Tension, Compression, Torsion, and Shear

Loads put stress on structures. The structures respond by stretching, compressing, twisting, and bending. If the stress is severe enough, the structure will collapse.

Tension and Compression

If you try to walk across a stream on a board, you put stress on the board. You are the load. One effect of a load on a beam is to make the beam bend (**Figure 1**). When a beam bends under a load, the bottom surface becomes longer—it is stretched. This pulling or stretching force is called **tension**. Meanwhile, the upper surface of the beam is being squeezed. The pushing force that squeezes the upper surface is called **compression**.

Tension and compression are often at work in the same part of a structure. For example, hydro wires are pulled tight as they are hung on the towers (tension), but there is also tension and compression caused as the wires sag. (The sag or bend is caused by the dead load created by the force of gravity pulling on the mass of the wires.) However, tension and compression can also act separately. When you pull on an elastic band (**Figure 2**), the band is under tension. When you squeeze a rubber ball (**Figure 3**), the ball is under compression.

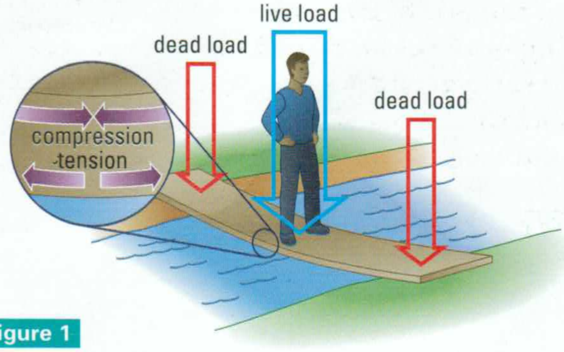


Figure 1
When you cross a stream on a board, you add to the load on the board. The board bends under the stress, creating forces of tension and compression within the structure.

Torsion

When you wring out a wet dishcloth by twisting the ends of the fabric, you are creating a force within the cloth. This force, created by applying opposite rotational forces on different parts of a structure, is called **torsion**. Objects that are under torsion twist (**Figure 4**).

A rotational force applied to any part of a structure, if the part is anchored, will result in torsional forces within the part. This is because the opposite rotational force is created by the structure itself, which resists the rotation of the part (**Figure 5**).

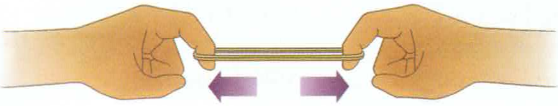


Figure 2
When forces pull in opposite directions, the force of tension is created in a structure. The object responds by stretching.

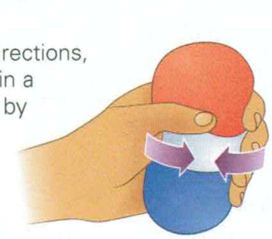


Figure 3
When forces push in opposite directions, the force of compression is created in a structure. The object responds by becoming smaller.

Figure 4
Torsion is created when opposite rotational forces are applied to an object. The object responds by twisting.

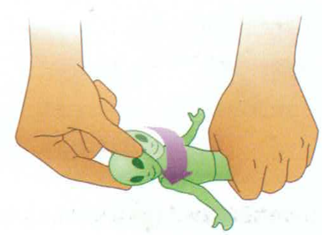


Figure 5
Torsion is also created when a rotational force is applied to one end of an anchored object.

Shear

When parallel forces acting in opposite directions are at work on a part in a structure, the part is said to be under **shear**. When you pull apart two pieces of licorice that are stuck together, you are creating a shear force (**Figure 6**).

When scissors are cutting paper, the two blades are moving in opposite directions at the surface of the paper. Scissors use forces of shear to cut through paper (**Figure 7**).

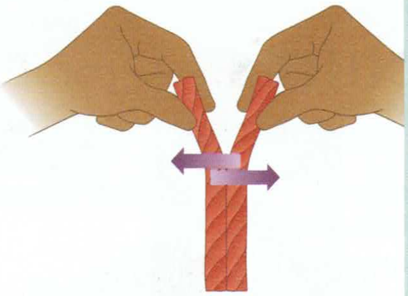
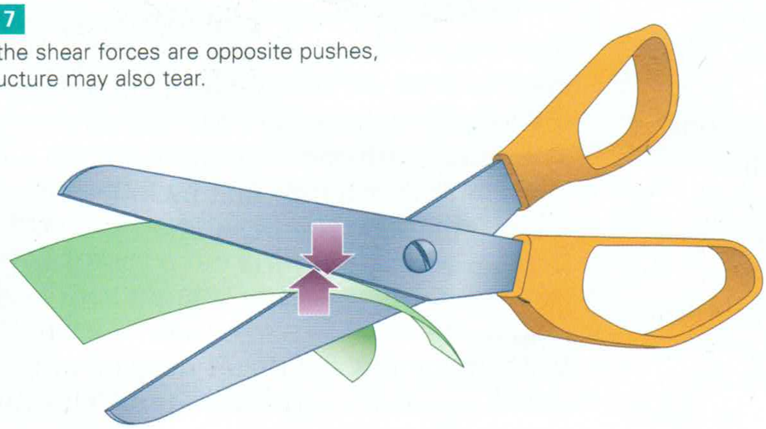


Figure 6
Shear forces are created when two parallel but opposite forces are at work at the same place within an object. When the opposing forces are pulls, the part responds by tearing, usually along a flat plane.

Figure 7
When the shear forces are opposite pushes, the structure may also tear.



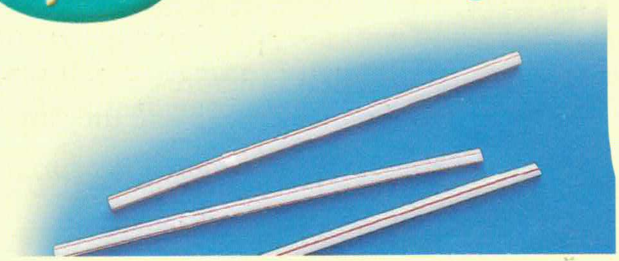
Understanding Concepts

1. In your own words, describe tension, compression, torsion, and shear.
2. (6C) Draw diagrams of each of the following situations and identify which forces are at work within the structure when they are being used:
   - **(a)** a gymnastic balance beam
   - **(b)** a diving board
   - **(c)** a model airplane powered by an elastic band
   - **(d)** a chain on a child's swing

Making Connections

3. (6C) Draw and label a diagram sharing the forces acting on and within a flagpole and its flag in a strong wind.

Try This *Straw Drawing*



Buildings are designed to resist forces that cause compression and tension. But not all structures are designed this way. Some are designed to yield to these forces, such as straws with corrugated (ridged) sections. The corrugated section allows the straw to bend when it is bearing a dynamic load (when you are drinking!). You can use a flexible straw to observe the forces of tension and compression.

- Sketch the ridges in the corrugated section of the straw when the straw is straight.
- Bend the straw. Sketch the ridges in the corrugated section.

1. On which side are the ridges closer together? Is this evidence of tension or compression?
2. What force is at work where the ridges are farther apart?
3. Explain how the ridges make this structure more flexible than an ordinary straw.