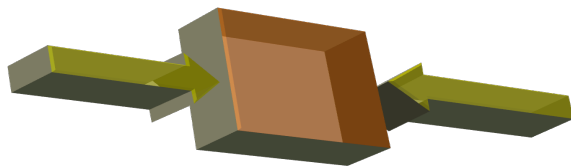# Mechanics of Materials-Tension and Compression

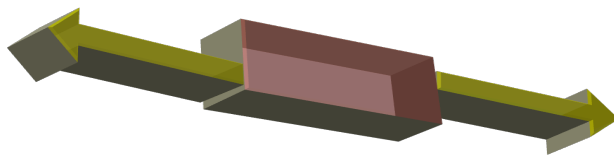## Tension and Compression Forces

Two key types of forces involved in building any structure are **tension** and **compression**. Every material has the ability to hold up to a certain amount of tension and a certain amount of compression. A tension force is one that pulls materials apart. A compression force is one that squeezes material together.

(Body compressed)

(Body stretched, tensioned)

Some materials are better able to withstand compression, some are better able to resist tension, and others are good to use when both compression and tension are present. For example, if you pull on a strong rope, it can support a large amount of tension. If you push on a rope, it cannot resist compression very well, and just bends. Marshmallows are an example of a material that is easily compressible, but pulls apart under a great amount of tension. From these examples, it is clear that materials may bend or stretch when under a compressive or tensile force.

Bending Stress

When two people sit on a seesaw, is the metal bar between the two seats experiencing compressive or tensile stress? This is a trick question! A "bar in bending" experiences both compressive and tensile stresses! To visualize this, grab a phone book and bend it down (see **Figure 1**).

When you do this, the phone book materials "want" to return to their normal state of rest, so it feels like the top pages try to pull your fingers together because they are in tension and the bottom pages push your fingers apart because they are in compression. The bending phone book experiences compressive and tensile stress, just like a seesaw bar that is being bent!

Figure 1. A demonstration using a phone book illustrates tensile and compressive stresses due to bending; the top pages stretch apart (tension) and the bottom pages push together (compression).

With the bending phone book, the greatest tensile and compressive stresses occur on the outer covers; the direction of these forces can be seen with the arrows in Figure 1. The **neutral axis** or layer runs along the middle of the book between the arrows, as if it was the middle page in the phone book. Amazingly, this axis experiences zero stresses while bending! This has practical applications.

For example, if you ever need to drill a hole in a support beam, like the ones along the ceiling in your basement, drill in the center of the beam where there are no stresses (see Figure 2).
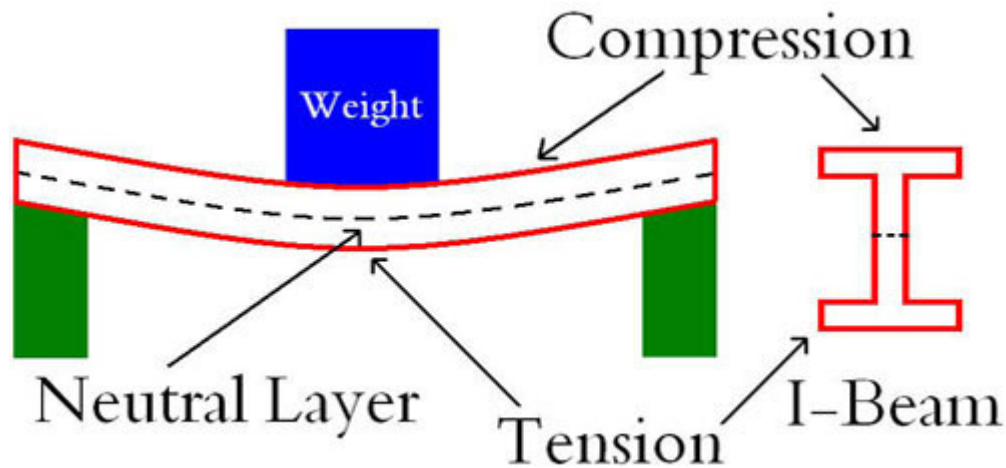
Figure 2. A diagram that shows the effect of a heavy weight placed on a beam. The beam experiences tension and compression. If the weight is too big, the beam will break!

The diagram in Figure 2 shows the effect on the beam when a heavy weight is placed on it, causing both tension and compression in the beam. The weight causes compression on the top of the beam as it squeezes together, and causes tensile stress on the bottom side of the beam where it is pulled apart. The beam shortens on the top due to compression, and elongates on the bottom due to tension.

With this in mind, what would happen if the beam had an even heavier weight placed on it? In this case, the forces would exert a greater amount of tension and compression on the beam, and if the forces were too great, the material would not be able to handle the stress and it would break in half.
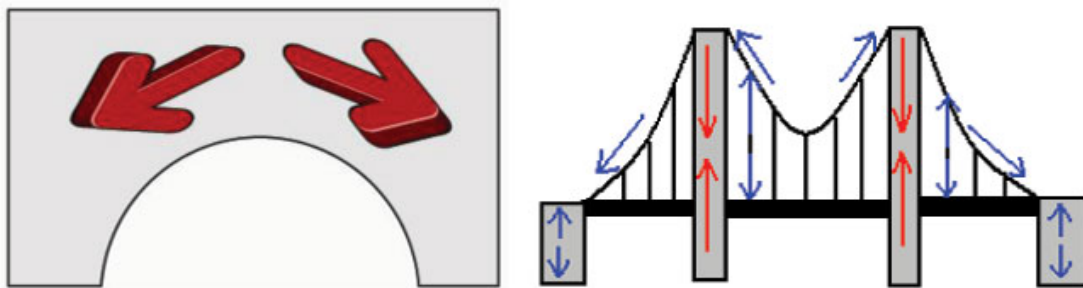
Tension and compression forces are important to keep in mind when designing a building or structure. If we construct a bridge with materials that are not strong enough to hold up to the amount of compression and tension that vehicles cause when they travel across it, the bridge could collapse. All structures **must** be able to handle the forces that act upon them, or they would not stay up. A great deal

of science, design and engineering goes into predicting the kinds of loads a structure might encounter (for example, wind, snow, weight of a bathtub full of water, etc.). For example, houses and bridges built in California must be designed to withstand earthquakes.

Compressive and tensile forces are present in all bridges, and it is the job of engineers to design bridges capable of withstanding these forces without buckling or snapping. **Buckling** occurs when compressive forces overcome an object's ability to handle compression, and **snapping** occurs when the tensile forces overcome an object's ability to handle tension. The best way to deal with these forces is to either dissipate them or transfer them. To **dissipate** force is to spread it out over a greater area, so that no one spot has to bear the brunt of the concentrated force. To **transfer** force is to move it from an area of weakness to an area of strength, an area designed to handle the force. An arch bridge is a good example of dissipation, while a suspension bridge is a good example of transference. Figures 3 and 4 illustrate tension and compression forces acting on three bridge types.
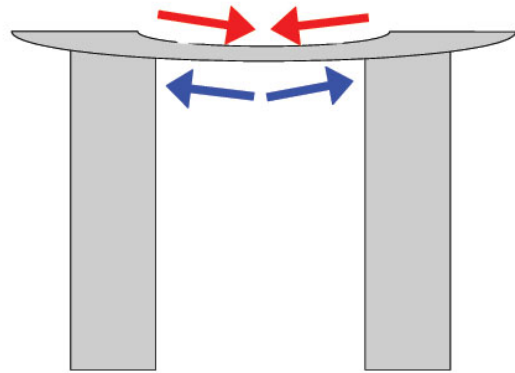
Figure 3. Tensile and compressive forces acting on a beam bridge; in a typical beam bridge tensile forces are negligible. Compressive forces are indicated by top arrows and tensile forces are indicated by bottom arrows.


Figure 4. Tension and compression forces acting on an arch bridge (left) and suspension bridge (right). Compressive forces are indicated by red arrows and tensile forces are indicated by blue arrows.

Zero-force members:

If only two members form a truss joint and no external load or support reaction is applied to the joint, the members must be zero-force members.

Example: We can quickly tell that members AF, AB, DE, and DC are zero-force members in the truss below. (Align the y-axis with AF and summing forces in the x-direction shows that F_{BA} = 0 as shown below.)
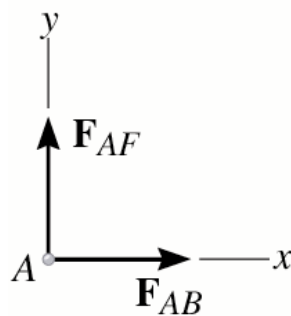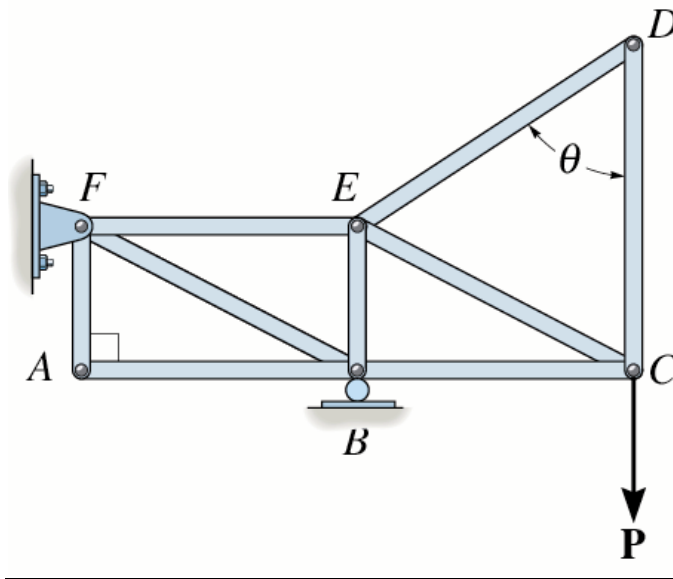
$$\xrightarrow{+} \Sigma F_x = 0; \quad F_{AB} = 0$$
$$+\uparrow \Sigma F_y = 0; \quad F_{AF} = 0$$

PE EXAM QUESTION ON TENSION AND COMPRESSION

In the PE exam morning section you will most likely be asked to find forces in a frame or truss and show which is compression or tension.

The answers will look like 20 k(C) or 20 (T) OR -20,etc….

So , its very important to know ,if the reaction is in Tension (outside) or compression(inside) for your final answer.

They actually might even has it easier for you by giving you the reaction forces so you don't have to calculate the reaction forces. THIS IS AN EASY EXAM DON'T MESS IT UP.

REMEMBER, IN THE MORNING IF IT TAKES YOU LOMGER THEN 4-6 MINUTES TO SOLVE A QUESTION , U ARE DOING SOMETHING WRONG.
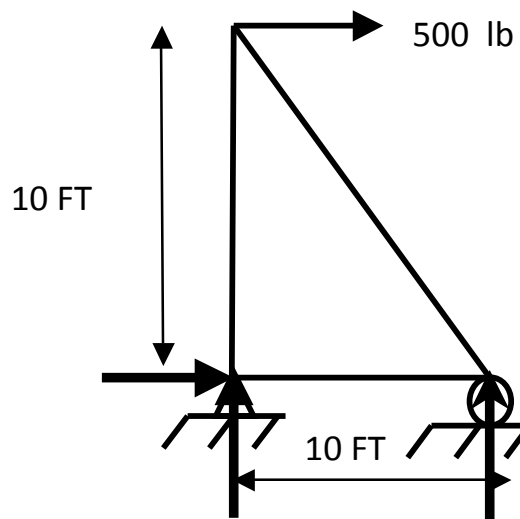
Exam example:

 I will demonstrate an example here to illustrate on what to expect.
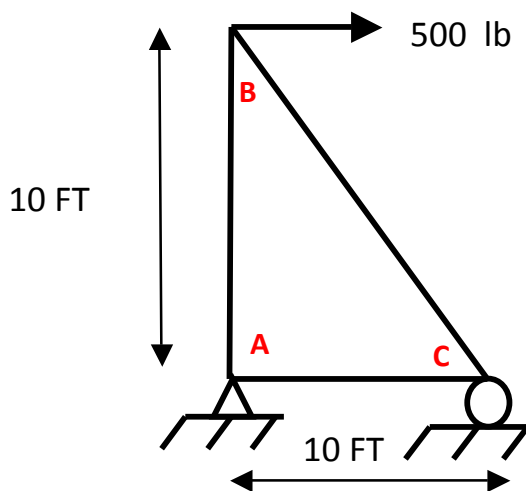
$M_A = 0 = -500$ lb.(10 ft) + Cy(10 ft) $C_y = 500$ lb

6

Fy = 0 = A$_y$ + Cy   A$_y$ = -500 lb

Fx = 0 = A$_x$+ 500 lb   A$_x$ = -500 lb

The equations of equilibrium for joint A.

F$_{AB}$
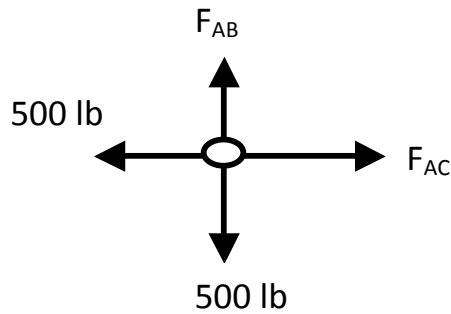
500 lb ⟵ ●⟶ F$_{AC}$

500 lb

Fx = 0 = F$_{AC}$ – 500 lb   F$_{AC}$ = 500 lb

Fy = 0 = F$_{AB}$ – 500 lb   F$_{AB}$ = 500 lb

The equations of equilibrium for joint B

● ⟶ 500 lb

F$_{BC}$

F$_{AB}$
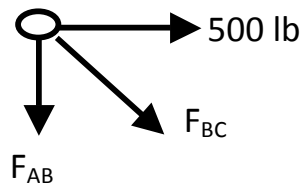
Fx = 0 = F$_{BC}$ cos45 + 500 lb

F$_{BC =}$ -707.2 lb.

The forces in the truss can be summarized as

F$_{AB}$ = 500 lb (T)

F$_{BC}$ = 500 lb (C)

F$_{AC}$ = 500 lb (T)