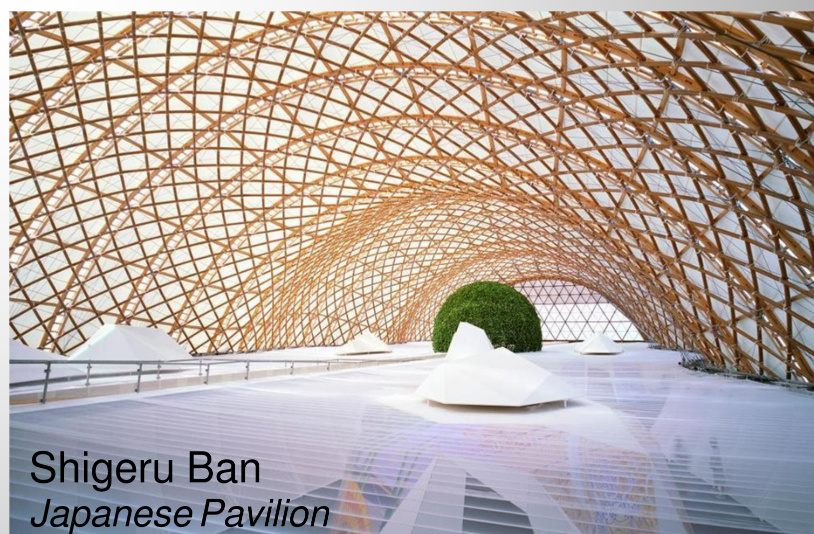
MEC-107: Basic Engineering Mechanics

Unit- 4
Analysis of Structures

Some Cool Trusses

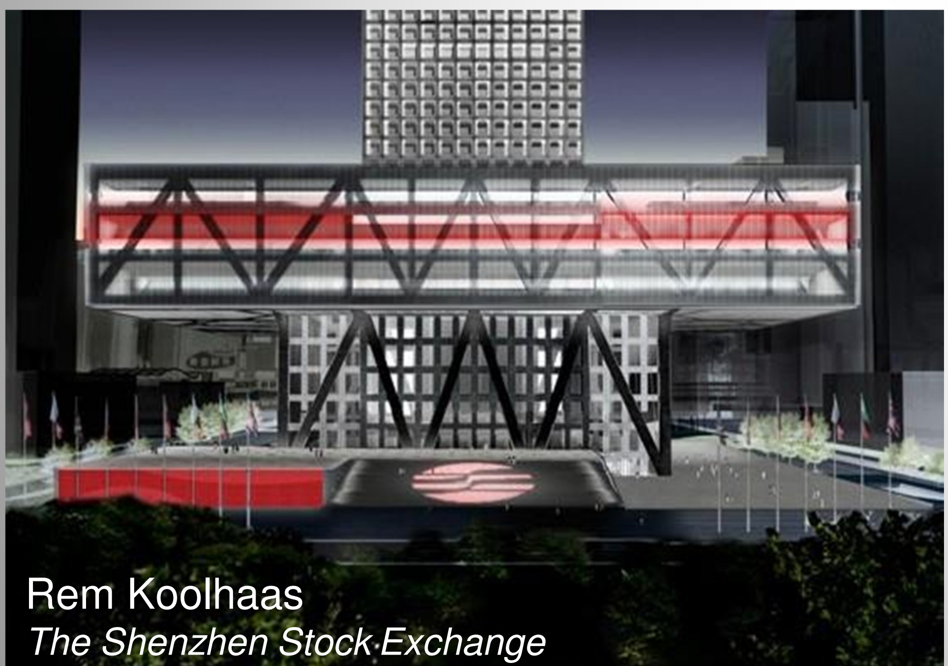
Santiago Calatrava
Turning Torso

Norman Foster
Sainsbury Centre



Shigeru Ban
Japanese Pavilion

… be inspired!



Rem Koolhaas
The Shenzhen Stock Exchange

Renzo Piano
Kansai International Airport

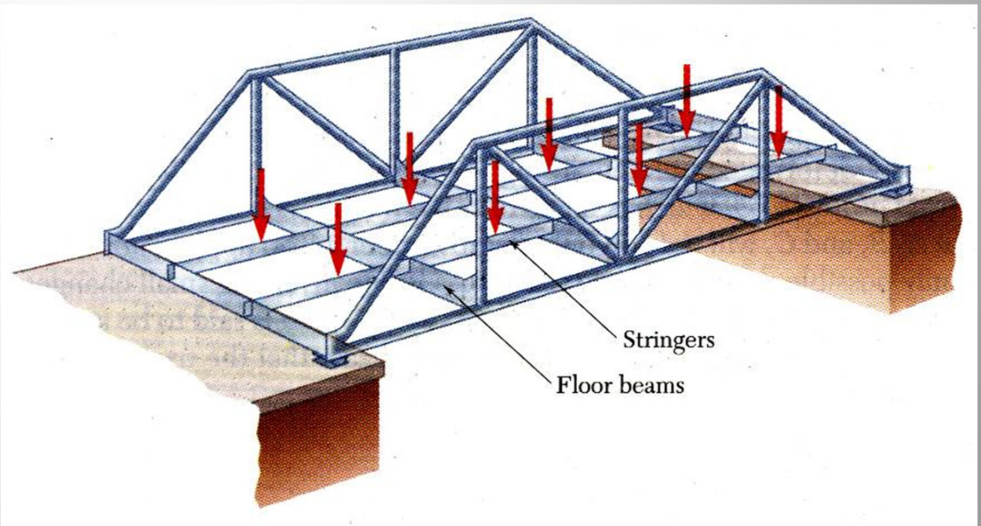
INTRODUCTION

- Trusses are commonly used to **support a roof**.
- For a given **truss geometry and load**, how can we determine the **forces** in the **truss members and select their sizes**?
- A more challenging question is that for a **given load**, how can we **design the trusses' geometry** to minimize cost?

INTRODUCTION

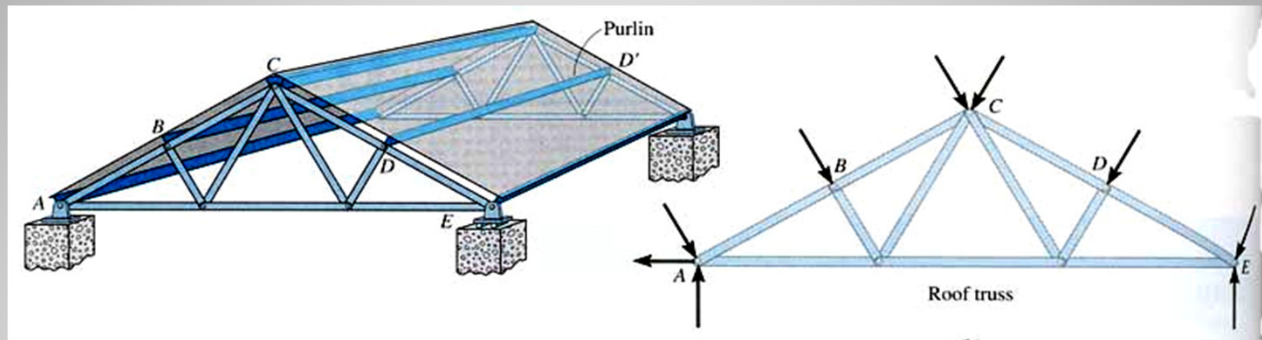
- Trusses are also used in a variety of structures like **cranes** and the **frames of aircraft or space stations**.

- How can we design a **light weight structure** that will meet **load**, **safety, and cost** specifications?

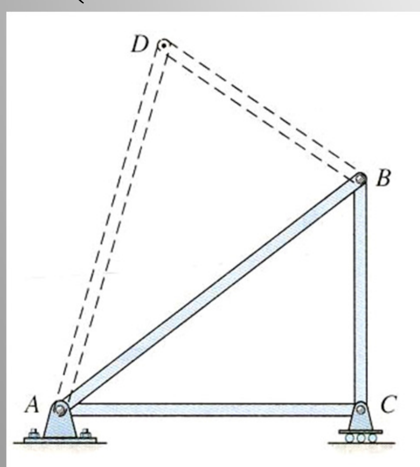


So What are Trusses?

<u>DEFINING A SIMPLE TRUSS</u>



- A **truss** is a **structure** composed of **slender members joined together** at their **end points**.
- If a truss, along with the imposed load, lies in a **single plane** (as shown at the top right), then it is called a **planar truss**.



- A **simple truss** is a **planar truss** which begins with a **triangular element** and can be expanded by adding **two members** and a **joint**.
- For these trusses, the **number of members (M)** and the **number of joints (J)** are related by the equation: $\boxed{\mathbf{M = (2J - 3)}}$.

PERFECT FRAME

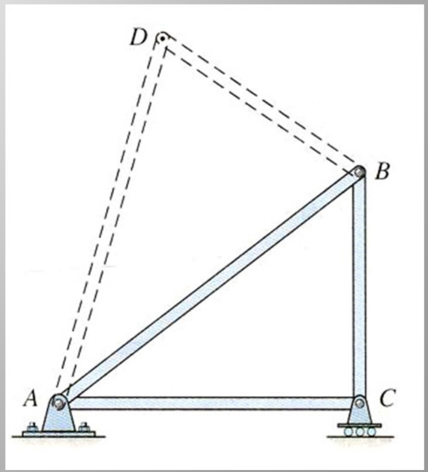
- A **pin-jointed frame** which has got just **sufficient number of members** to **resist the loads** without undergoing appreciable **deformation** in shape is called a **perfect frame**,
- **Triangular frame** is the simplest perfect frame and it has **03 joints and 03 members**,
- It may be observed that to **increase one joint** in a perfect frame, **two more members** are required. Hence, the following expression may be written as the relationship between **number of joint (j), and the number of members (m)** in a perfect frame.

$$\boxed{m = 2j - 3}$$

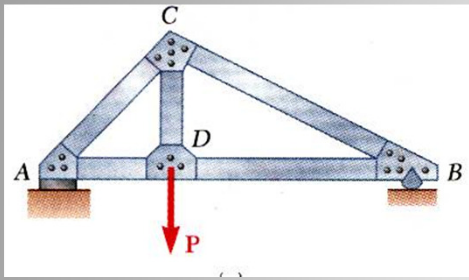
(a) When LHS = RHS, **Perfect frame,**

(b) When LHS<RHS, **Deficient frame**,

(c) When LHS>RHS, **Redundant frame**.

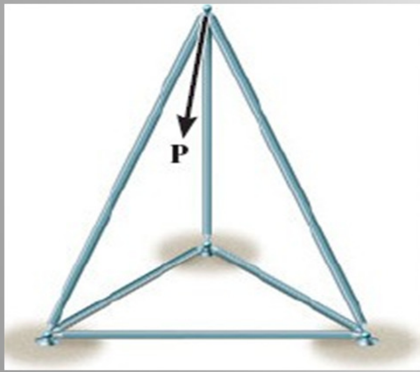


Types of Trusses



(a) <u>Plane frame:</u> A frame in which **all members** lie in a **single plane** is called plane frame. They are designed to **resist the forces acting in the plane** of frame.

Examples: Roof trusses and **bridge trusses.**

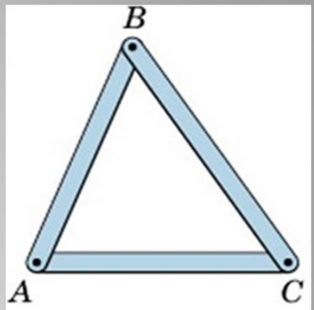


(b) <u>Space frame:</u> If all the members of frame **do not lie in a single plane,** they are called as **space frame**.

Examples: Tripod, transmission towers etc.

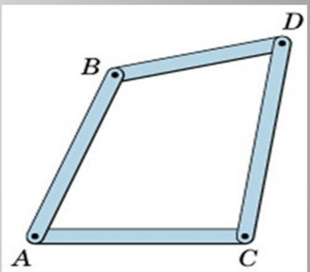
Plane Trusses

- **Basic element** of a Plane Truss is a **Triangle,**

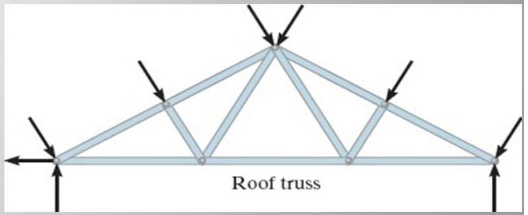


- **Three bars** joined by **pins** at their ends to form a **Rigid Frame,**

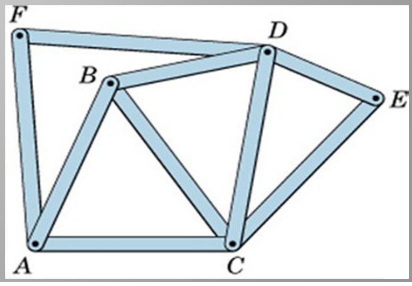
- **Four or more bars** joins to form **polygon type non-rigid frame,**



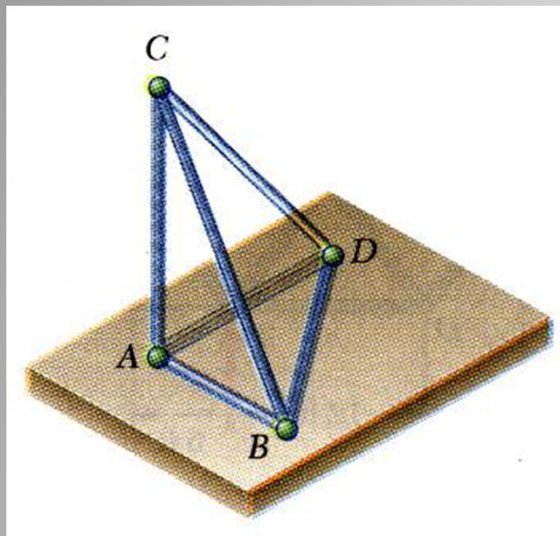
<u>**How to make it Rigid or Stable?**</u>



- By forming more triangles!

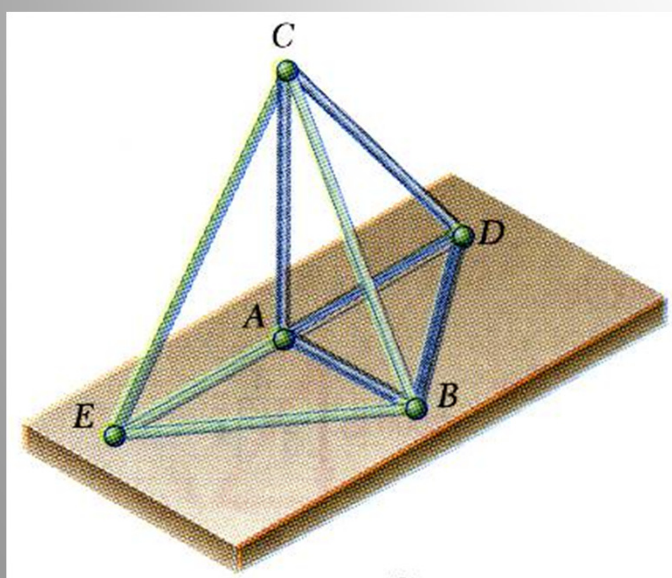


Space Truss



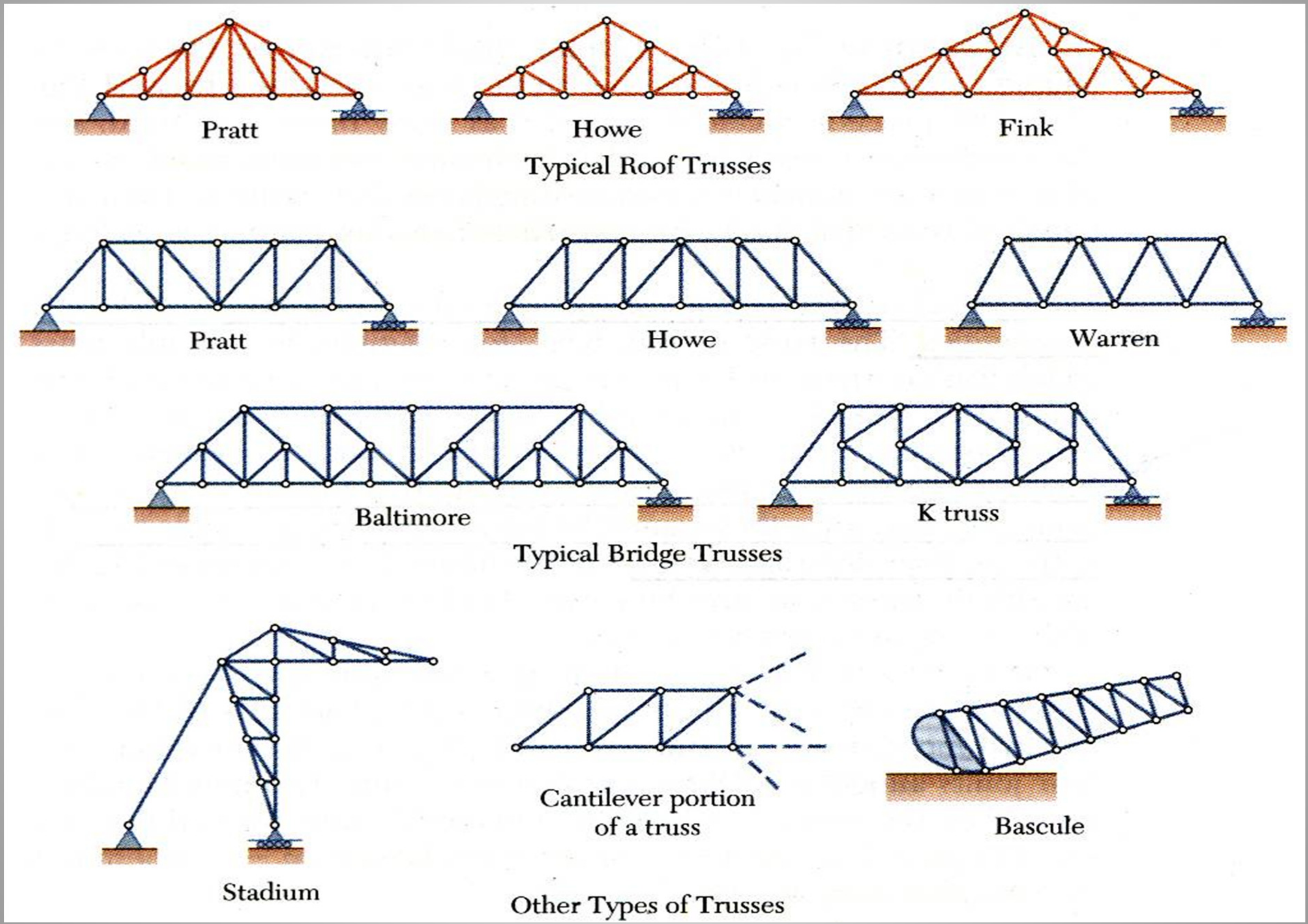
- An ***elementary space truss*** consists of **6 members** connected at **4 joints** to form a tetrahedron,

- A ***simple space truss*** is formed and can be extended when **3 new members** and **1 joint** are added at the same time,

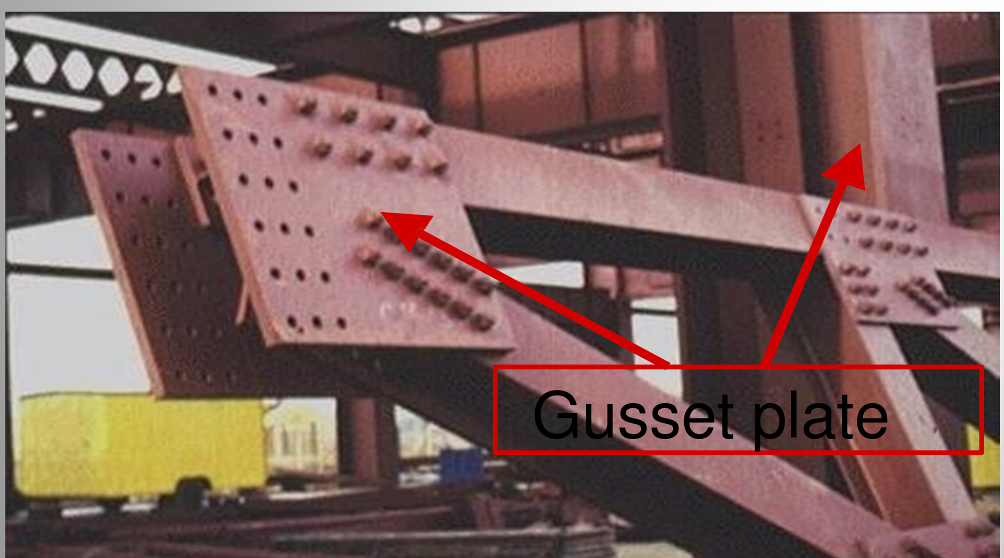


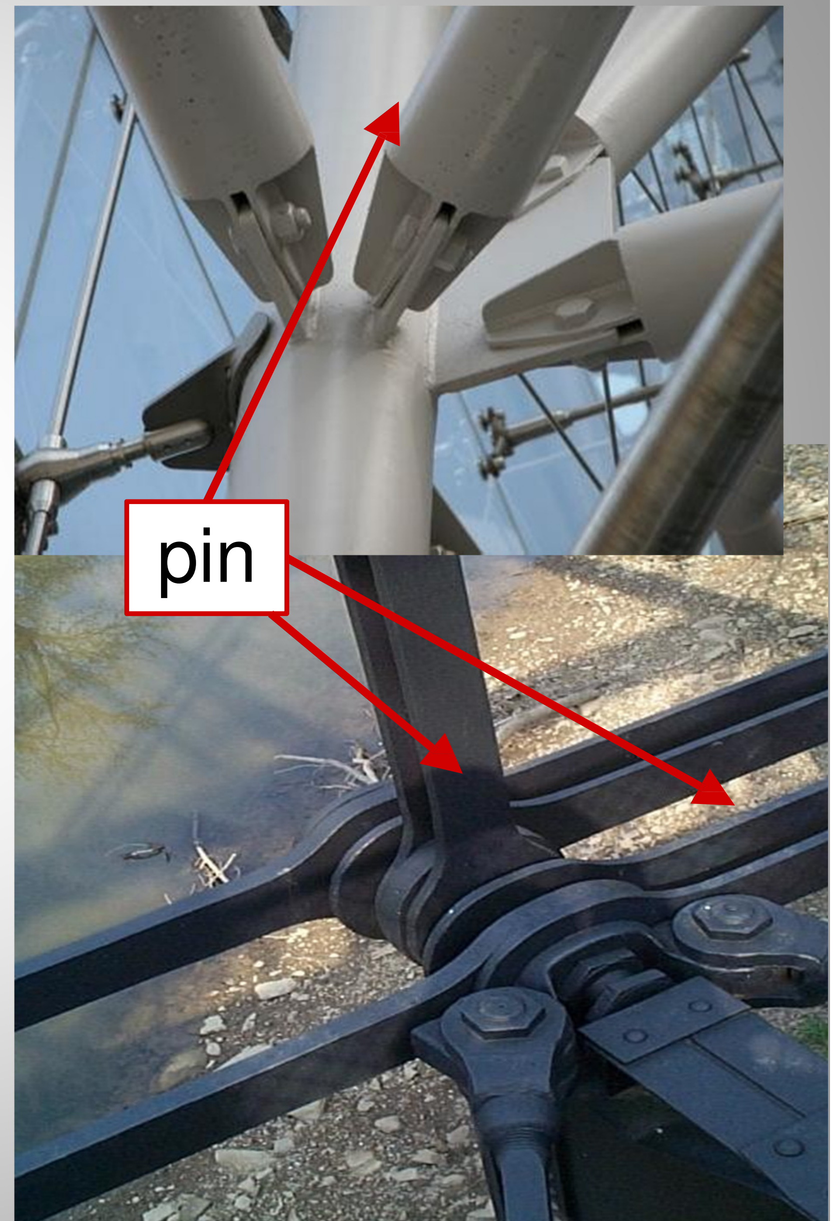
- In a simple space truss, $\boldsymbol{m = 3n - 6}$ where m is the number of members and n is the number of joints.

Some Plane Trusses



Joint Connections





Truss Supports

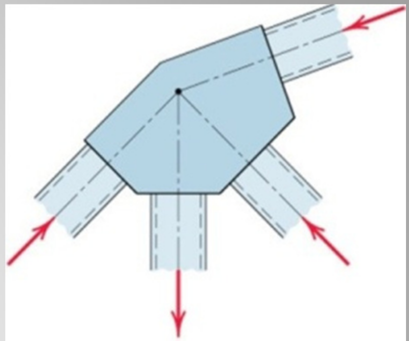
Rocker support

Roller supports

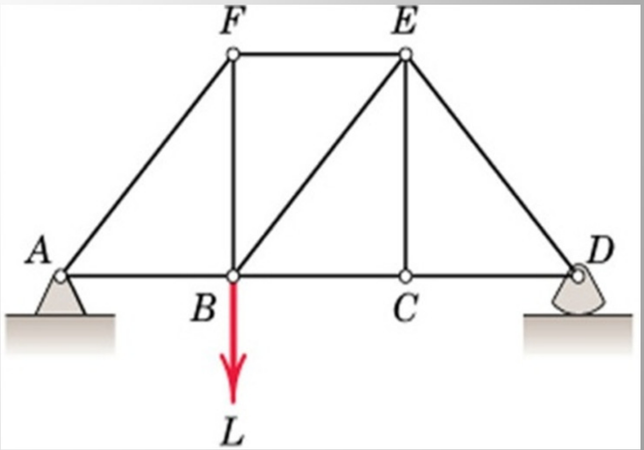
http://www.dot.state.mn.us/historicbridges/bridge-pictures.html

Why Roller/ Rocker Supports

- To accommodate **deformations** due to **temperature changes** and **applied loads**,



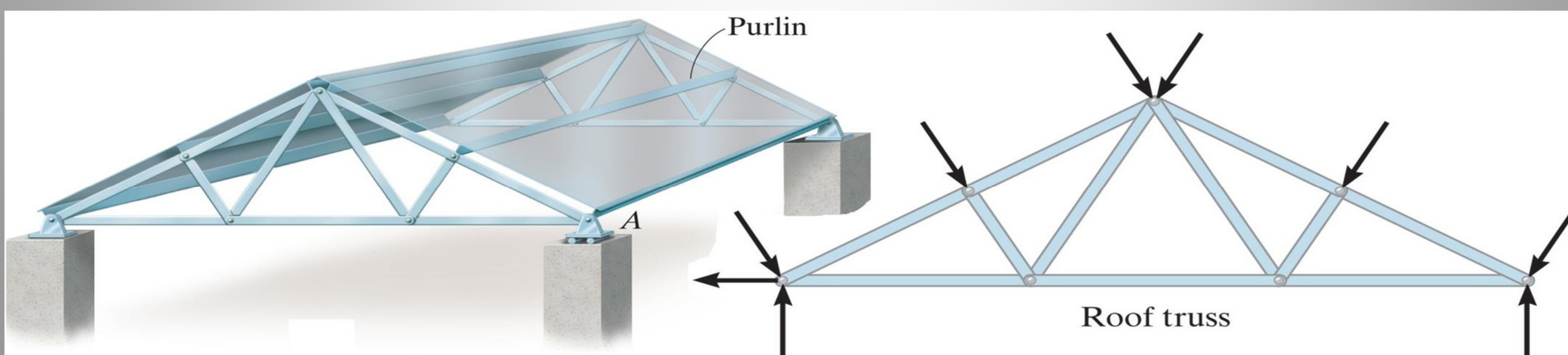
- Otherwise, structures will be a **statically indeterminate** truss.



- **Statically indeterminate structures** are those in which, **static equilibrium equations** (force and moment equilibrium conditions) are **insufficient** for determining the internal forces and reactions on that structure).

Trusses are …

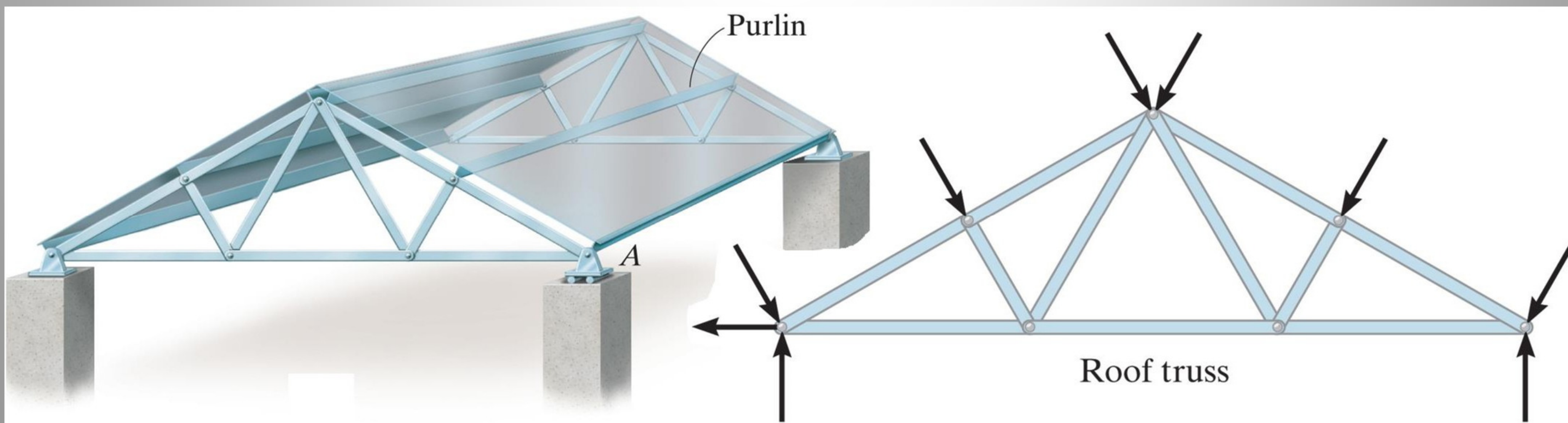
- **Structures designed to support loads:**
  - **Transmit loads through the joints** of the structure,
  - Ultimately **transmit loads to the foundation**
- **Cost effective in design because:**
  - Weight is minimized *(weight of members is typically light compared to loads carried, so it is often neglected)*
  - **Strength to weight ratio** is maximized



Working with Trusses

Assumptions

- All loads are applied / transmitted at **joints,**
- All members are joined by **'pin-connections',**
- Consist entirely of '**two-force members'**
- Can contain '**zero-force members**' also



Zero-Force Members

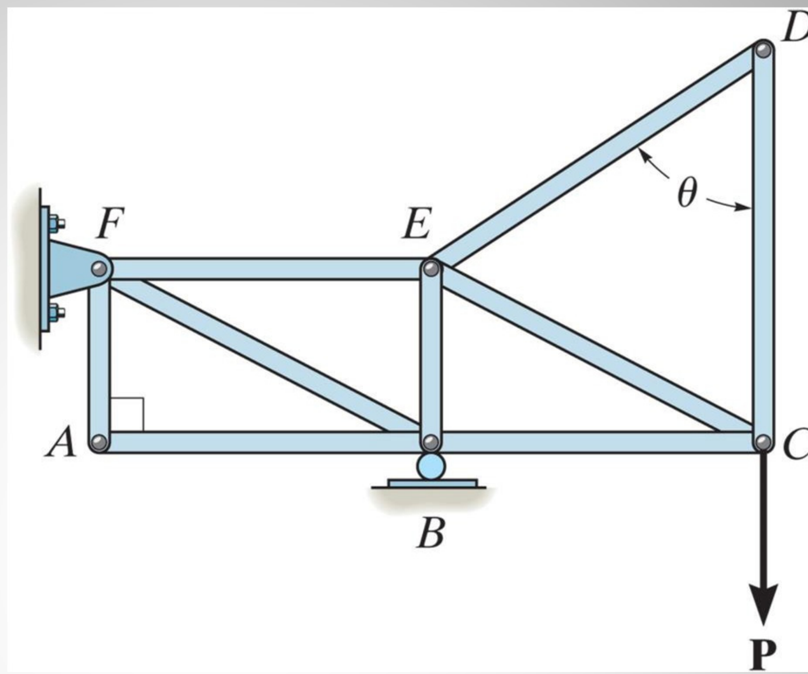
What are zero-force members?

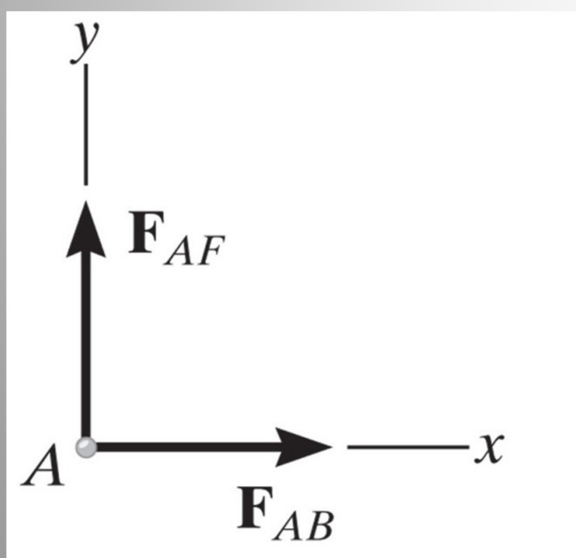
- Structural members that carry **no force,**

Why do we use them?

- Used to **provide stability,**
- It **increases the buckling strength** of compression members.

Zero-force Members: Case 1

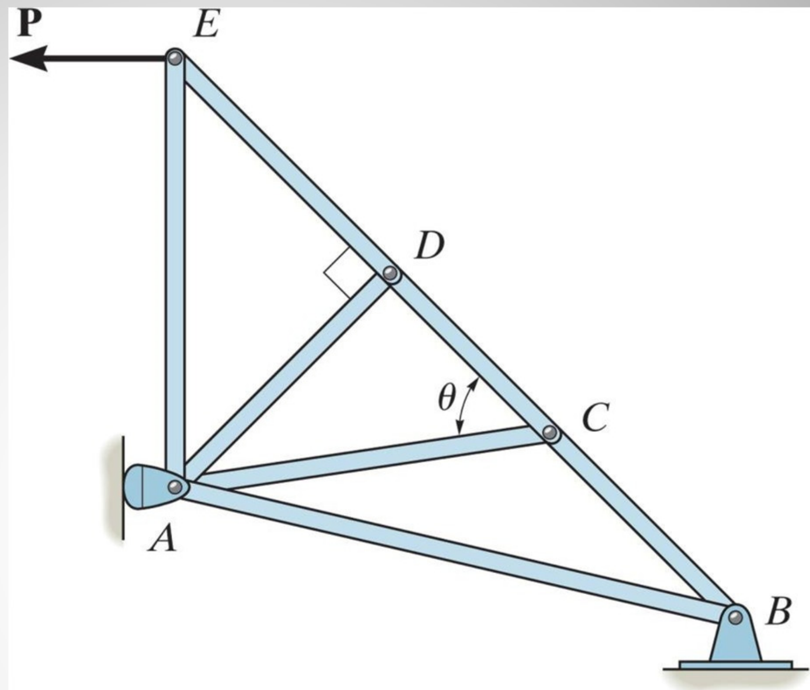


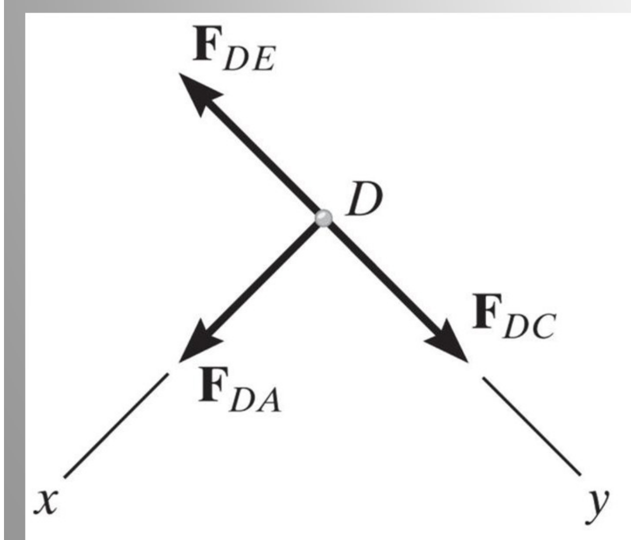


$$\xrightarrow{+} \Sigma F_x = 0;\ F_{AB} = 0$$

$$+\uparrow \Sigma F_y = 0;\ F_{AF} = 0$$

Zero-Force Members: Case 2



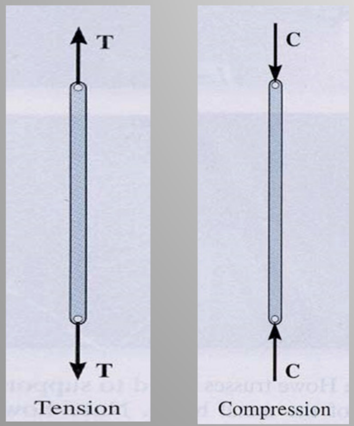


$$+\swarrow \Sigma F_x = 0; \quad F_{DA} = 0$$

$$+\searrow \Sigma F_y = 0; \quad F_{DC} = F_{DE}$$

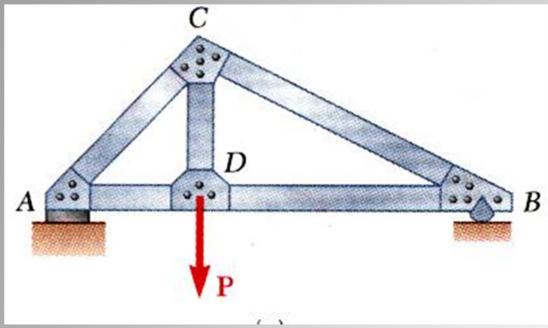
ANALYSIS and DESIGN ASSUMPTIONS

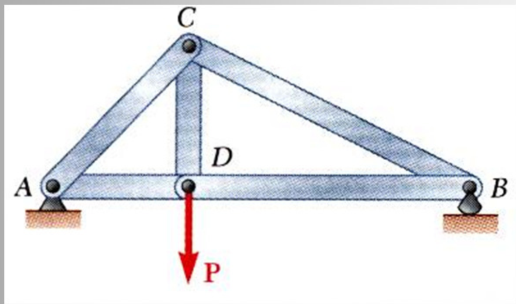
- When **designing** both the members and the joints of a truss, first it is necessary to determine the **forces** in **each truss member**. This is called the **force analysis** of a truss. When doing this, two assumptions are made:
  1. All **loads** are applied at the **joints**. The **weight** of **truss members** is often **neglected** as the weight is usually small as compared to the **forces supported by the members**.
  2. The **members are joined together** by **smooth pins**. This assumption is satisfied in most practical cases where the joints are formed by **bolting or welding**.

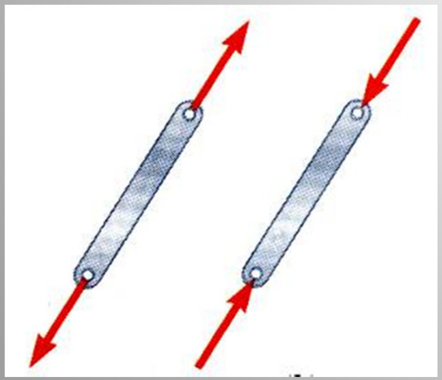


With these two assumptions, the members act as **two-force members**. They are loaded in **either tension or compression**. Often compressive members are made **thicker to prevent buckling**.

ANALYSIS and DESIGN ASSUMPTIONS

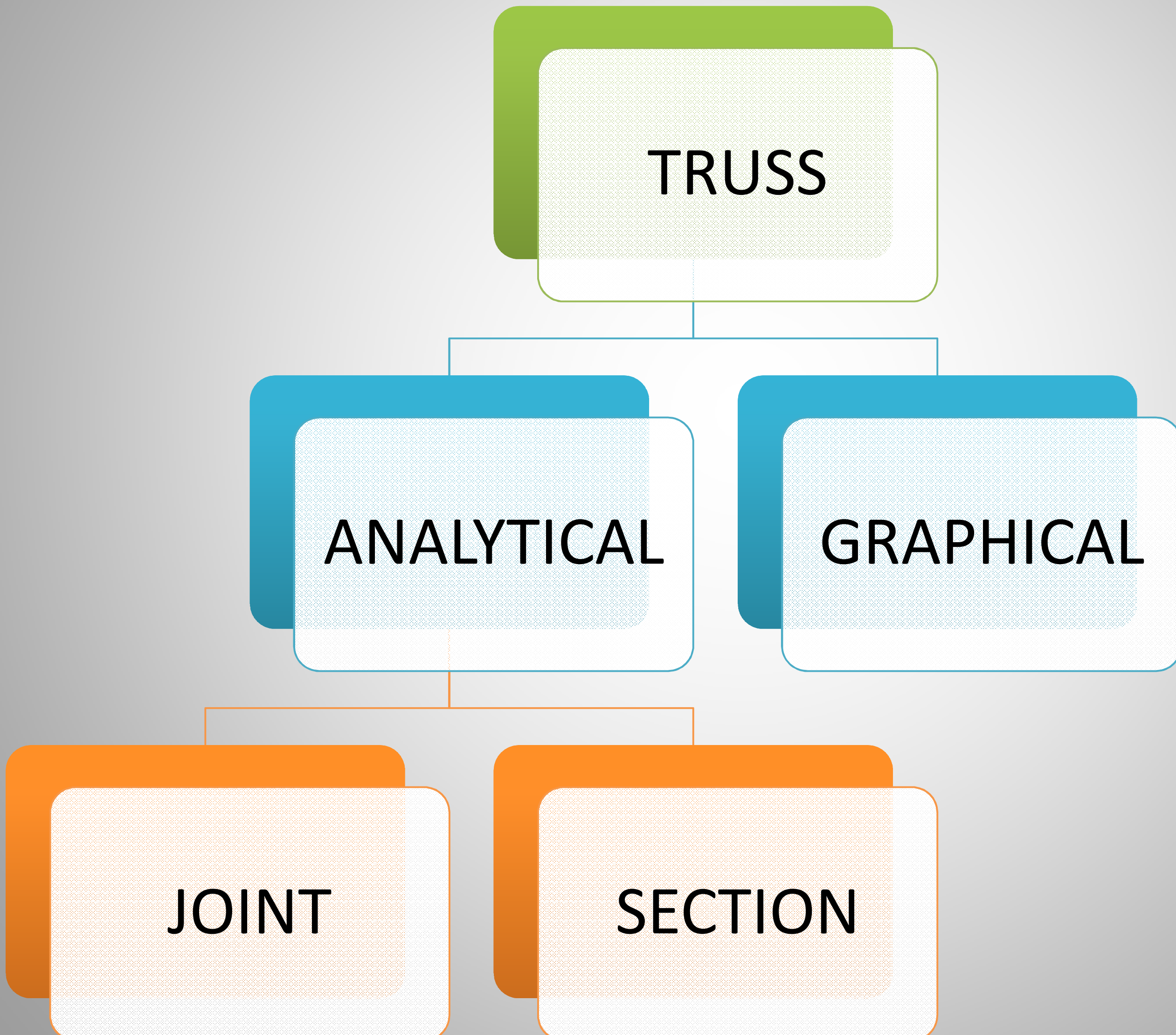




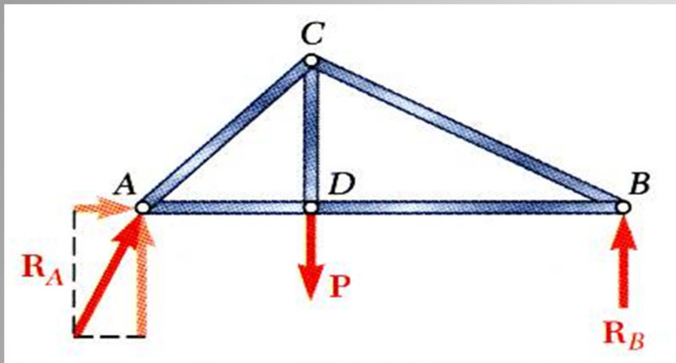


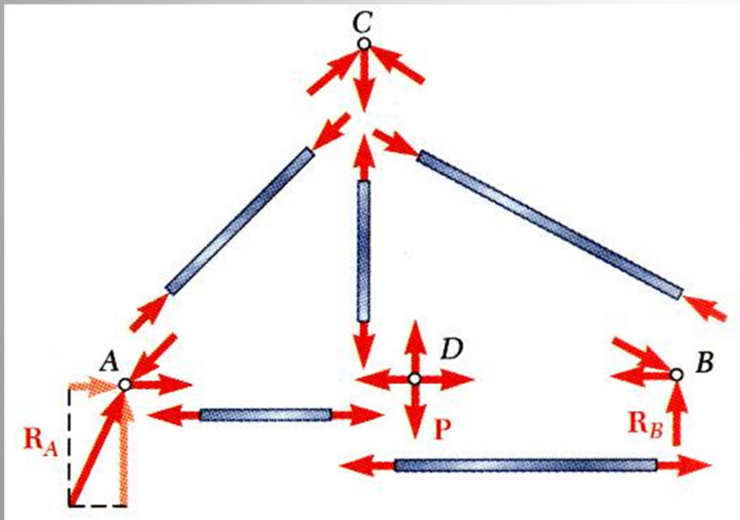
- A truss consists of **straight members** connected at **joints**. No member is **continuous** through a joint.
- **Structures** are made of **several trusses** joined together to form a **space framework**. Each truss carries those loads which act in its **plane** and may be treated as a **two-dimensional structure.**.
- **Bolted or welded connections** are assumed to be **pinned together**. **Forces** acting at the **member ends** reduce to a **single force** and **no couple**. Only ***two-force members*** are considered.
- When forces tend to **pull** the member apart, it is in ***tension***. When the forces tend to **compress** the member, it is in ***compression***.

Analysis of Truss



Analysis of Trusses by 'Method of Joints'



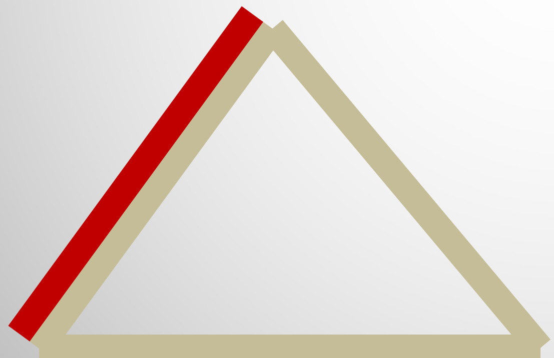


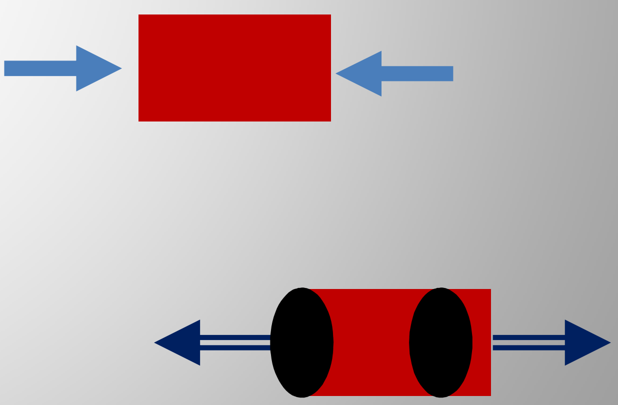
- Dismember the truss and create a free body diagram for each member and pin,
- The two forces exerted on each member are **equal**, have **same line of action**, and **opposite sense**,
- Forces exerted by a member on the pins or joints at its ends are directed along the member and equal and opposite.
- Conditions of equilibrium on the pins provide $2n$ equations for $2n$ unknowns. For a simple truss, $2n = m + 3$. May solve for m member forces and 3 reaction forces at the supports.

ANALYSIS OF TRUSS BY METHOD OF JOINTS

- TENSILE / COMPRESSIVE FORCES

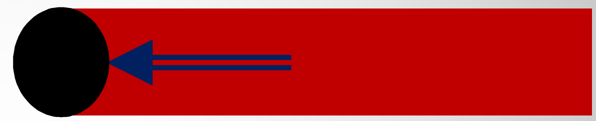
- BY DEFAULT TAKE TENSILE



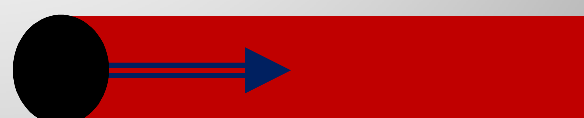


DIRECTION

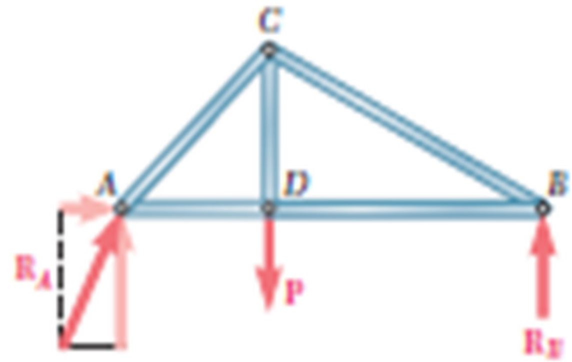
- COMPRESS- Towards the joints



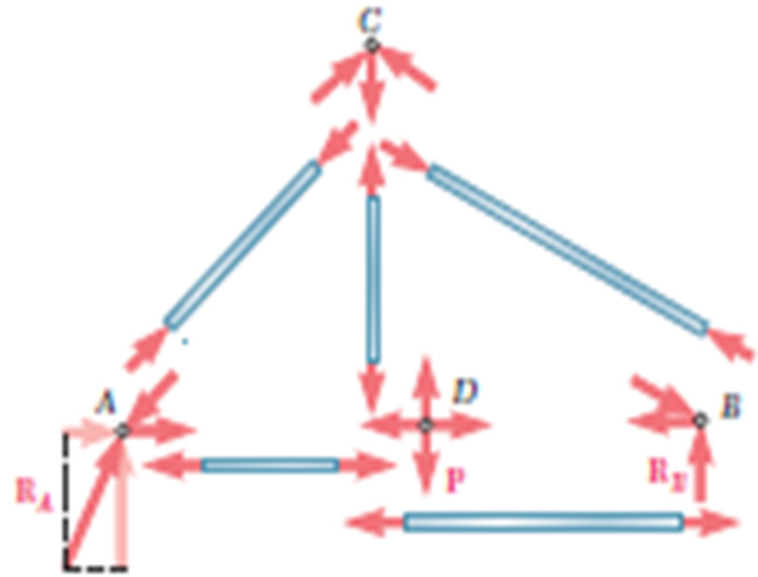
- TENSILE-Away from the joints



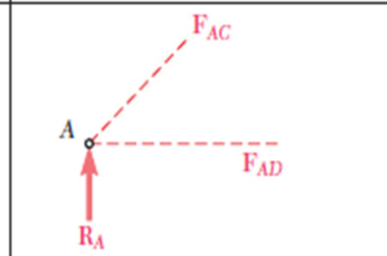
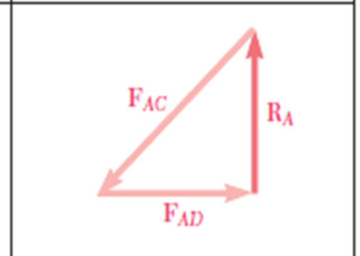
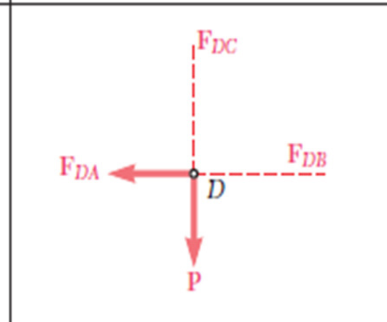
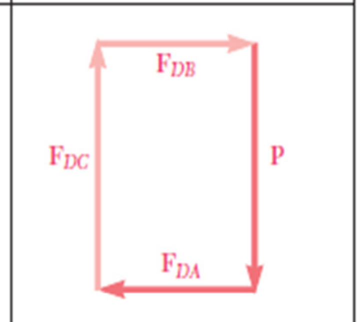
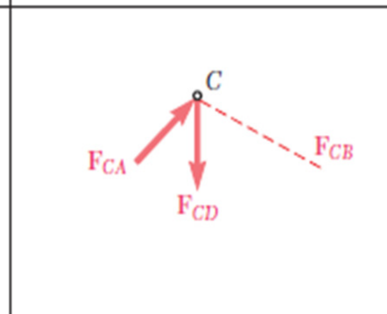
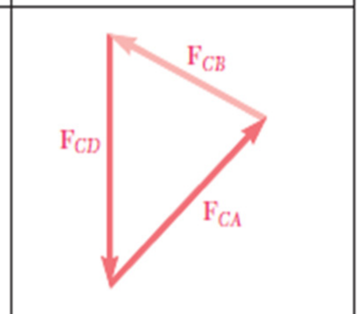
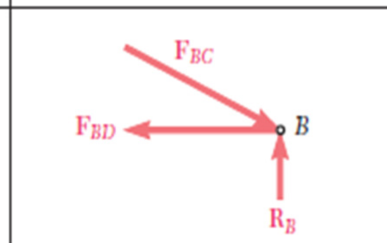
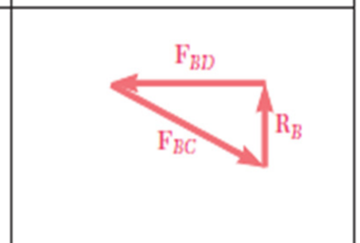
ANALYSIS OF TRUSS BY METHOD OF JOINTS



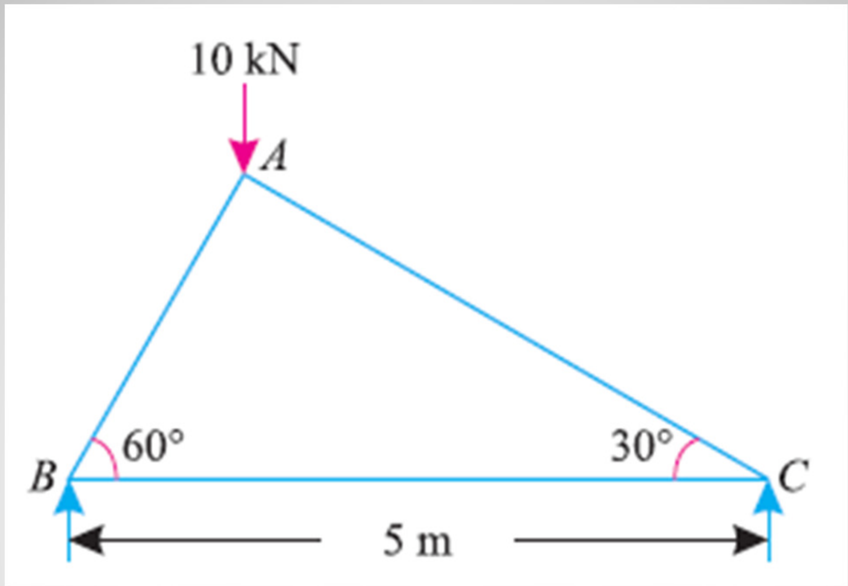
(a)

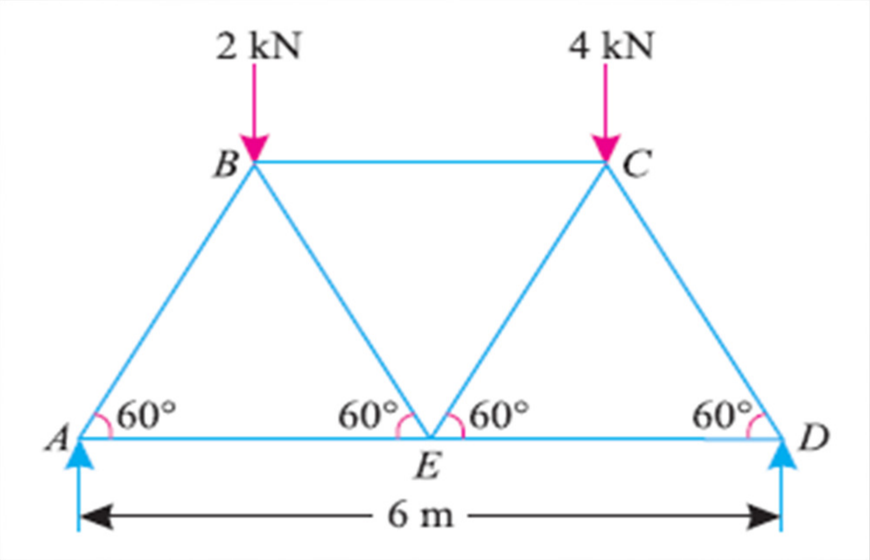


(b)

	Free-body diagram	Force polygon
Joint A		
Joint D		
Joint C		
Joint B		

Truss Numericals





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