University of HUDDERSFIELD

The Engineering Design Process

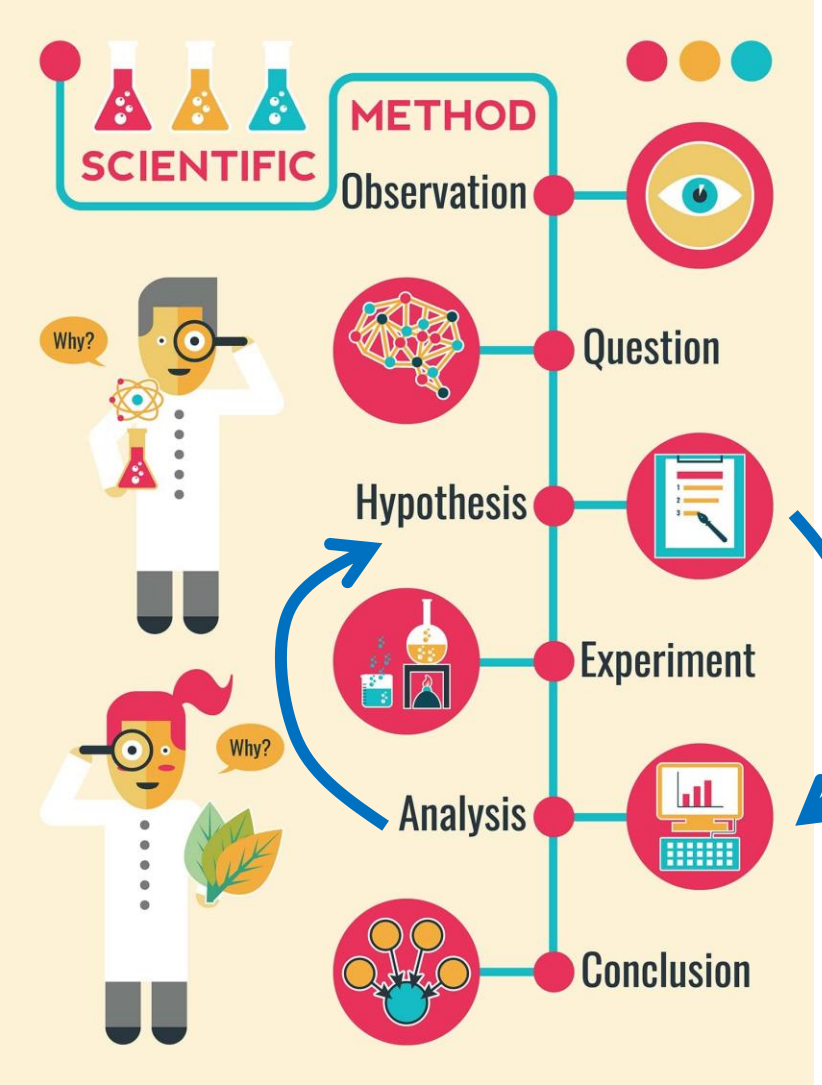
Ciprian D. Coman

Learning objectives

- ❑ to provide a broad introduction to the **Engineering Design Process**
- ❑ to illustrate some "**harder" concepts** relevant to Engineering

Assumption: familiarity with A-level Mechanics (UK)

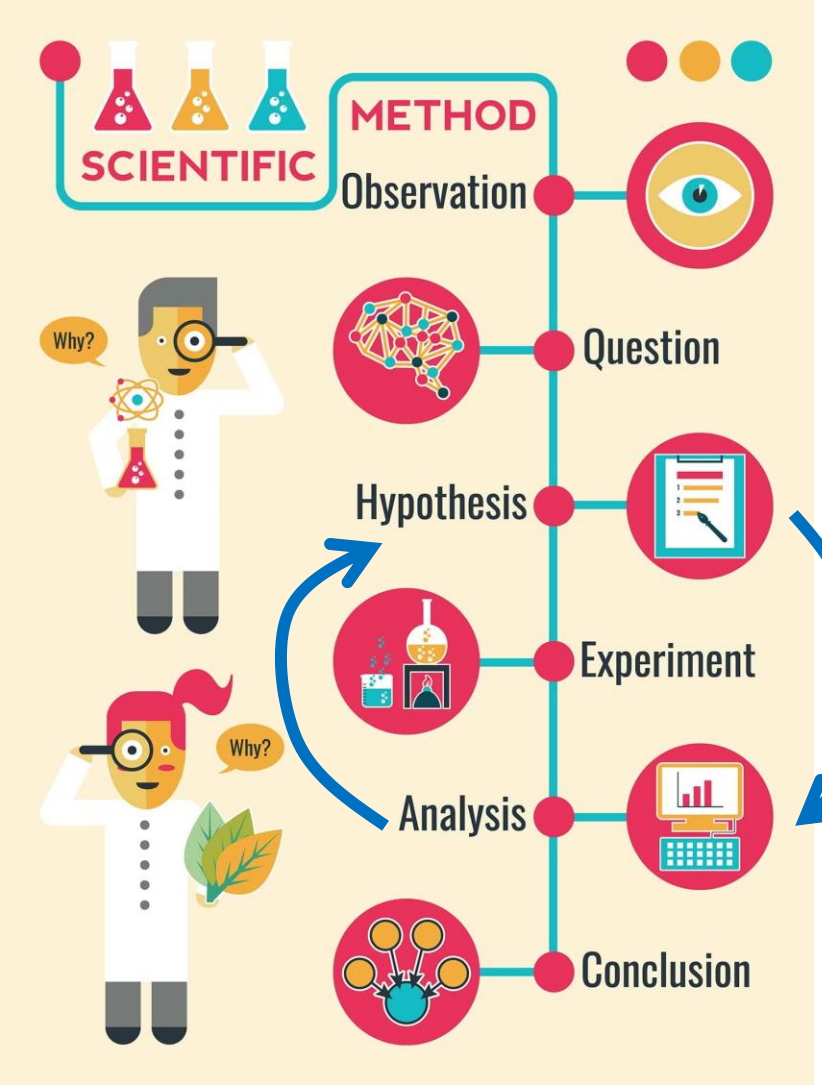
The Scientific Method



- **empirical method for acquiring knowledge**
- has been in use since the 16-17th century

feedback loop

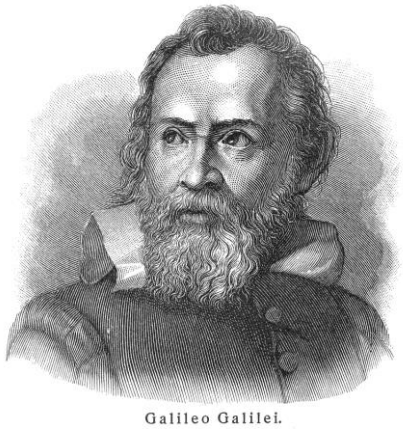
The Scientific Method

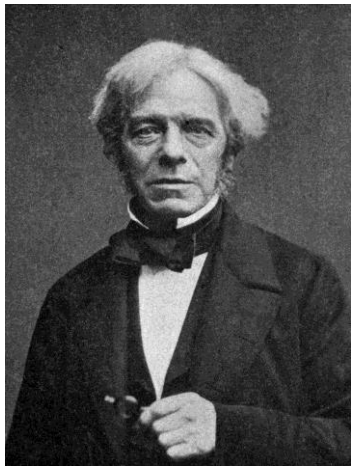


feedback loop

- ❑ empirical method for acquiring knowledge
- ❑ has been in use since the 16-17th century

(**Galileo** Galilei, Isaac **Newton**, Michael **Faraday**, etc)

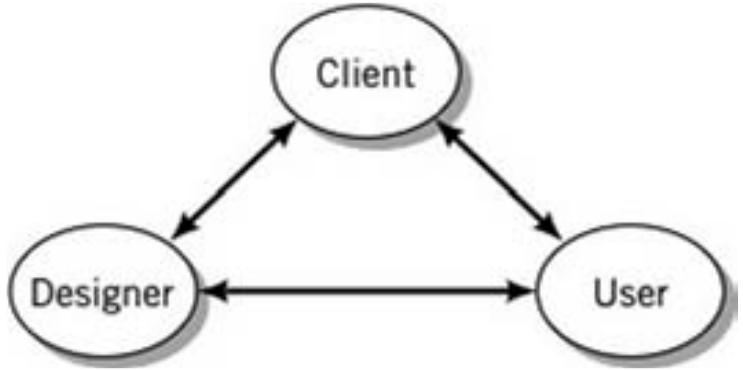

Galileo Galilei.



The Engineering Design Process (EDP)

- a **series of steps** that engineers use to guide them as they solve problems

- it is cyclical (i.e., an **iterative process**)



The **three parties** involved in the design process

Design problems are

ill-structured
(their solutions cannot be found by applying a set of mathematical formulae *in a routine way*)

open-ended
(they typically have *several* acceptable solutions)

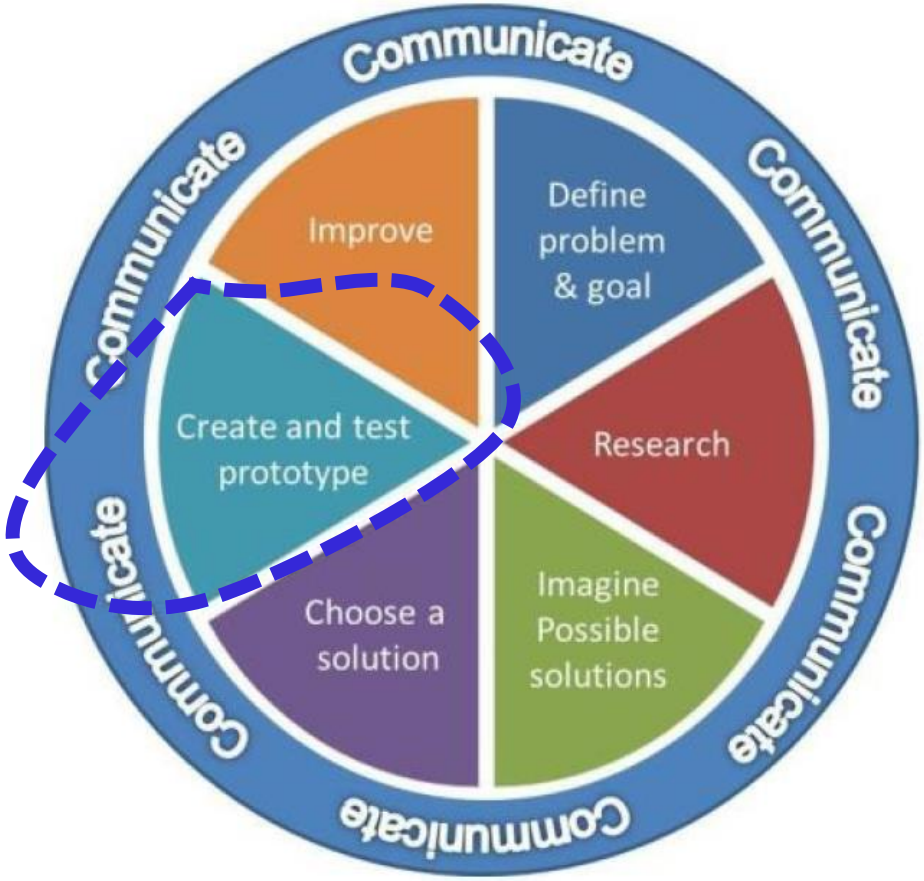
Example:





A useful tool: CAE (computer-aided engineering)

the use of computer software to simulate physics-based performance to improve product designs or assist in the resolution of engineering problems



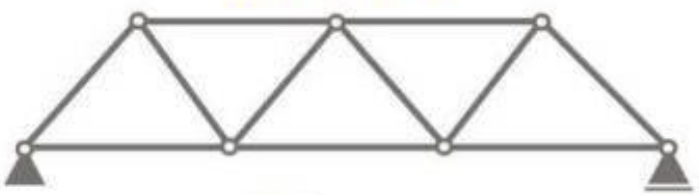
Aim: to provide a basic intro to the use of computers in engineering design

Suppose we want to design a roof support….

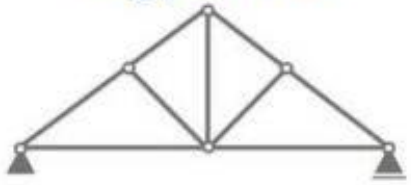
QUESTION: What's the "best" mechanical design to support **a given load**, while keeping the amount of **material** to a **minimum**?

Some possible configurations:

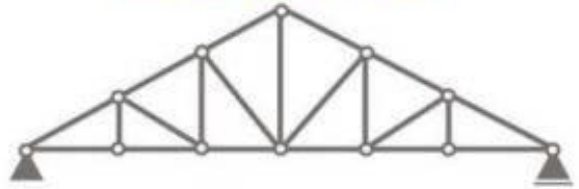
Warren truss



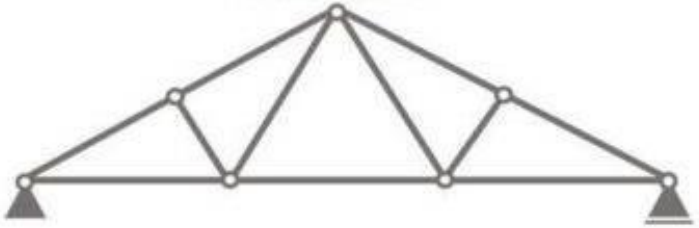
King post truss



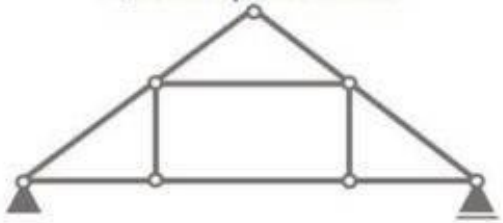
Double howe truss



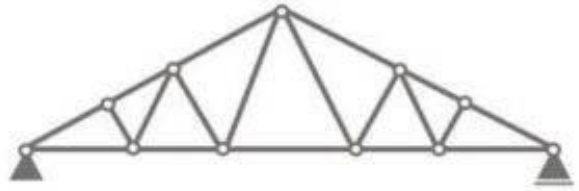
Fink truss



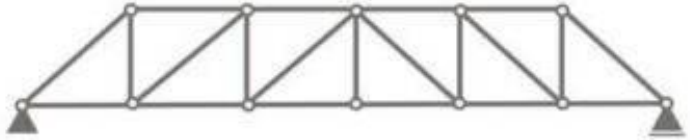
Queen post truss



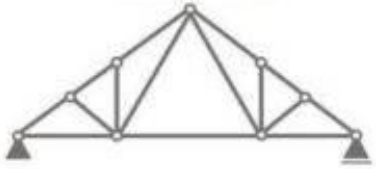
Double fink truss



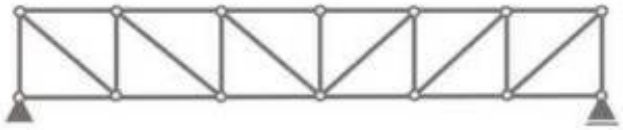
Howe truss



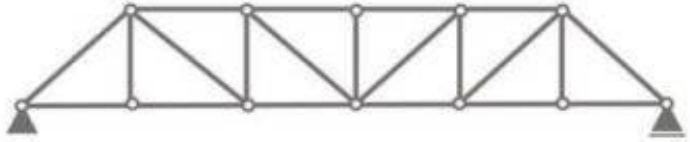
Fan truss



Flat truss



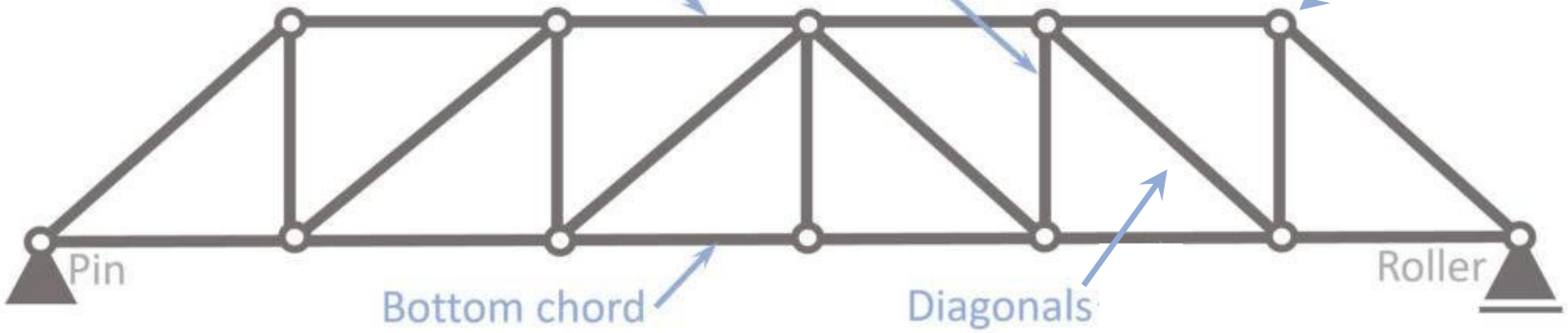
Pratt truss



Scissors truss

Terminology

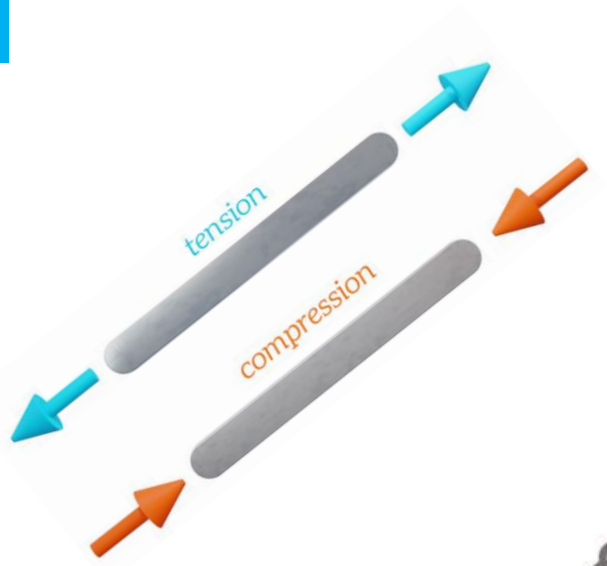
- (**2D**) **Trusses** are structural elements that can carry loads with relatively long spans compared to beams.

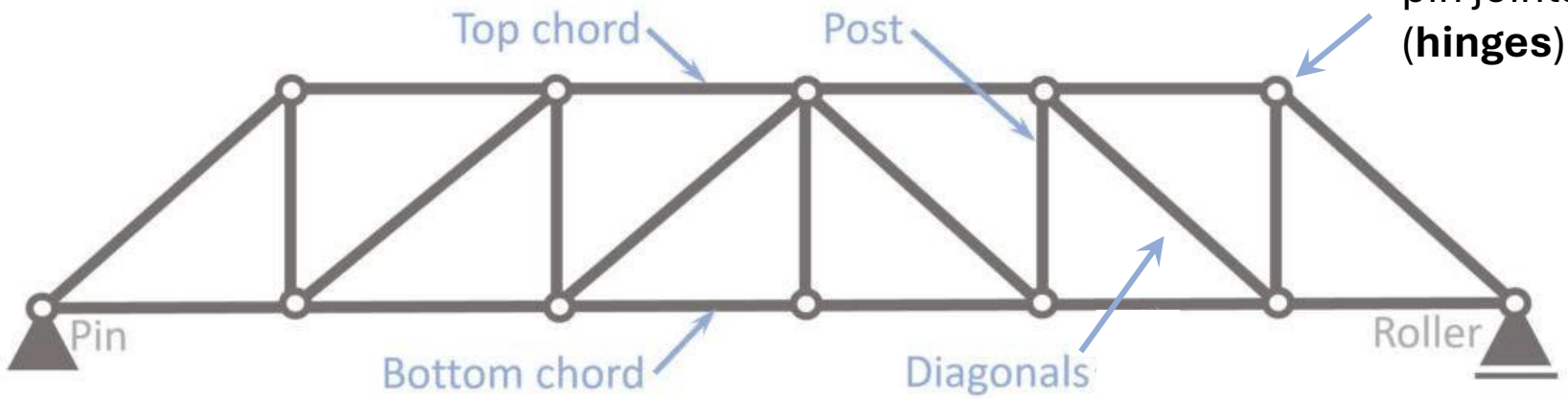


(aka **struts** or **ties**)

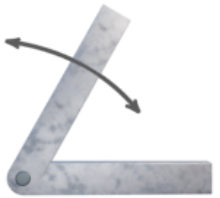
Terminology

- (**2D**) **Trusses** are structural elements that can carry loads with relatively long spans compared to beams.
- The beams in a truss are either in **tension** or in **compression**.





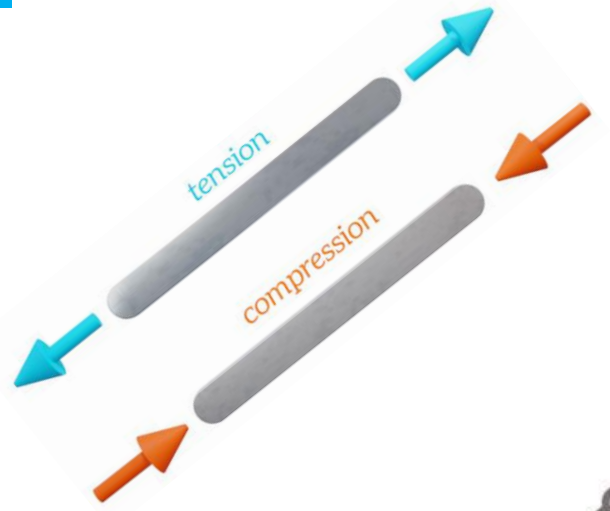
pin joints (**hinges**)

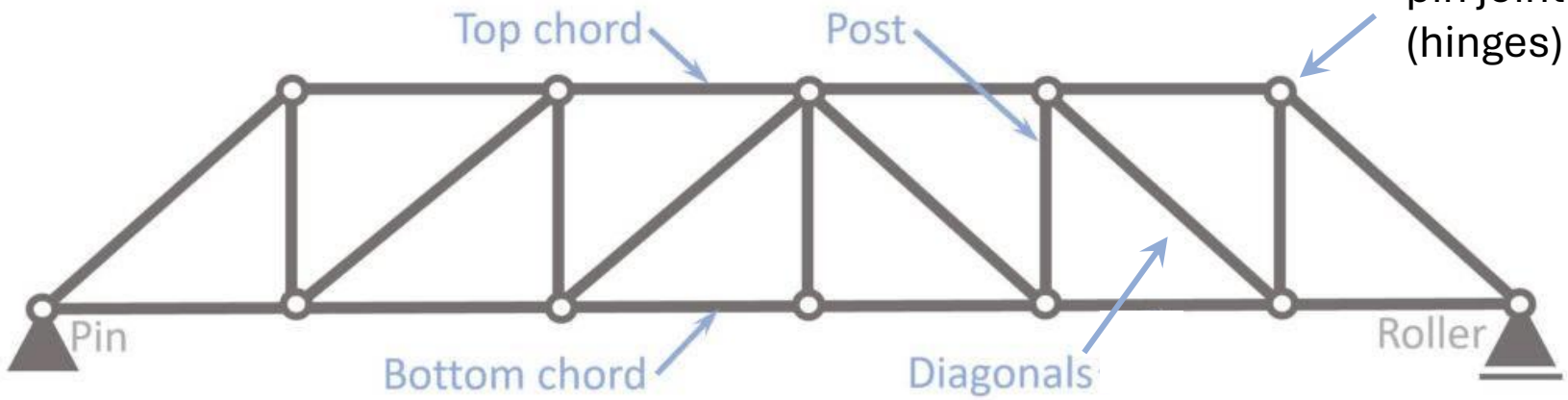


(aka **struts** or **ties**)

Terminology

- (**2D**) **Trusses** are structural elements that can carry loads with relatively long spans compared to beams.
- The beams in a truss are either in **tension** or in **compression**.
- The entire assemblage behaves as a single object.

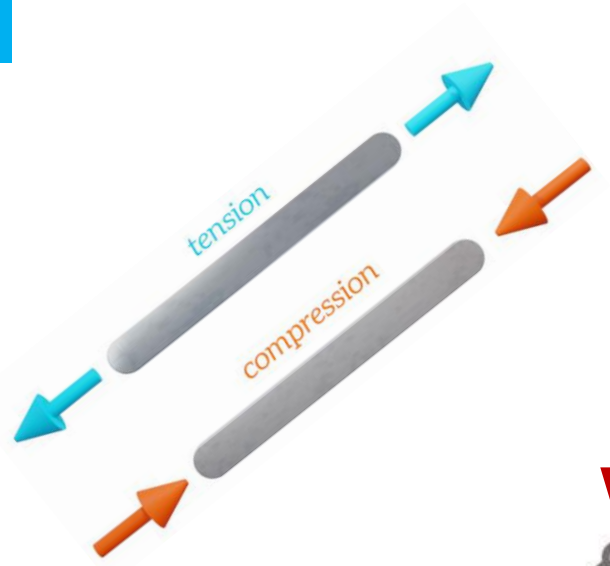


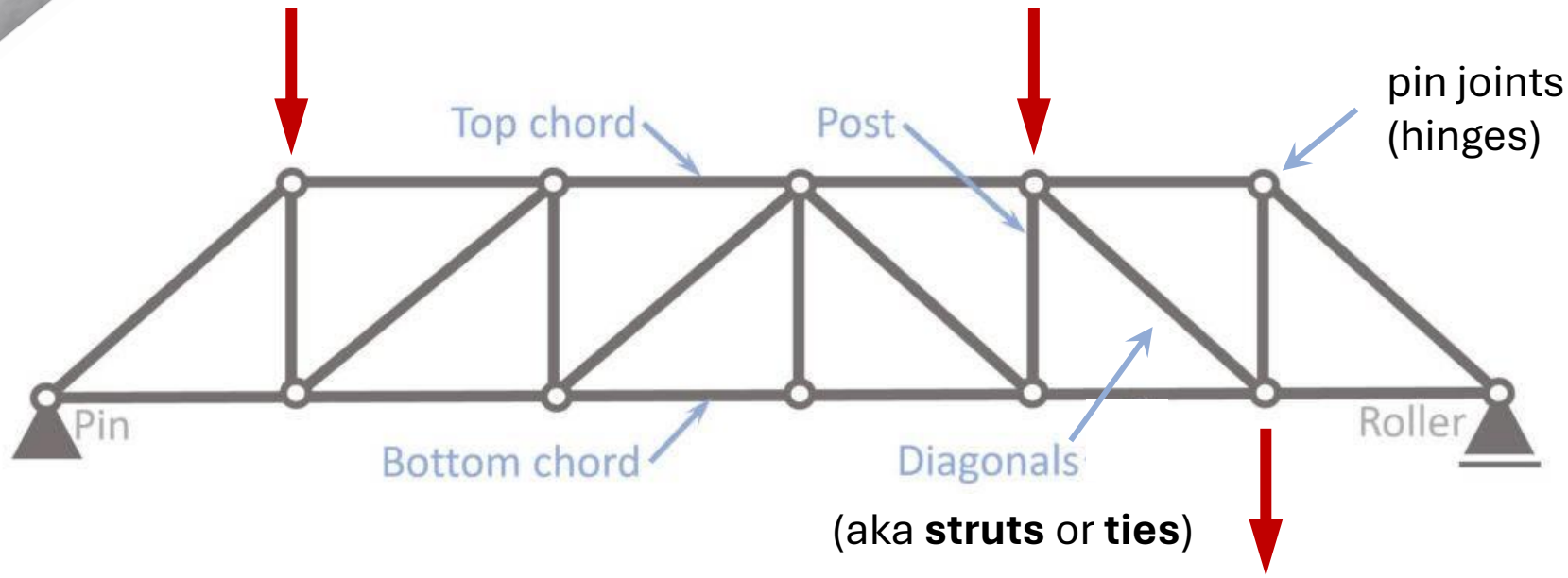


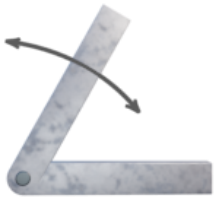
(aka **struts** or **ties**)

Terminology

- (**2D**) **Trusses** are structural elements that can carry loads with relatively long spans compared to beams.
- The beams in a truss are either in **tension** or in **compression**.
- The entire assemblage behaves as a single object.
- The **loads** on a truss are assumed to be applied at the joints.





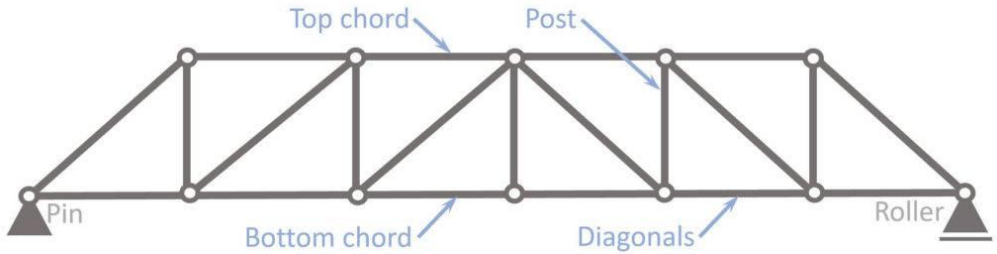


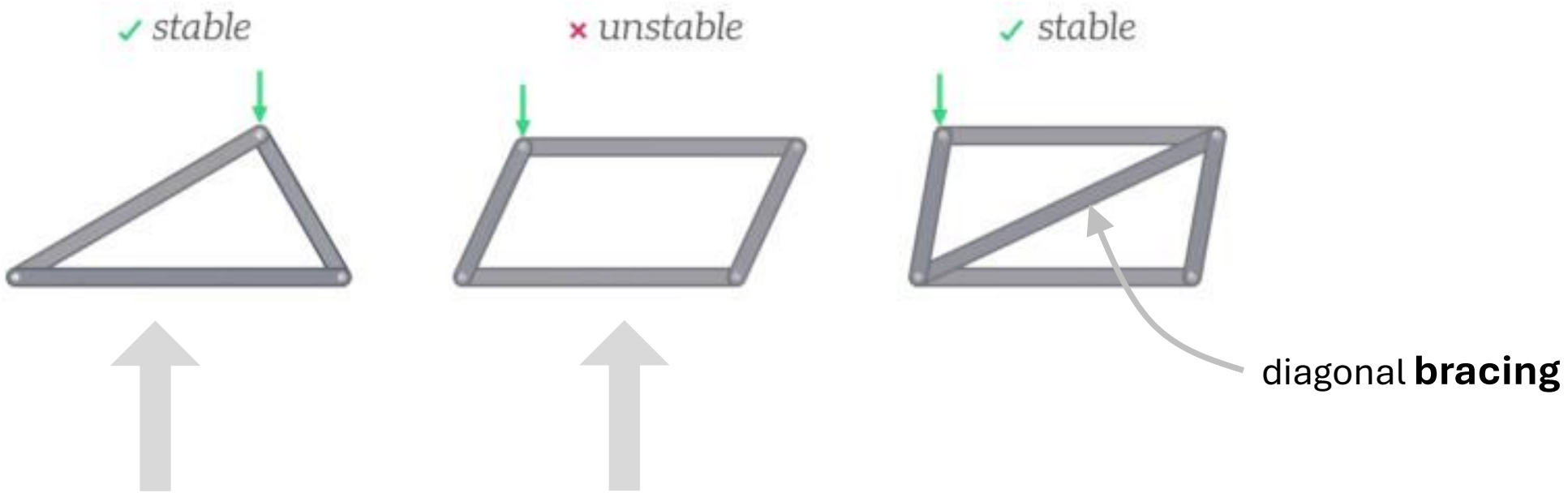
Scope

In a truss analysis problem, **member forces** are **unknown**. The purpose of such analysis is to identify the values of these forces.

For a large class of planar (or 2D) trusses, these internal forces can be found from the usual **equilibrium conditions** from *Statics* (studied at A-level). The technical name for this is the Method of Joints.

Why triangles?



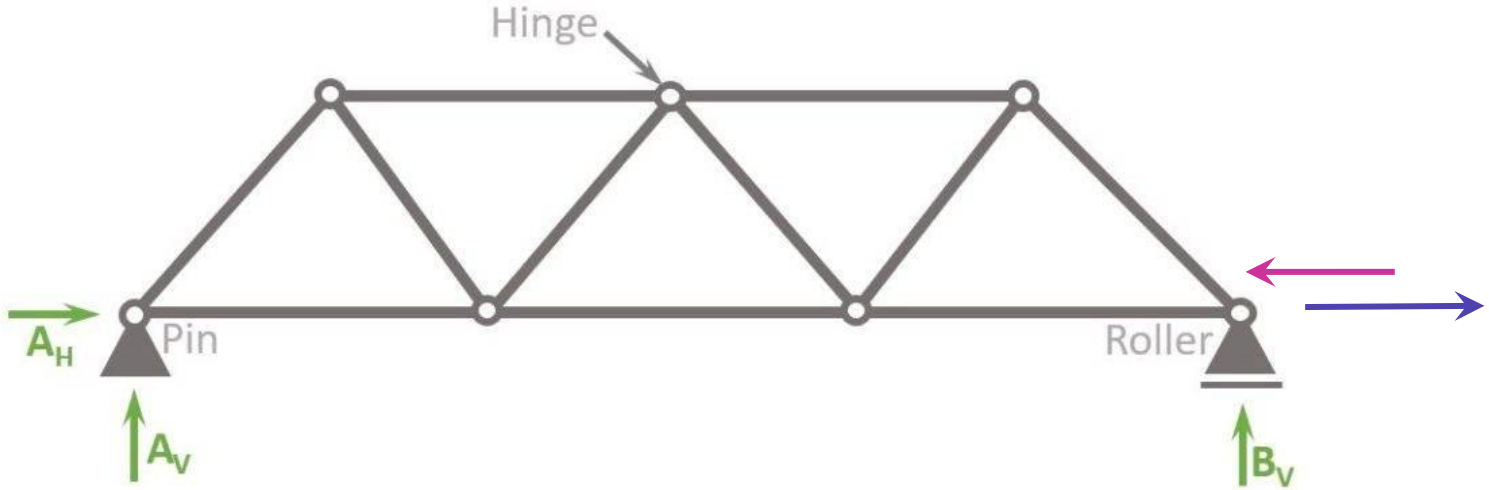


Pin-jointed triangles are **rigid**

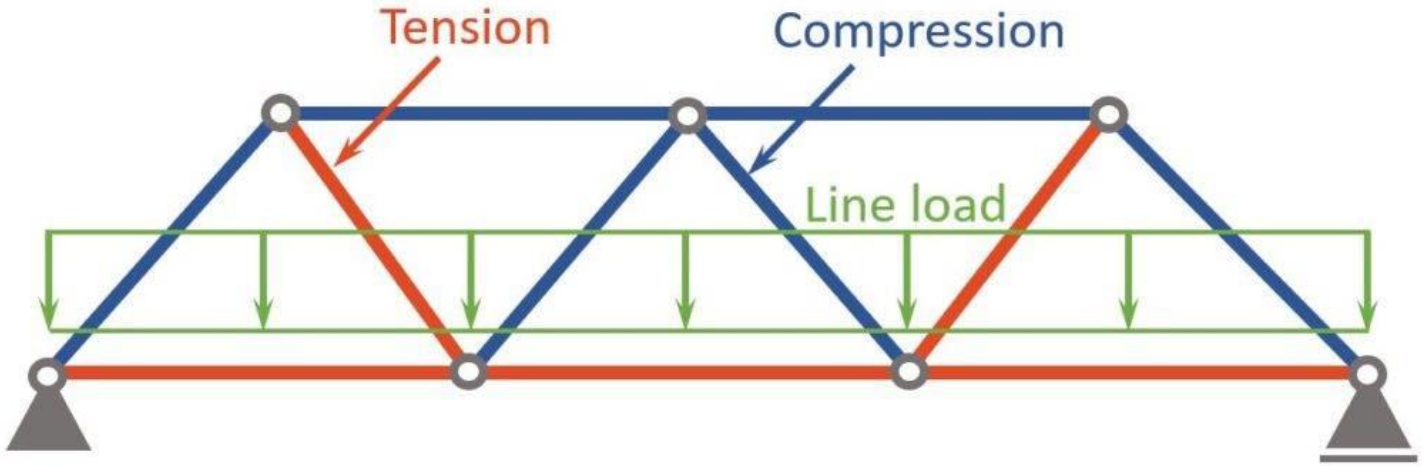
Pin-jointed rectangles are NOT **rigid**

The Warren truss

REACTION FORCES

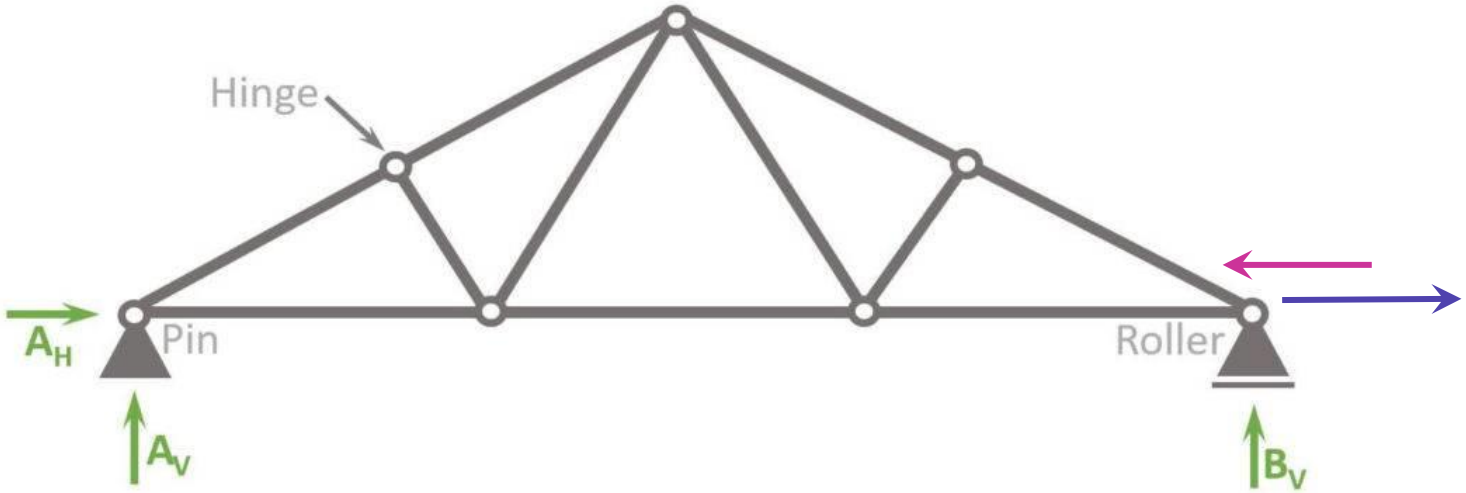


Uses: railway bridges

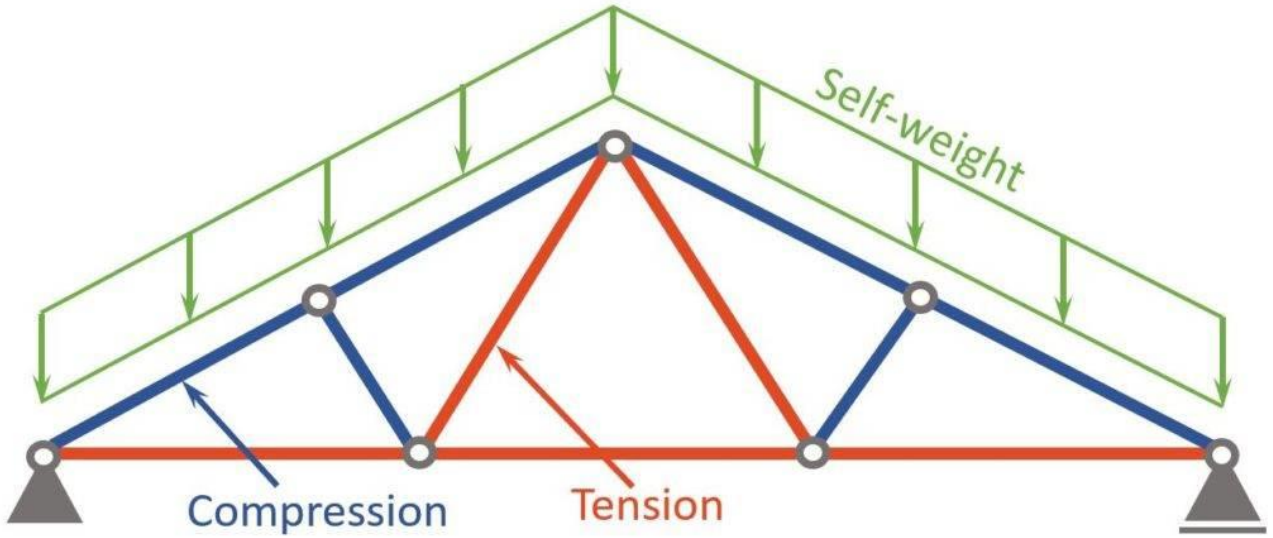


The Fink truss

REACTION FORCES

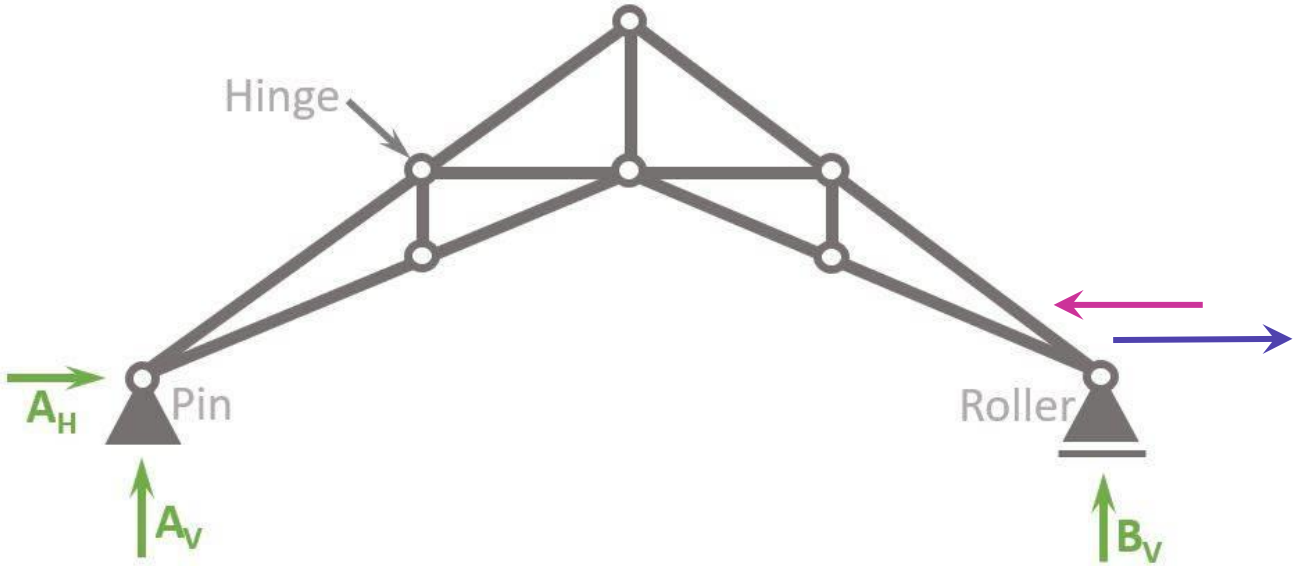


Uses: roof structures

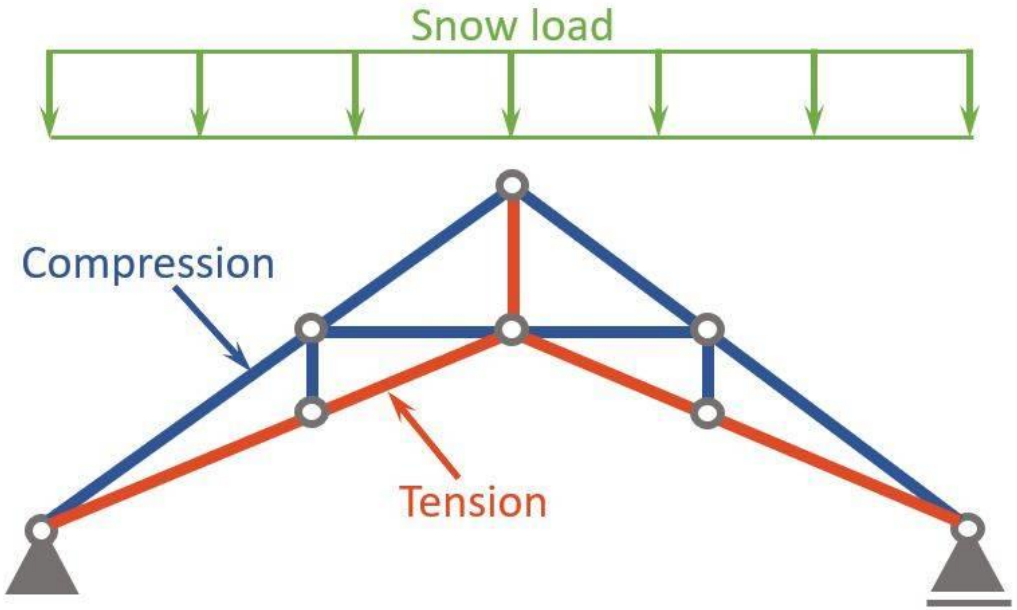


The Scissors truss

REACTION FORCES

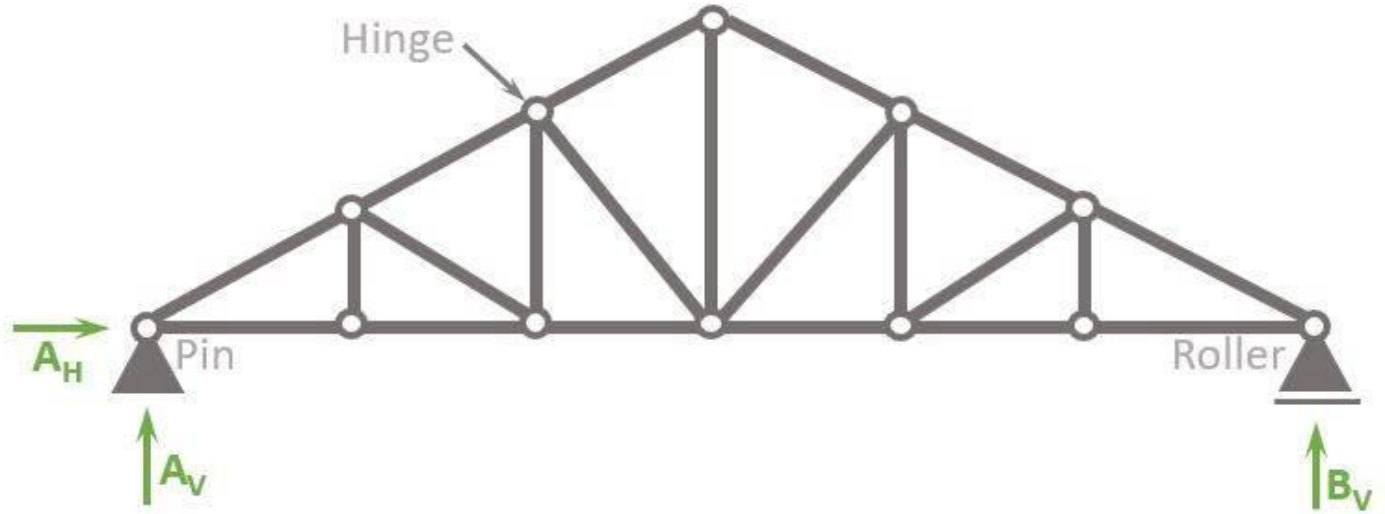


Uses: roof structures

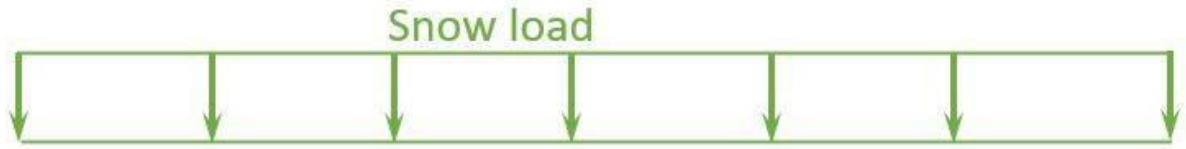


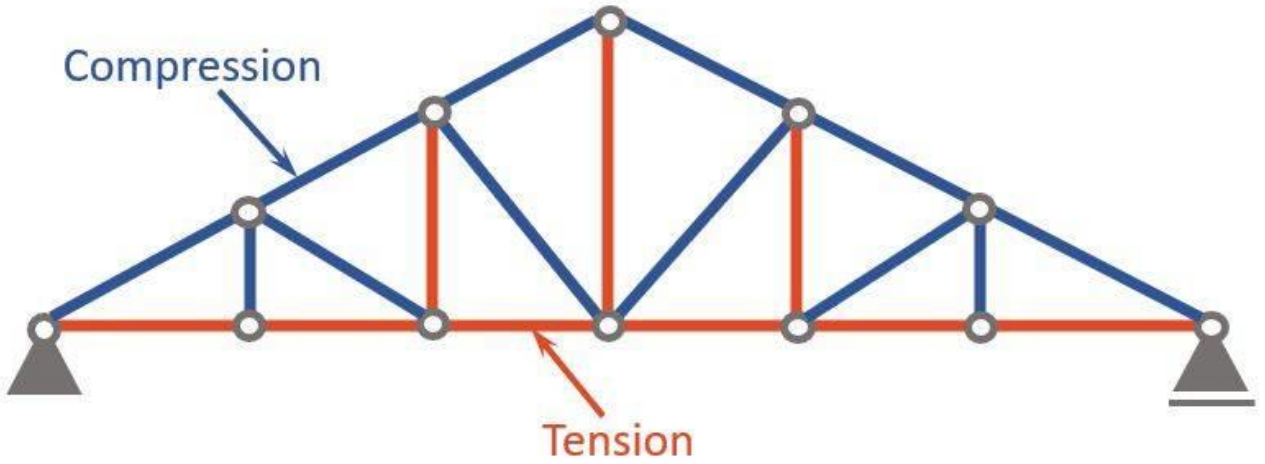
Double Howe truss

REACTION FORCES



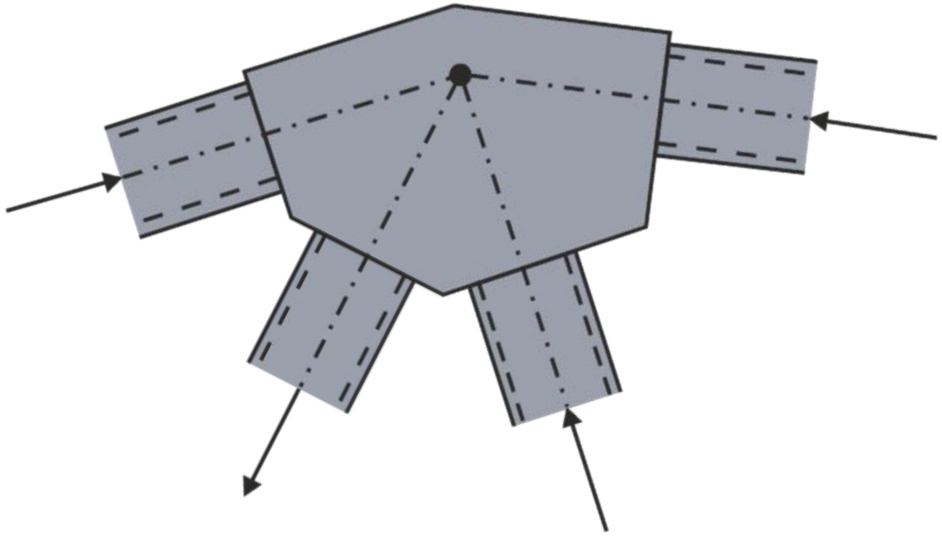
Uses: roof structures





The need for simplifications…

When structural members are connected using **welded or riveted joints**, it is generally acceptable to assume that the connection acts as a pin joint if the centrelines of the members intersect at the joint

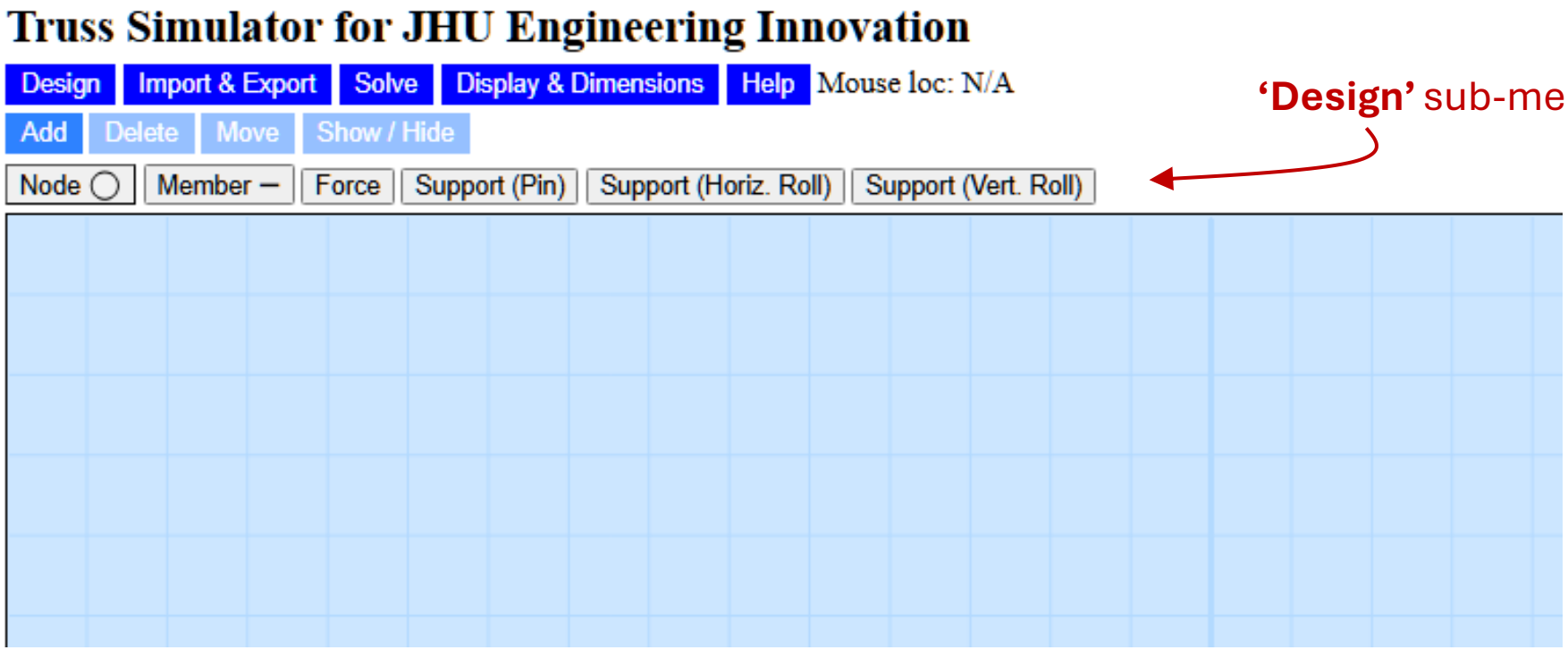


Computing the loads in a truss

- Open-source software available
- We will use the **Truss Simulator** developed at *Johns Hopkins University*

Computing the loads in a truss

- ❑ Open-source software available
- ❑ We will use the **Truss Simulator** developed at *Johns Hopkins University*



'Design' sub-menu

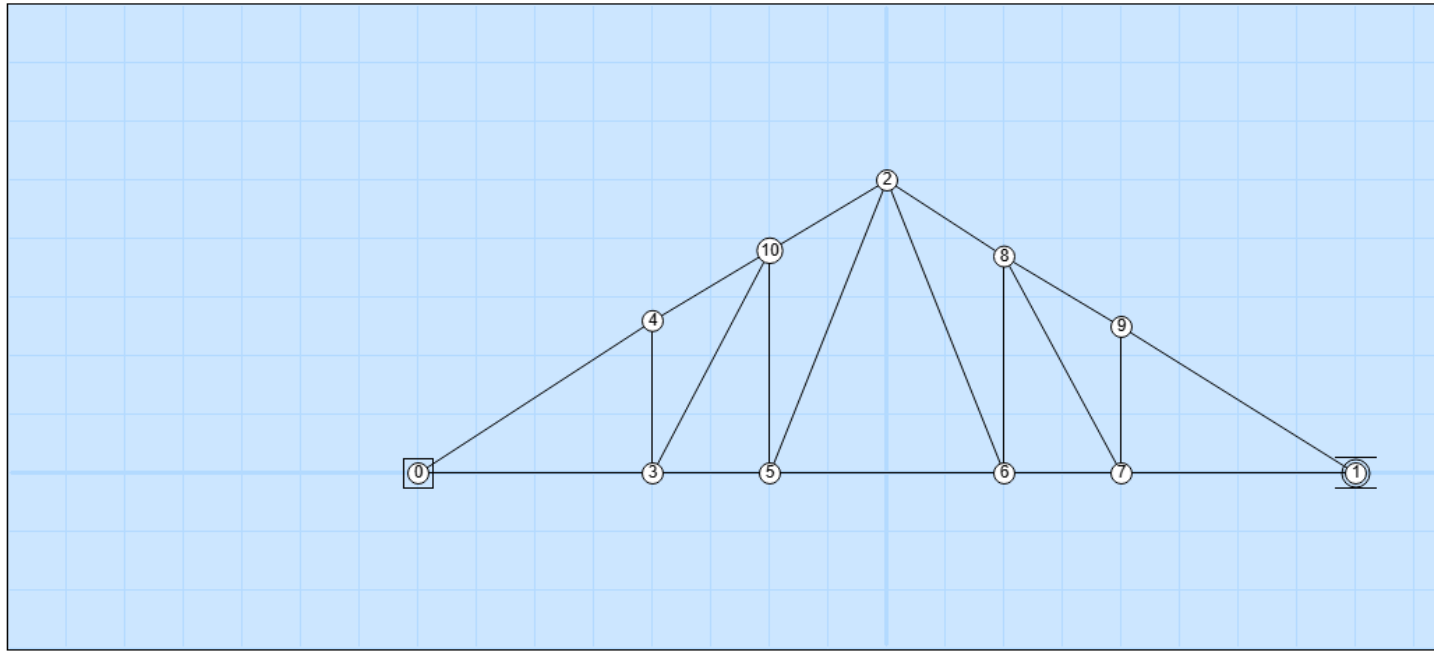
Computing the loads in a truss

Truss Simulator for JHU Engineering Innovation

Design | Import & Export | Solve | Display & Dimensions | Help | Mouse loc: (-3 cm, 7 cm)

Add | Delete | Move | Show / Hide

Node ◯ | Member — | Force | Support (Pin) | Support (Horiz. Roll) | Support (Vert. Roll)



Nodes

#	x [cm]	y [cm]
0	-8	0
1	8	0
2	0	5
3	-4	0
4	-4	2.6
5	-2	0

Members

#	Nodes	Length [cm]	Force [N]
0	0-3	4	
1	3-5	2	
2	5-6	4	
3	1-7	4	
4	6-7	2	
5	2-5	5.385	
6	2-6	5.385	

External Forces

Node	Fx [N]	Fy [N]

*Reaction forces at a support

STEP 1: ADD + NODE
STEP 2: ADD + MEMBER
STEP 3: ADD + SUPPORT (PIN)
STEP 4: ADD + SUPPORT (HORIZ ROLL)

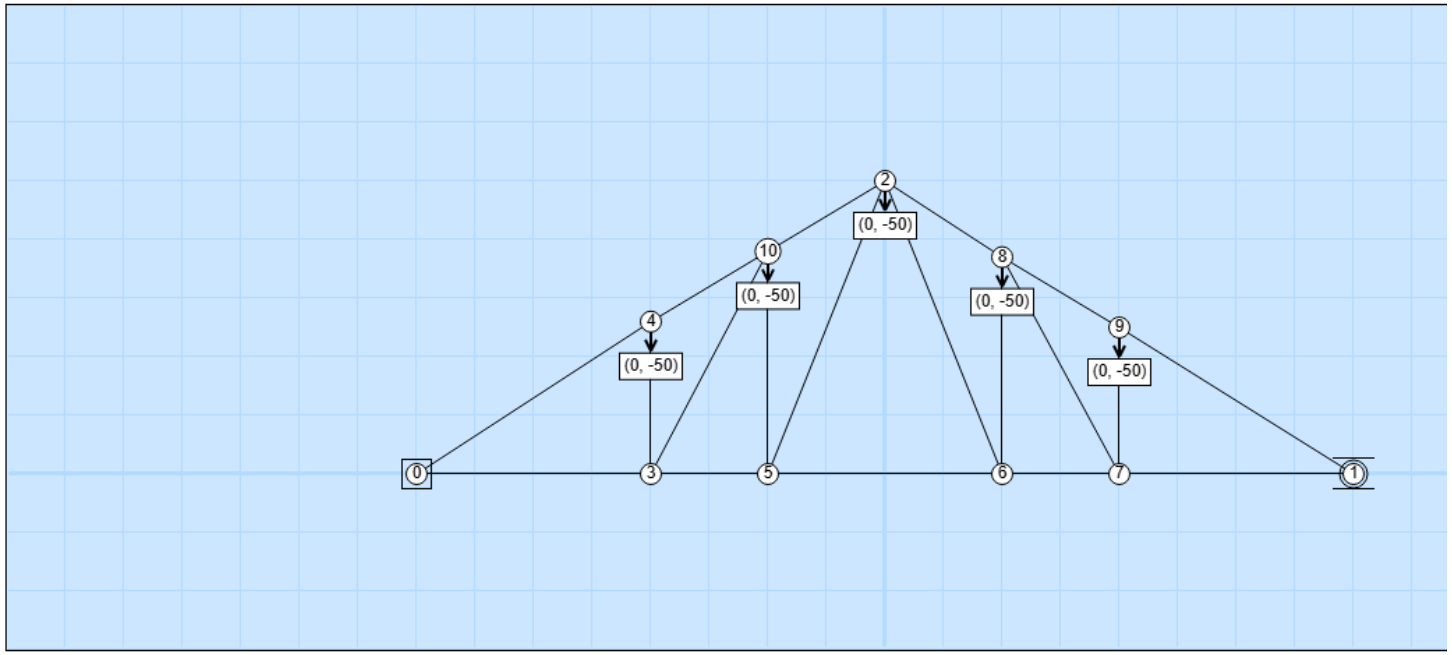
Computing the loads in a truss

Truss Simulator for JHU Engineering Innovation

Design | Import & Export | Solve | Display & Dimensions | Help | Mouse loc: N/A

Add | Delete | Move | Show / Hide

Node ◯ | Member — | Force | Support (Pin) | Support (Horiz. Roll) | Support (Vert. Roll)



Nodes

#	x [cm]	y [cm]
0	-8	0
1	8	0
2	0	5
3	-4	0
4	-4	2.6
5	-2	0

Members

#	Nodes	Length [cm]	Force [N]
0	0-3	4	192.3077
1	3-5	2	171.0526
2	5-6	4	140
3	1-7	4	200
4	6-7	2	175.6757
5	2-5	5.385	83.6118
6	2-6	5.385	96.0597

External Forces

Node	Fx [N]	Fy [N]
4	0	-50
10	0	-50
2	0	-50
8	0	-50
9	0	-50
1*	0	125

STEP 5: ADD + FORCE

Computing the loads in a truss

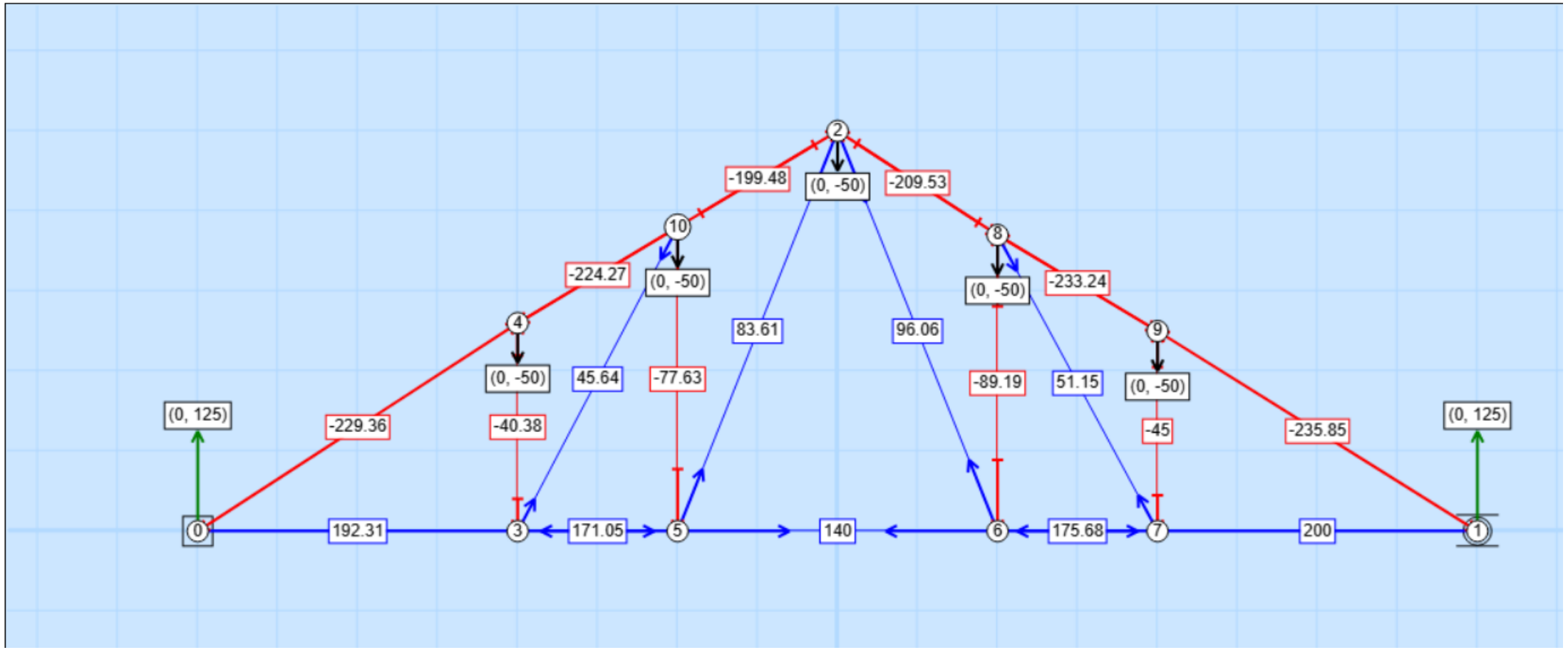
Truss Simulator for JHU Engineering Innovation

Design | Import & Export | Solve | Display & Dimensions | Help | Mouse loc: (0 cm, 5 cm)

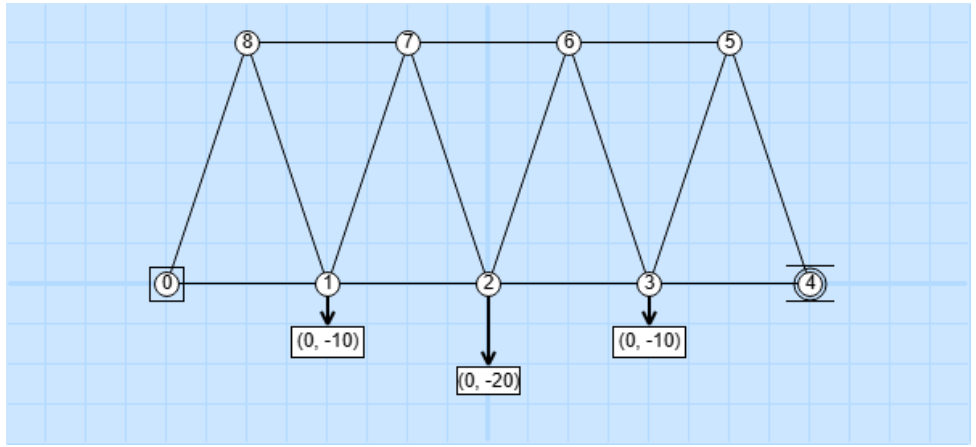
Compression (red,negative). Tension (blue,positive). Reaction forces (green).

Show matrix at bottom of page: on/off

STEP 6: SOLVE



Other designs

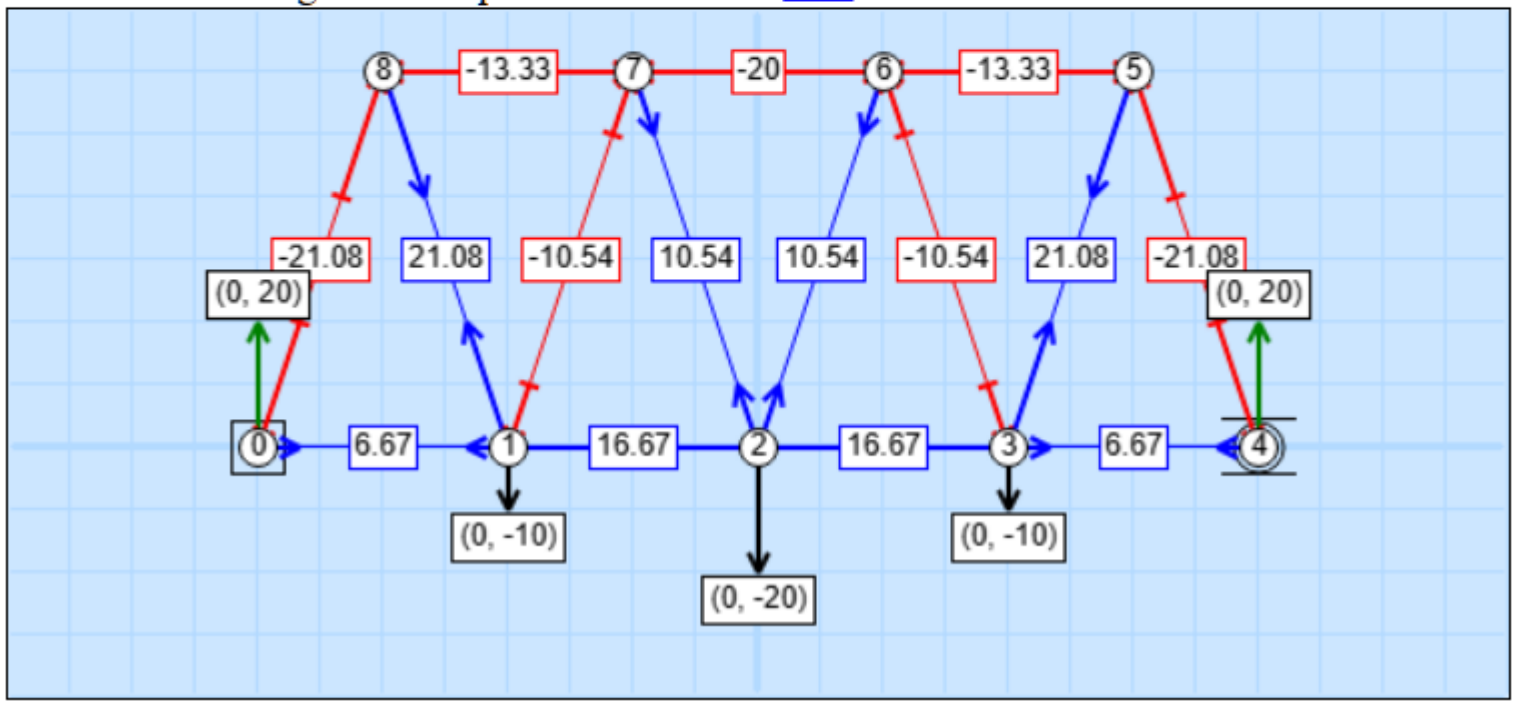


Truss Simulator for JHU Engineering Innovation

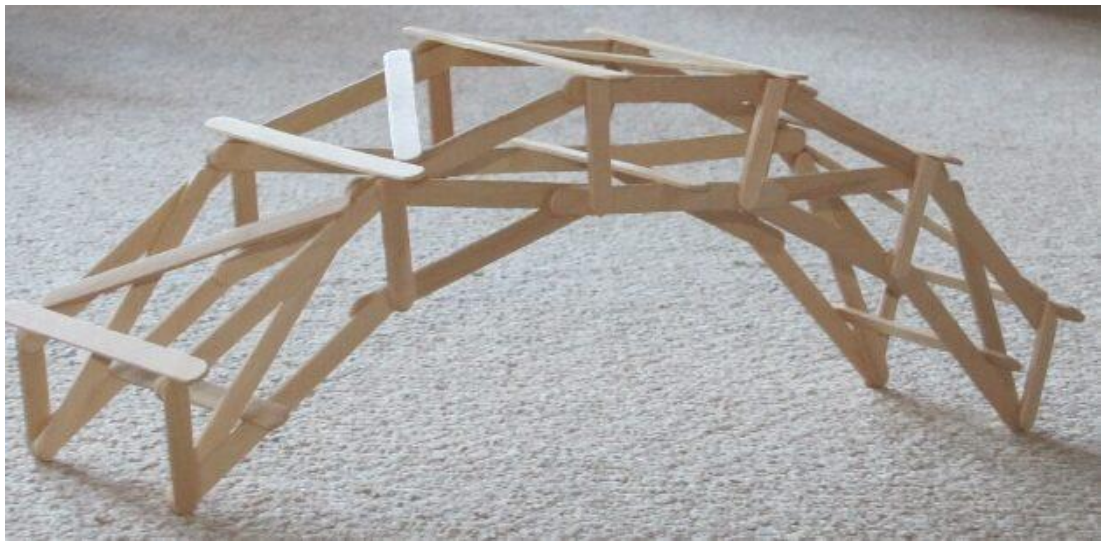
Design | Import & Export | Solve | Display & Dimensions | Help | Mouse loc: N/A

Physical Dimensions | Window Size | Zoom / Pan / Extend | Show / Hide Labels

The units of length for this simulation are **cm** and units of force are **N**.
The current workspace has a width of **12 cm** and a height of **5.5 cm**.
There is a snap grid with a spacing of **0.5 cm** in the x-direction and **0.5 cm** in the y-direction.
An arrow with length 1 cm represents a force of **20 N**.



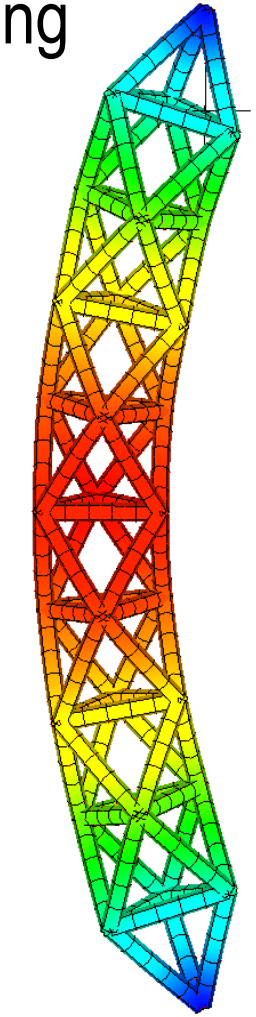
Trusses & popsicle sticks



(all pictures courtesy of Google)

Personal experiences….

global buckling



local buckling