Free Body Diagrams

Equilibrium follows naturally once the concept of force is introduced. According to Newton's laws, the forces acting on a body must be "balanced," i.e., in equilibrium, or the body will accelerate in the direction of the net force. The requirement that a body, such as a portion of a beam or an entire truss, must be in equilibrium, helps us find reaction forces at the supports and internal forces in the structure. Structures that allow all reactions and internal forces to be determined by equilibrium alone are called "statically determinate." As a starting point for working with equilibrium, consider the cantilevered beam in Figure 1a), completely clamped on the left-hand side and carrying a point load, F, acting at the other end. Figure 1b) is a free body diagram of the beam. It shows all potential forces that act on the body, including applied loads and reactions forces at supports. Figure 1c) shows the forces that appear when the following equilibrium equations are satisfied:

- Sum of forces in the horizontal direction is zero: $\Sigma F_x = 0$
- Sum of forces in the vertical direction is zero: $\Sigma F_y = 0$
- Sum of moments about any point is zero: $\Sigma M = 0$

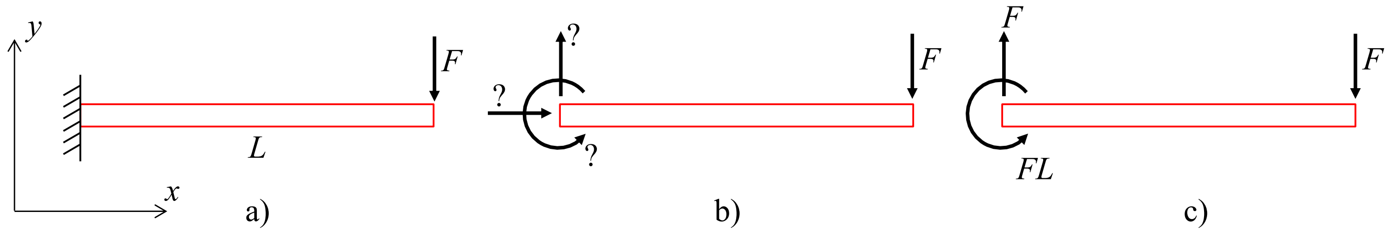


Figure 1: Free body diagram of cantilevered beam.

For 2D structures, i.e., structures we draw in a plane, the three available equilibrium equations mean that we cannot have more than three unknown forces. That is the case for the cantilever in Figure 1a), which has the horizontal force, vertical force, and moment at the support as the three unknowns. For 3D structures the are six equilibrium equations available; sum of forces in the x, y, and z directions, and sum of moments about those axes.

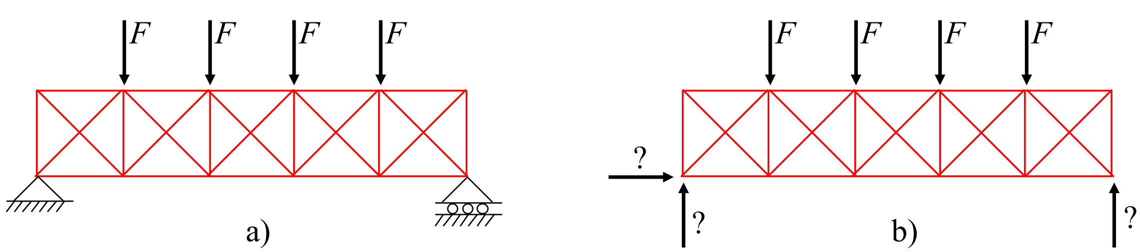
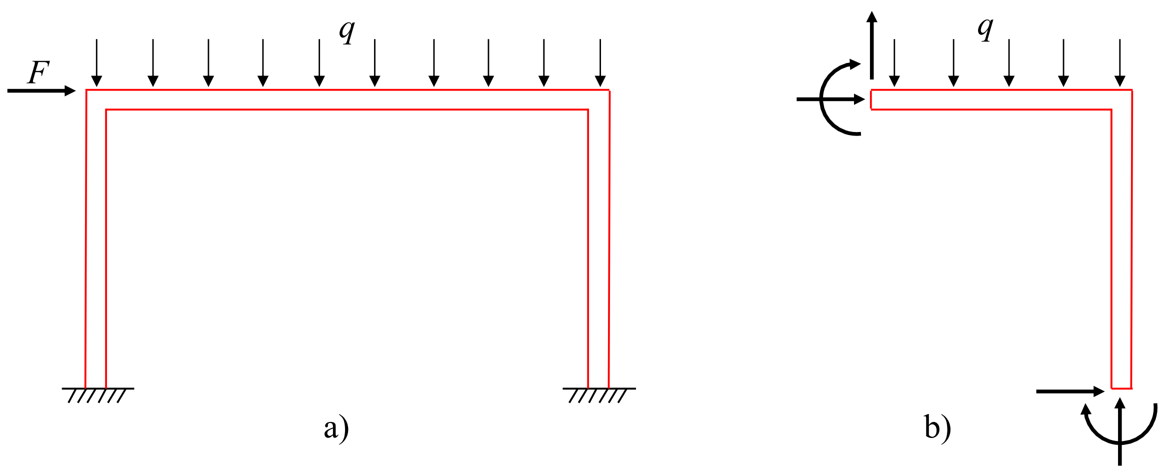


Figure 2: Free body diagram of truss.

Figure 2a) shows a truss, whose free body diagram is shown in Figure 2b). The principle is simple; the supports are replaced by the reaction forces that may act there. The subsequent consideration of equilibrium would reveal that the horizontal reaction force is zero while the two vertical reaction forces are each $2F$.



a) b)

Figure 3: Free body diagram of portion of a frame.

In Figure 1 as well as in Figure 2 the free body diagram is established simply by pulling the structure away from the support. In contrast, the free body diagram in Figure 3b) is formulated by also making a "cut" in the beam of the portal frame in Figure 3a). Free body diagrams and equilibrium considerations for portions of a structure or portions of a structural member is as valid as the previous cases. For example, Figure 3b) may be employed to determine the bending moment at midspan of the beam of the portal frame. However, note that this is a "statically indeterminate" case, where the equilibrium equations listed earlier are insufficient to determine the forces in the frame.