HOW TO ACE STATICS

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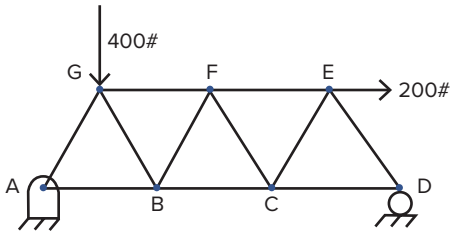
INTRODUCTION TO TRUSSES, FRAMES, AND MACHINES

WATCH VIDEO

STATICS LESSON 37
Introduction to Trusses, Frames, and Machines

This entire topic is about finding the internal force(s) in connections or members in trusses, frames, and machines.

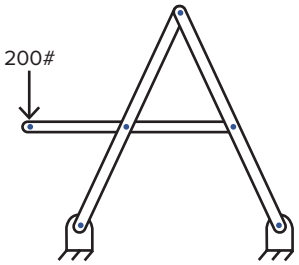
TRUSS



- Trusses are made entirely of two force members
- All members are assumed to be pin connected
- Weight of the members are assumed negligible
- Loaded only at the joints. No forces at the middle!
- Methods for solving include:
  - Method of joints
  - Method of sections

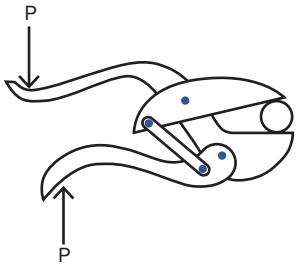
Note the # symbol is used to represent pounds force, sometimes represented as lb, lbs, or lbf.

FRAME



- Difference between truss and a frame is that it contains multiforce members and not only loaded at the pins
  - Reminder: A multiforce member has more than two forces or moments (can be loaded along its length and not only at the ends)
- Frames do not have to be pinned connected

MACHINE



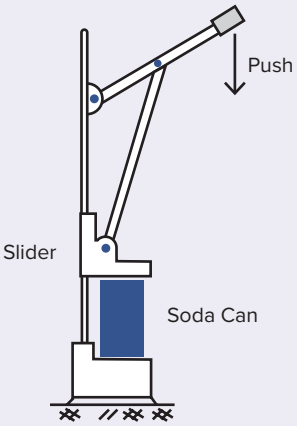
- Machines have moving parts
- Can contain the same characteristics as a frame except it does not necessarily require a reaction force with the ground (i.e. it is not hooked to the world so you don't need to find global equilibrium)

TEST YOURSELF

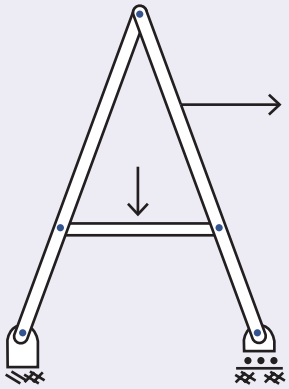
SOLUTION TO TEST YOURSELF: Trusses, Frames, and Machines

Trusses, Frames, and Machines

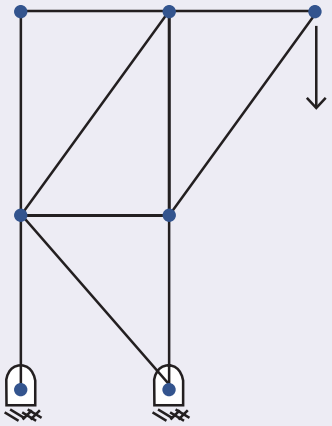
Label the images as either a truss, machine, or frame.



1



2



3

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9

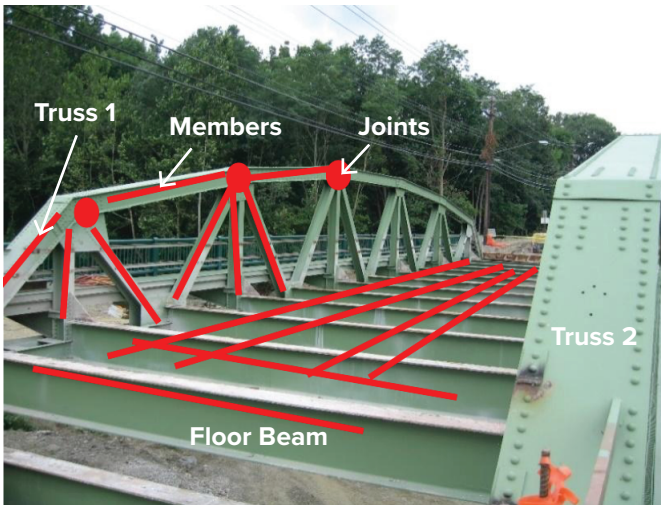
TRUSSES

Why Do I Need to Know About Trusses?

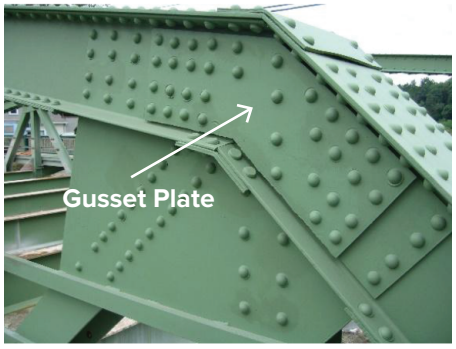
When engineers design bridges in order to correctly size the members of the truss, they have to know the forces carried in each member of the truss. Some common questions that engineers might want to answer are:

- Is the bridge safe under given loading?
- Might it fail?
- Does it need repair?

A bridge consists of the following parts:



The joints are the location where different members of the truss are joined together typically via welding, riveting, or bolting them to a gusset plate. In a truss we often call gusset plates a joint.



To simplify gusset plates (joints) between members we:

- Ignore the weight of the members
- Assume that the loads are concentrated at the ends (so pin-connected).

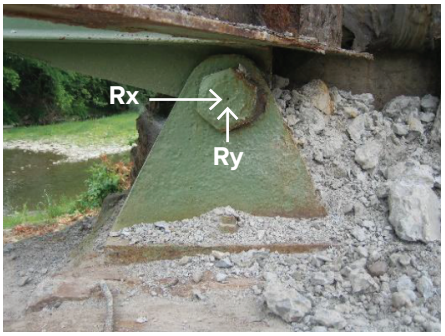
Pins and rollers are common reaction forces at supports as it allows for expansion and contraction due to temperature changes.

ROLLER OR ROCKER

[1] *Reaction force*

- Allows the bridge to expand and contract easily without breaking
- Restricts vertical movement only [Ry] (it allows movement in the horizontal direction)
- When replaced with a reaction force, the force only exists in vertical direction

PIN



[2] *Reaction forces*

- Common assumption is that the pin is frictionless
- Restricts horizontal [Rx] and vertical movement [Ry]

Sign Convention for Truss Structures: Tension or Compression

Need a Refresher?

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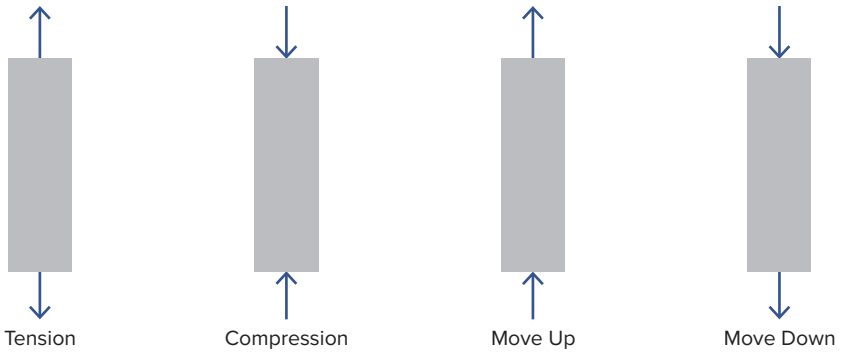
STATICS LESSON 30
System Equilibrium, 2D Reactions at the Supports

Members in a truss are either in tension (*pulling apart*) or compression (*pushing together*). If this wasn't the case and both arrows pointed in the same direction, then the entire member would be moving in the direction of the arrows.



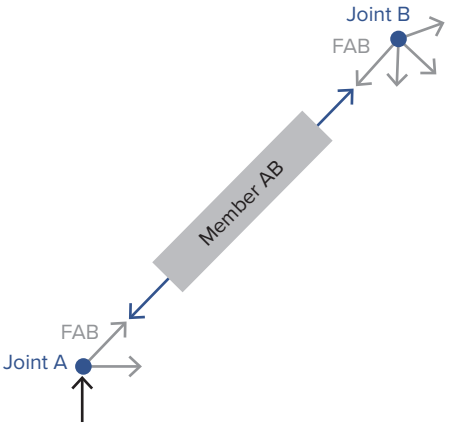
Whether a member is in tension or compression is important because:

- Members can fail differently when experiencing tension or compression
- Some materials behave differently when experiencing tension or compression

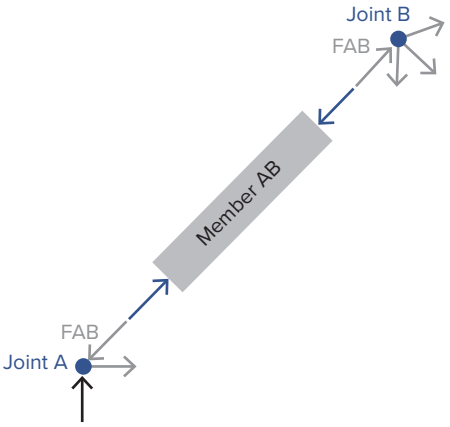
According to Newton's 3rd law (for every action there is an equal and opposite reaction):

- If you assume the forces are pointed away from a joint, then you are assuming member is in tension
- If you assume the forces are pointed toward a joint, then you are assuming member is in compression

MEMBER AB IN TENSION



MEMBER AB IN COMPRESSION



CAUTION

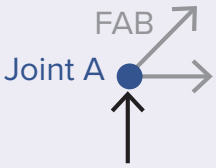
When solving problems, if you get a negative sign when solving for FAB, then it is opposite to what you assumed!

TEST YOURSELF

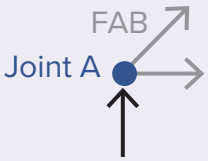
SOLUTION TO TEST YOURSELF: Tension versus Compression

Tension versus Compression

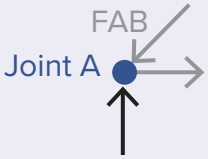
If you drew your FBD as shown in the images below, answer each question.



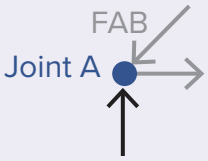
1. If you drew your FBD like this and you find FAB is positive, then member AB is in:



2. If you drew your FBD like this and you find FAB is negative, then member AB is in:



3. If you drew your FBD like this and you find FAB is positive, then member AB is in:



4. If you drew your FBD like this and you find FAB is negative, then member AB is in:

Method of Joints

WATCH VIDEO **STATICS LESSON 38**
Trusses, Method of Joints

Find the force in each member and state whether in tension or compression. Fill in the following questions, and only press play after you have tried it yourself.

Method of Joints Recipe

STEP 1: Find global equilibrium (i.e., find the reactions at the supports)

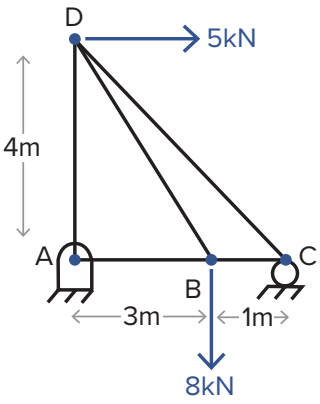
STEP 2: Select a joint
(***Note:*** Do not pick a joint with more than two unknowns)

STEP 3: Draw a free-body diagram of that joint

STEP 4: Resolve into cartesian components

STEP 5: Solve by taking sum of forces

STEP 6: Repeat



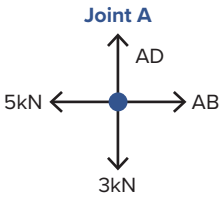
Step 1: Find Global Equilibrium

$\Sigma M_A =$

$\Sigma Fx =$

$\Sigma Fy =$

Steps 2 to 5

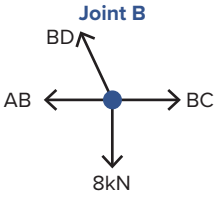


$\Sigma Fx =$

$\Sigma Fy =$

$AD =$

$AB =$

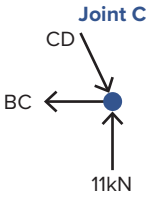


$\Sigma Fx =$

$\Sigma Fy =$

$BD =$

$BC =$



$\Sigma Fx =$

$\Sigma Fy =$

$CD =$

Method of Sections

WATCH VIDEO **STATICS LESSON 39**
Trusses, The Method of Sections

Find the force in members HG, HE, and DE. Only press play after you have tried it yourself.

Method of Sections Recipe

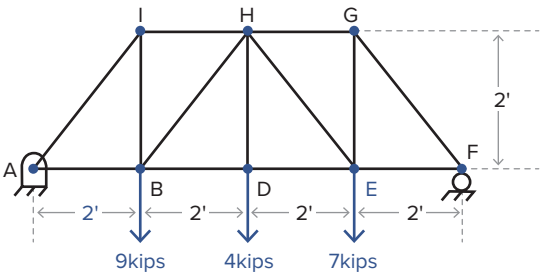
STEP 1: Find global equilibrium (i.e. find the reactions at the support)

STEP 2: Cut through members of interest
(***Note:*** Do not cut thru more than 3 members)

STEP 3: Draw a free-body diagram of the easiest side

STEP 4: Resolve into cartesian components

STEP 5: Solve by taking sum of forces and/or moments

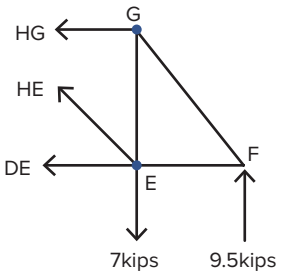


Step 1: Find Global Equilibrium

$\Sigma M_A =$

$\Sigma Fy =$

Steps 2 to 5: Cut through Members of Interest



$\Sigma M_E =$

$HG =$

$\Sigma Fy =$

$HE =$

$\Sigma Fx =$

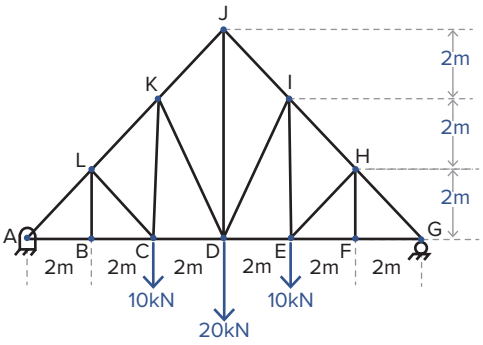
$DE =$

Identifying Zero Force Members

WATCH VIDEO

STATICS LESSON 40
Trusses, Identifying Zero Force Members

Watch the beginning of the video and press pause once you get to the problem. Find the force in every member of the truss. State whether each member is in tension or compression. Don't forget to utilize the pro-tips!



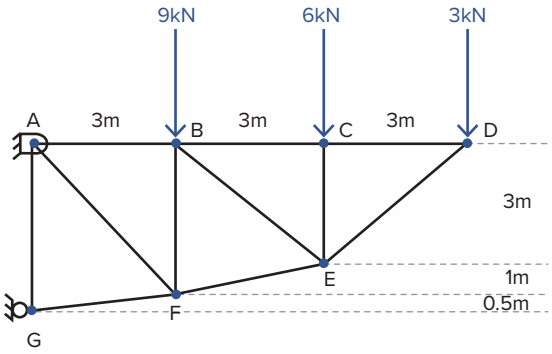
Pro Tip

- **Always look for symmetric truss with a symmetric load. You can then quickly add up all of the downward forces and divide by 2 to immediately obtain the global equilibrium.**
- **Look for zero force members**
  - **Occurs when two forces on same line of action with a third one *OR* two members not on same line of action**

WATCH VIDEO

STATICS LESSON 41
Trusses, Method of Sections, Truss Tips and Tricks

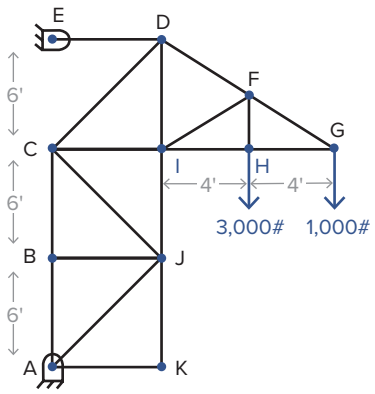
Find forces in members BC, BE, and FE. State whether each member is in tension or compression. Try working this problem out before watching the video.



WATCH VIDEO

STATICS LESSON 42
Truss Problem, The Combo Problem

Find the forces in members IJ, CJ, CB, and CI below. State whether each member is in tension or compression. Try working this problem out before watching the video.



PRACTICE PROBLEM

SOLUTION TO: Practice Problem

The ceiling truss supports the roof (and any loads on it). Now, the designer wants to hang a very heavy light fixture (1,000 lbs.) directly at the center of the bottom member of the truss. Find the forces in the two members closest to the left support. The room width is 16', height of the truss is 6', and the 2 diagonal members meet the top members at a right angle.

Trusses

Recipes for Solving Truss Problems

Method of Joints

STEP 1: Find global equilibrium (i.e., find the reactions at the supports)

STEP 2: Select a joint (***Note:*** Do not pick a joint with more than two unknowns)

STEP 3: Draw a free-body diagram of that joint

STEP 4: Resolve into cartesian components

STEP 5: Solve by taking sum of forces

STEP 6: Repeat

Method of Sections

STEP 1: Find global equilibrium (i.e. find the reactions at the support)

STEP 2: Cut thru members of interest (***Note:*** Do not cut thru more than 3 members)

STEP 3: Draw a free-body diagram of the easiest side

STEP 4: Resolve into cartesian components

STEP 5: Solve by taking sum of forces and/or moments

How Do You Know When to Use Method of Joints or Sections?

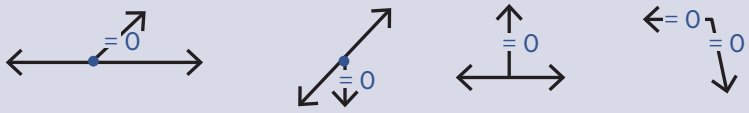
METHOD OF SECTIONS: Use when only specific members of the truss are asked for

METHOD OF JOINTS: Use if it asks for every member of a truss

Trusses

PRO TIPS

- Use different colors to draw components of angled vectors and label them to make construction of equations simpler.
- Always look for symmetric truss with a symmetric load. You can quickly add up all of the downward forces and divide by 2 to immediately obtain the global equilibrium.
- Look for zero force members
  - Occurs when two forces on same line of action with a third one *OR* two members not on same line of action
  - Example of zero force members



PITFALLS

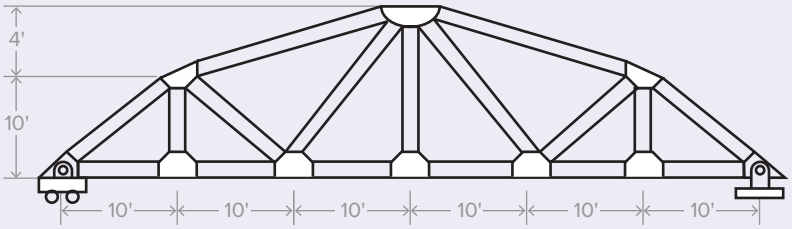
- When using method of joints, if global equilibrium is wrong then everything is wrong so take your time!
- When breaking into x and y components, make sure to correctly use sine and cosine.
- When using the method of joints, don't forget to include the external force on the joint if one exists.
- When using the method of sections, don’t cut through more than three members.
- Be consistent with labeling member forces when going from free body diagram (FBD) to free body diagram
  - Be consistent with how you assumed your arrows
  - If the arrow representing the force due to a member points away from the free body diagram of the joint, then the force due to the member has to point away in the FBD of the other joint
- If a force is going away from the joint it is tension and if going towards it is compression. If you get a negative, it is opposite from what you assumed.

REAL WORLD TRUSS PROBLEM

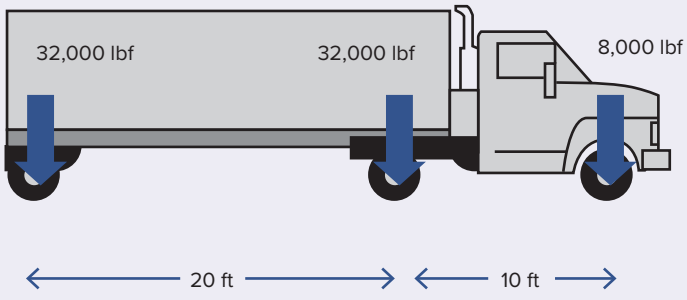
SOLUTION TO: Real World Truss Problem

Determine the forces that develop in the following bridge.

Shown below is an idealization of the actual bridge. We choose this simpler version to make our analysis easier.



The first step is to determine how the bridge truss is loaded. We will assume a truck to have the following loads:



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Real World Truss Problem *(continued)*

For this analysis assume this bridge is a single lane bridge with one truck. Because the bridge is symmetric, we are only looking at one side (left or right). Because of symmetry, each truss on the side of the roadway will take half the total load. The truck is positioned as below: