Lecture 3: Structures (Frames and Trusses)

So far we have only analysed forces and moments on a single rigid body, i.e. bars. Remember that a structure is a formed by ________________________________ and this lecture will investigate forces in such structures.

A _______________ composed of ______________ joined at their ends to form a ________________________ is called a _________________.

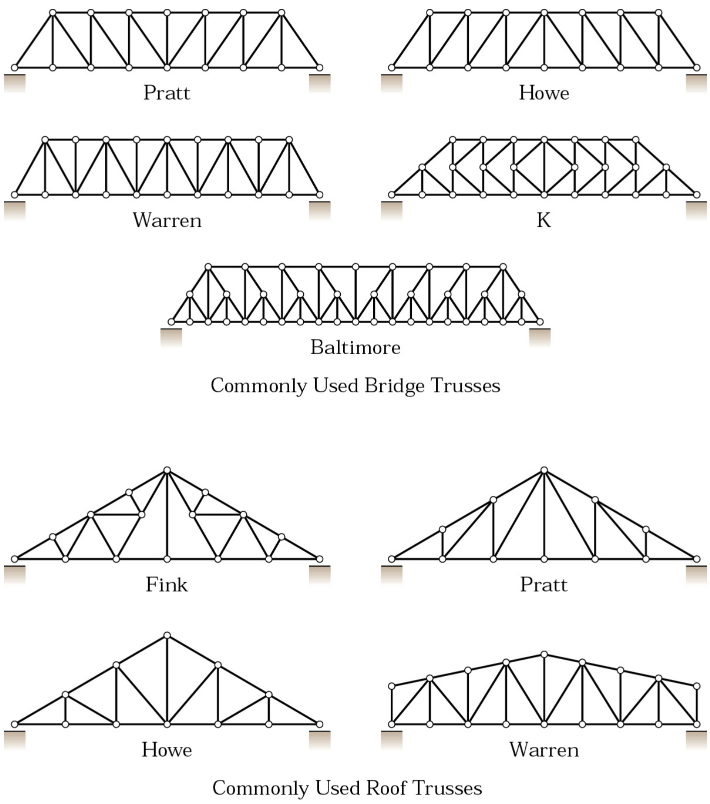

Figure 1 – Examples of different types of trusses

Members of a structure

We will concentrate on structures consisting of _____________________________. These bars are also called members. In a large structure, there may be hundreds or thousands of members and they all carry loads of different magnitudes and directions.

Load carrying members can be classified into three categories

1. Compression

2. Tension

3. Unloaded

Note: There is no specific sign convention for the directions of forces, however it is very important that a consistent system is used throughout the calculation. Here, we will take compression forces to be positive and tension to be negative.

Method of Joints

Recall that a pin joint connects two or more members (bars) together. The joint resists ________________________________ but allows ___________________________, i.e. the joint only exerts forces but not moment.

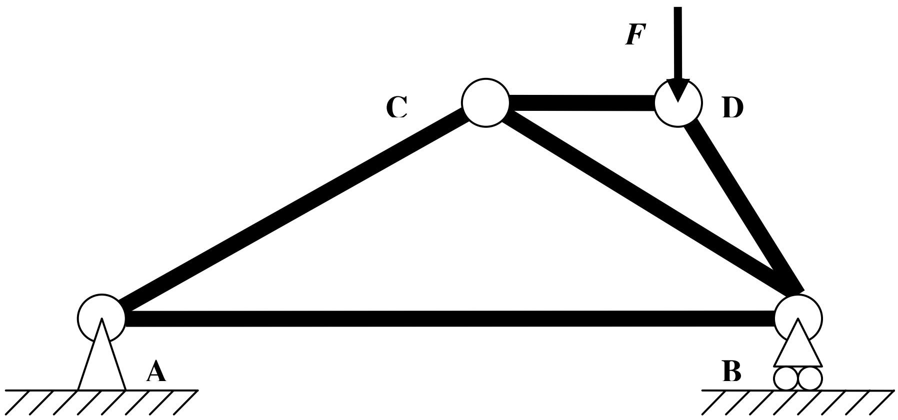

Figure 2

Figure 2 shows an example of a pin jointed frame whose properties are given in the table below. Note that *F* is an externally applied force which acts on the structure at point *C*.

Number of	*Quantity*	*Names*	
Members			**M =**
Reactions			**R =**
Joints			**J =**

Table 1

Example of framework analysis

Here, we will attempt to determine all the forces in the structure shown in figure 2.

Step 1

The reaction forces must be determined. There is no externally applied force in the horizontal direction, therefore we can deduce that the reaction $R_1 = 0$. The vertical reaction forces R_2 and R_3 can be given as functions of the externally applied force F.

Step 2

Consider joint A and the members connected to it, namely AB and AC. The joint is in equilibrium and therefore the resultant force at the joint must be zero. By resolving the forces into horizontal and vertical components and using two equilibrium equations in both directions, the two unknown (AB and AC) can be found.

Step 3

At joint C, the vertical equilibrium equation will give the load in the member BC, since the load in AC is already known. The load in member CD is given by the horizontal equilibrium equation.

Step 4

Finally, the load in member BD can be found by applying the equilibrium condition at joint B.

This analysis is based on ____,
therefore this method is also known as the __________________________.

Static determinacy

In the previous part, we were able to determine the loads in ________members of the structure. When such calculation is possible, the structure is said to be ____________ _____________. The condition for a structure to be statically determinate is given by

____

where M represents the number of members

R represents the number of reactions

J represents the number of joints

For a system where______________________________, such a structure is said to be ____. This is because there are more unknowns than available equilibrium equations and one or more members will be indeterminate. Such a system is also called a ____________________ system because it has ____.

A system where ______________________ is called an ______________________ _______________. This is not normally found in standard applications because they are flexible and collapsible under loads.

Examples of redundant frameworks are shown in figure 3.

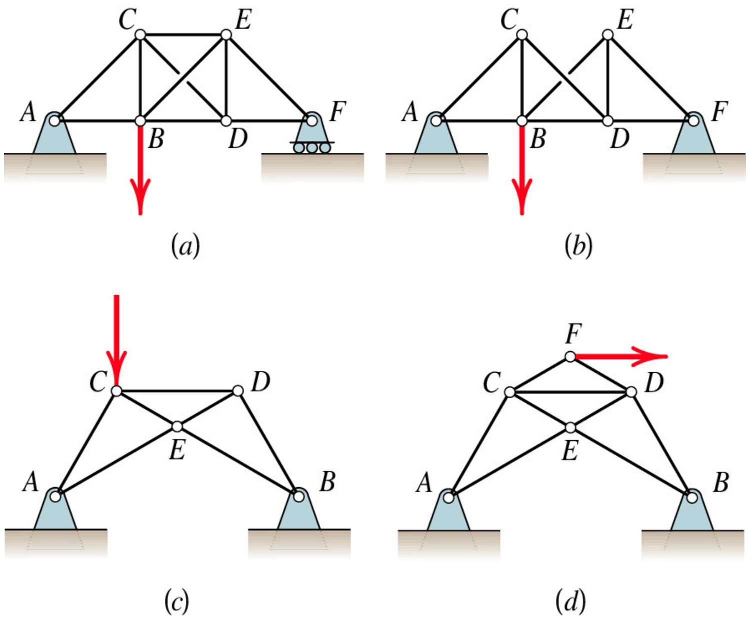

Figure 3

Method of Sections

Previously, we resolved the forces in a framework by the _______________________, where the forces around a joint are computed using the equilibrium conditions. An obvious disadvantage of this method is that many calculations will be required if the member that needs to be analysed is far from the reaction forces.

Example 1

Consider the member *FE* in the framework in figure 4. The force in this member can be computed by the method of joints, i.e. ____________________________________

____.

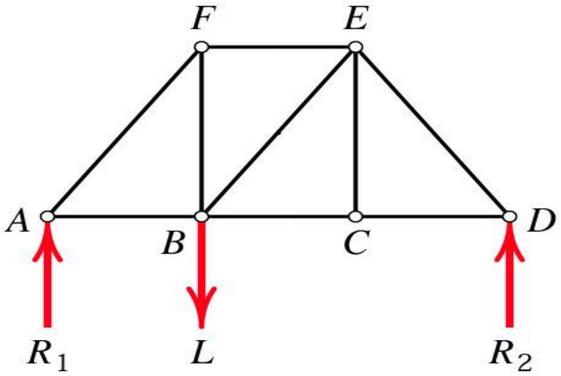

Figure 4

Here, we will introduce the _______________________________. This will help in quickly determining the force in the member in a structure without having to follow the steps shown before. The following describes how the method of sections can be used to determine the force in ____________________ in figure 4.

Step 1

Make an ____.

In this case, the structure is cut vertically through the members *FE*, *BE* and *BC*.

Step 2

Draw _________________________ of the two separate sections with appropriate forces. Each section should be treated as ___________________________________.

The free body diagrams for the two sections are shown in figure 5.

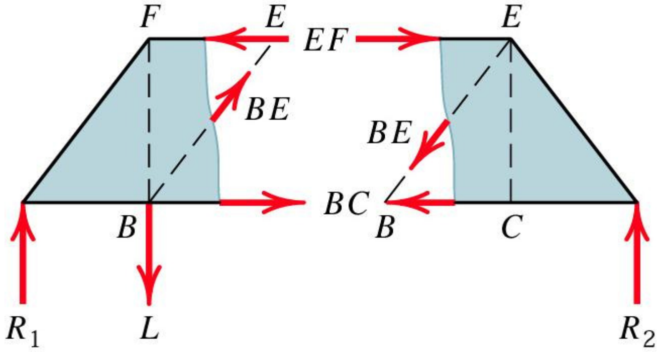

Figure 5

The arrows indicating the direction of the forces in the diagrams show that member *EF* is in tension while members *BE* and *BC* are in compression. This structure is considerably simple and the direction of the forces can be quite easily predicted.

Note that an incorrect direction of the force (tension or compression) in the cut member does not result in an incorrect calculation. It will only lead to the final value of the force being ____________________.

The most important step while making a cut is that the forces in the cut members __________________________________ at the cut on either side of the sections, i.e. the force *EF* on the left section (towards *F*) must be equal and opposite to the force *EF* on the right section (towards *E*).

Step 3

The required force *EF* can be computed by ________________________________ ___________________________________. This will eliminate forces *L*, *BE* and *BC* as their moment arms are zero, leaving only forces R_1 and *EF*.

The force *EF* is given by the expression

____

Example 2

Using the framework in figure 4, how would you make a cut to separate the structure into two separate sections in order to determine the force *BC*?