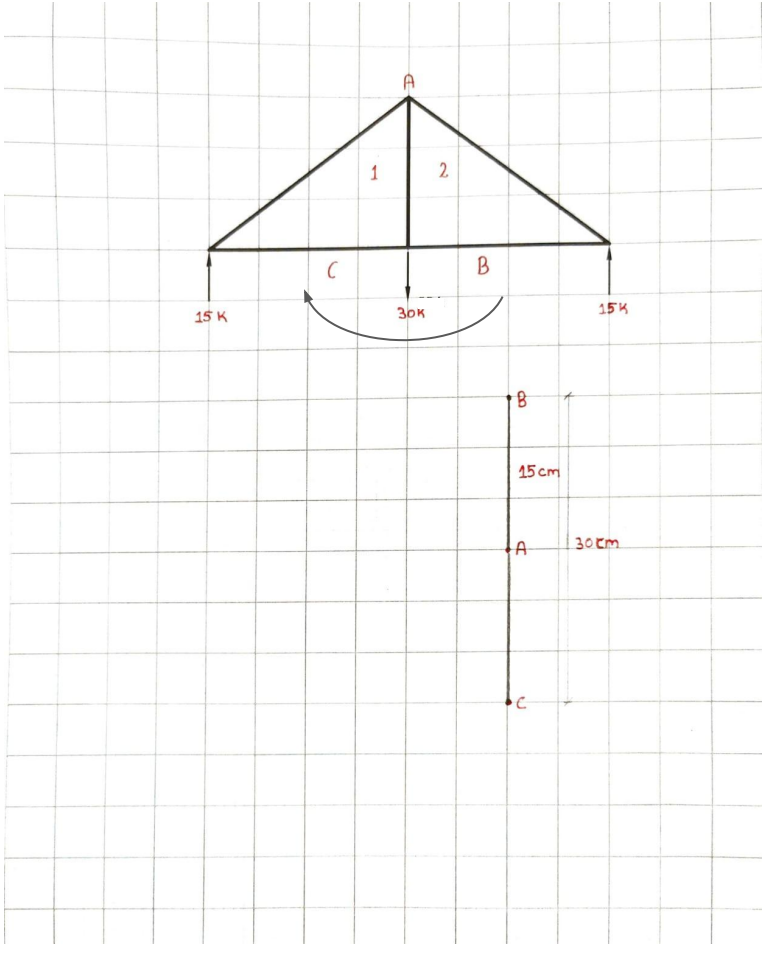
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

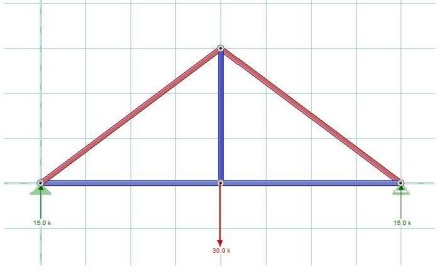
This project provides opportunity to explore the graphic method of truss analysis

Goals

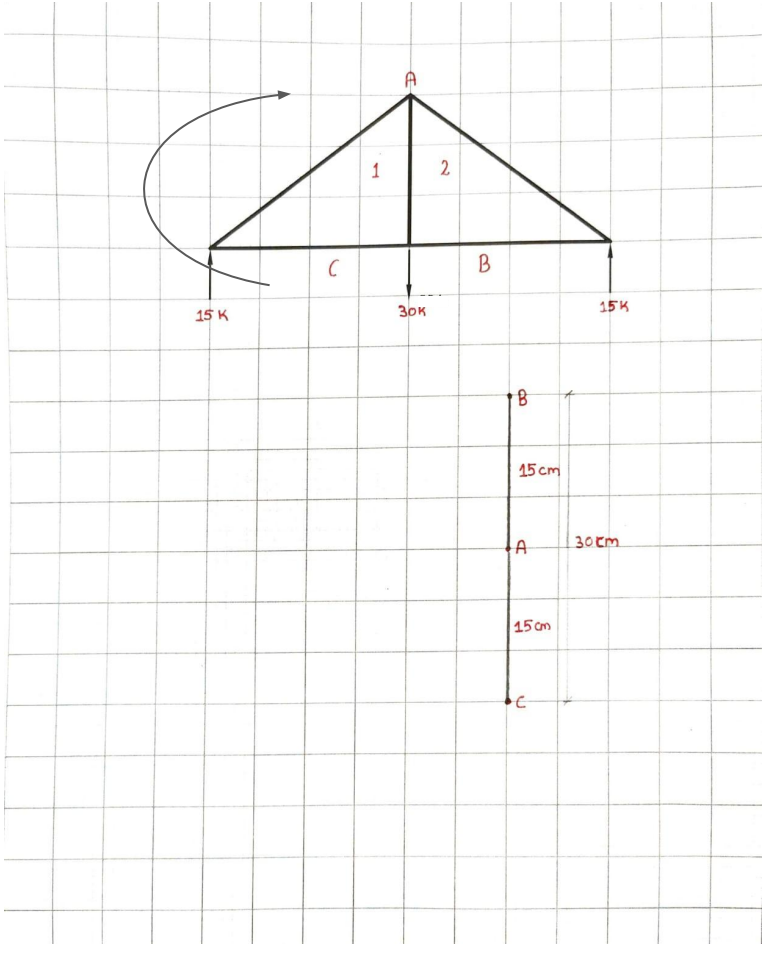
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

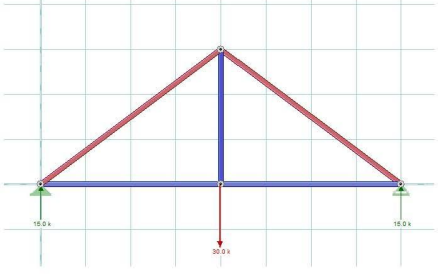
This project provides opportunity to explore the graphic method of truss analysis

Goals

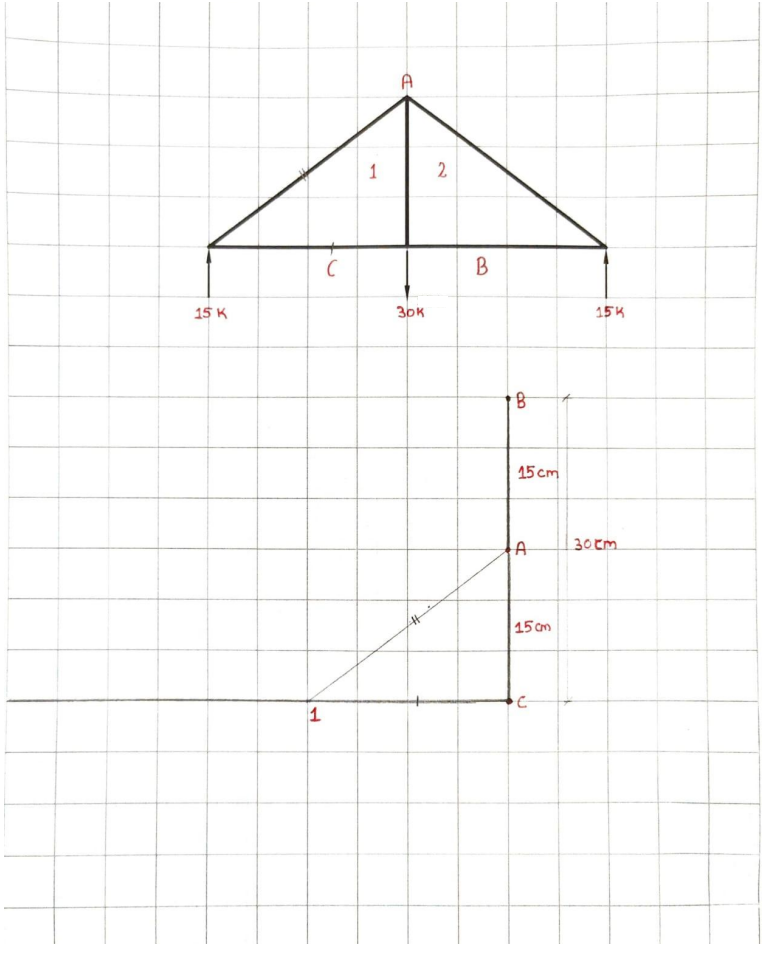
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

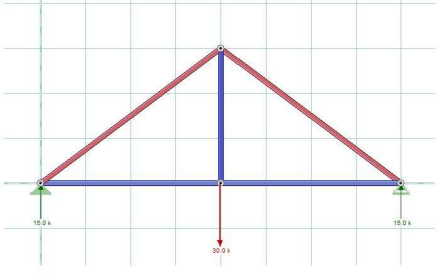
This project provides opportunity to explore the graphic method of truss analysis

Goals

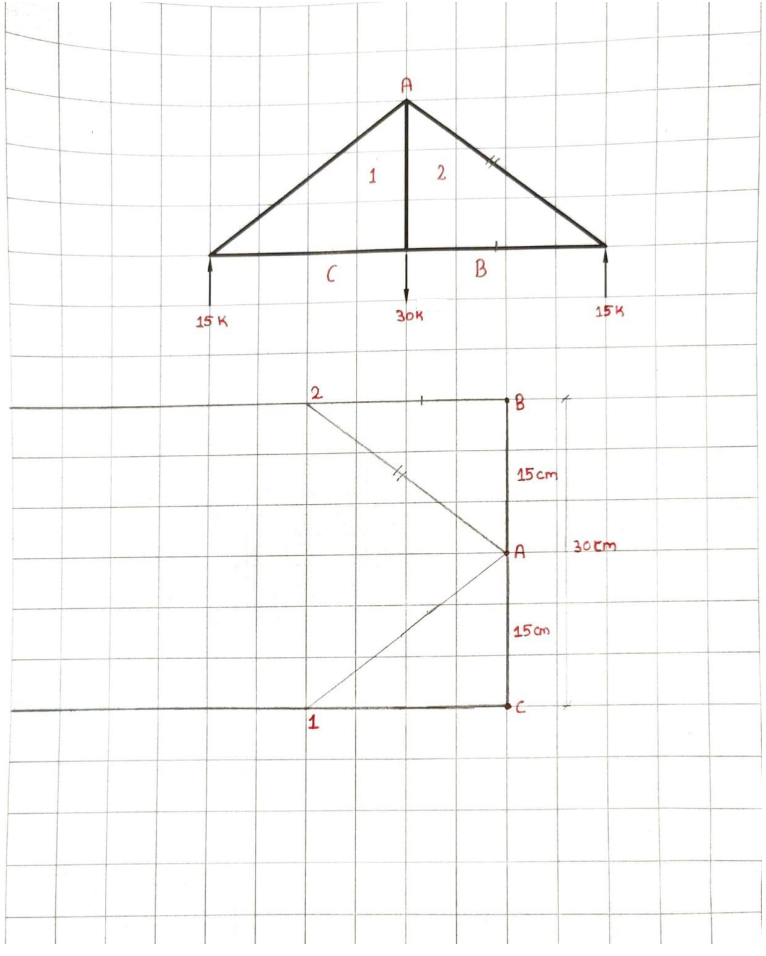
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

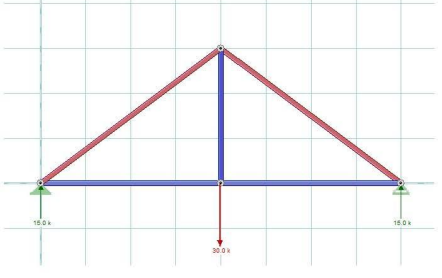
This project provides opportunity to explore the graphic method of truss analysis

Goals

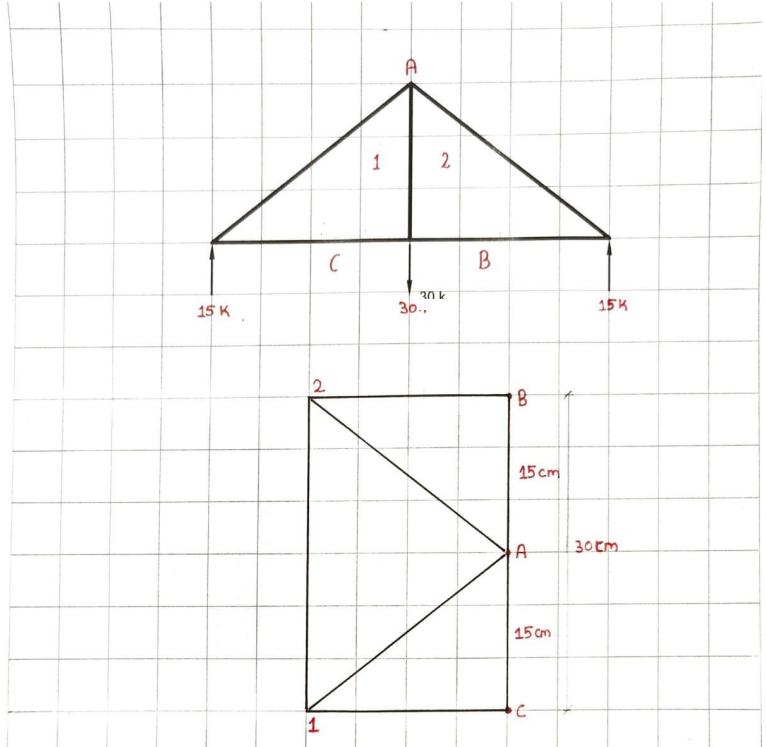
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

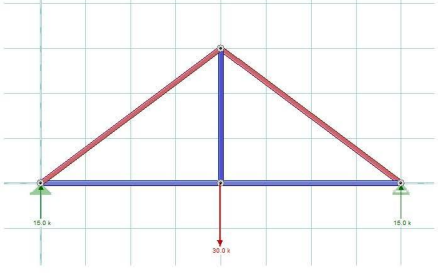
This project provides opportunity to explore the graphic method of truss analysis

Goals

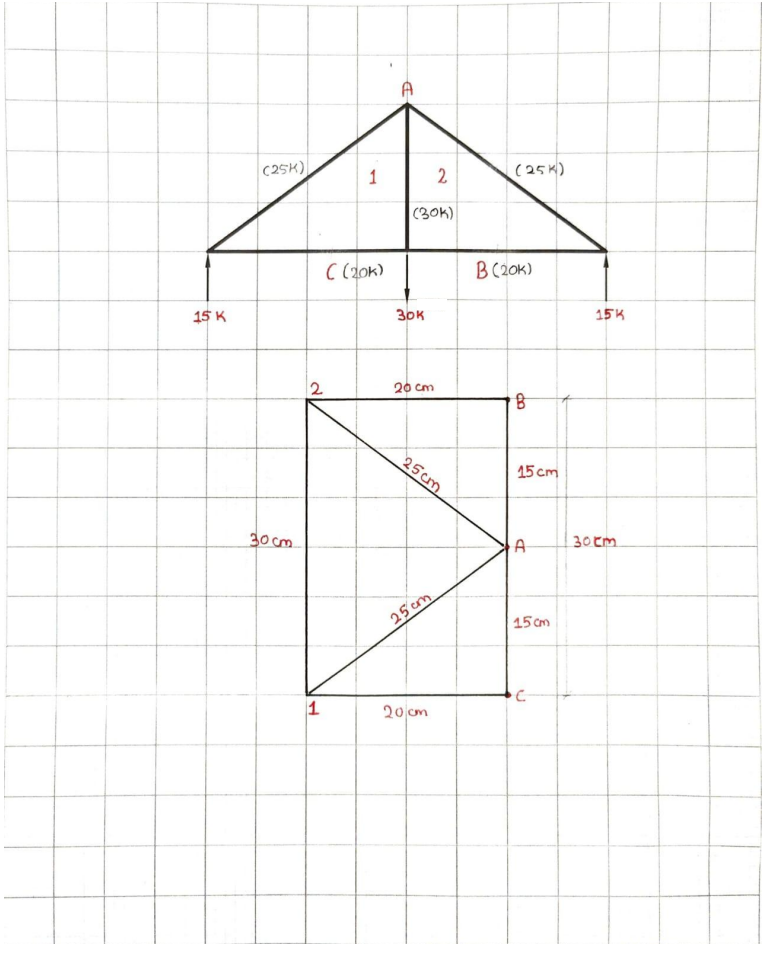
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

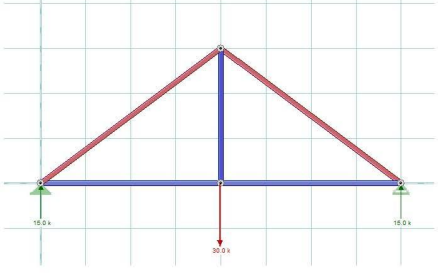
This project provides opportunity to explore the graphic method of truss analysis

Goals

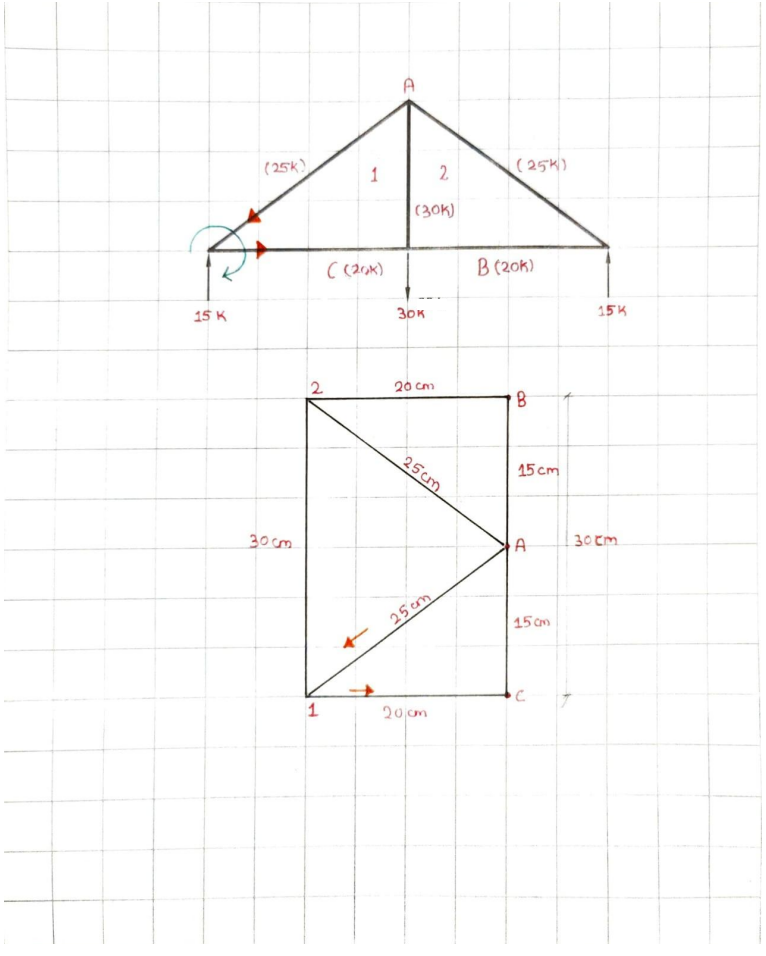
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

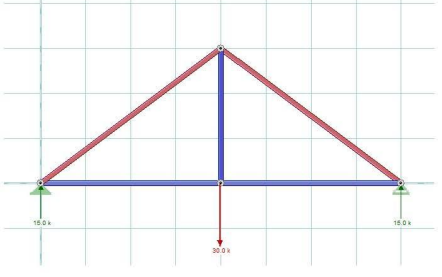
This project provides opportunity to explore the graphic method of truss analysis

Goals

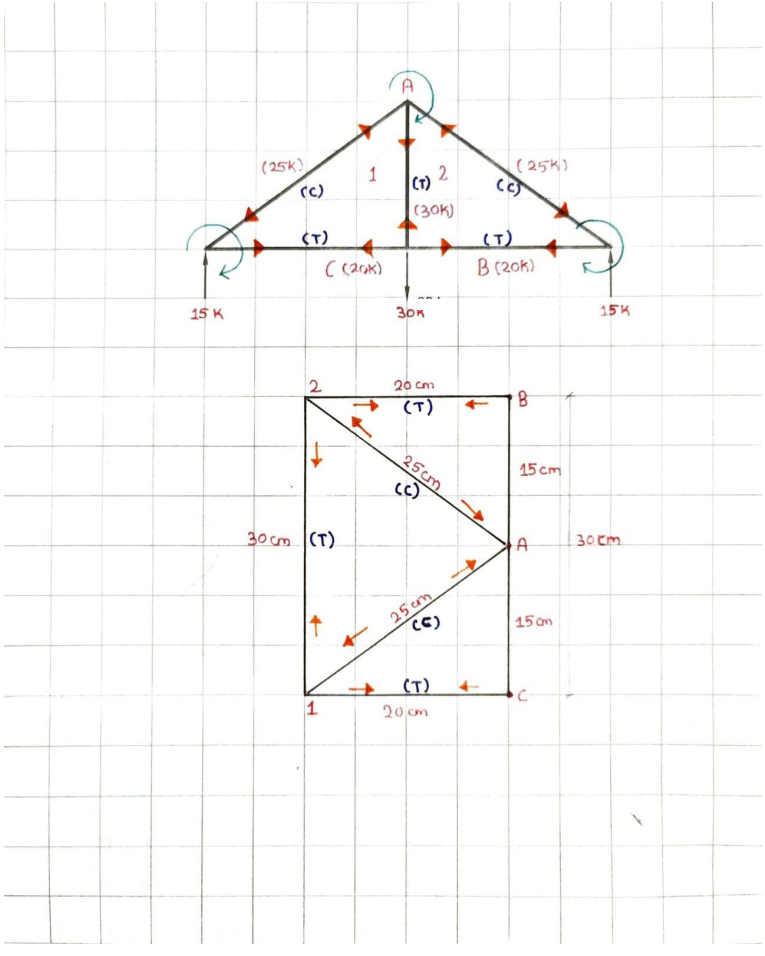
To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.



Analysis of Truss by Graphical Method:



Graphic Statics

Description

This project provides opportunity to explore the graphic method of truss analysis

Goals

To draw a graphic force diagram for a given truss.
To determine the member forces.

Procedure

1. Determine the end reactions for the given king post truss.
2. Label the external cells. (A, B, C)
3. Label the internal cells. (1, 2)
4. Draw the force vectors. (*AB*, *BC*, *CA*)
5. Draw vector *C1* through point C.
6. Draw vector *A1* through point A.
7. Label the intersection of *C1* and *A1* as point 1.
8. Draw vector *B2* through point B.
9. Draw vector *A2* through point A.
10. Label the intersection of B2 and A2 as point 2.
11. Draw vector *12* connecting points 1 and 2.
12. Measure each vector to determine the force in the member.
13. Record the force value next to the member on the truss drawing.