A chief characteristic of solid objects is that they tend to hold their shape. This is due to the nature of the bonds between the atoms in the solid. The bonds hold the atoms or molecules in "fixed" positions relative to each other. The atoms cannot easily slide past each other.

**Density** (Primary Importance)

- The mass of a block of iron depends on the size of the block. In particular it is proportional to the volume of the block. If I double the volume, the mass is doubled. As a result we define another quantity call the density or mass density of a material. It is the mass of the material divided by its volume.

\[
\text{Density} = \frac{\text{Mass}}{\text{Volume}}
\]

- For a homogeneous material, the density does not depend on the volume, i.e. 1m³ of iron will have the same density as 0.01m³ of iron or 1000m³ of iron. The density of a material is a property of the type of material.
- The density does depend on the temperature and pressure, but only slightly for most solids and liquids. We will discuss this in a later chapter.
- 2m³ of water have a mass of 2000kg. What is the density of water? What will be the mass of 0.001m³ of water (0.001m³ is 1 liter or just over 1 quart)?
- If I have 1000kg of water (density 1000kg/m³) and 1000kg of aluminum (density 2700kg/m³) the water will occupy a volume of 1m³. The aluminum will only occupy a volume of 0.37m³. Equal masses of water and aluminum will occupy different volumes and the one with the greater density, will have the smaller volume.

**Elasticity** (Secondary Importance)

- Even though the atoms are held in "fixed" positions they can move a little about those "fixed" positions. The bonds between the atoms can stretch and flex, i.e. bend.
- If I pull on the ends of a rod, the bonds will stretch a little and the length of the rod increases. The increase may be slight, but it will increase some. In this case we say the rod is in tension.
- If I push on the ends of a rod the bonds will compress or shorten a little and the length of the rod decreases. In this case the rod is in compression.
- If I remove the force on the rod and it returns to its original shape or dimensions, the deformation is said to be elastic. If it does not return to its original dimensions, the deformation is not elastic. In this non-elastic deformation some of the bonds were broken.

- For elastic deformations, the amount of deformation is proportional to the force (or stress). If I pull on a spring with 10N of force and it stretches 0.1m, it will stretch 0.2m if I pull on it with 20N of force. (How much will it stretch if I pull on it with 5N of force?) This is called Hooke’s Law and if \( F \) is the force applied to the object and \( x \) is the change in length

\[
F = kx
\]

Where \( k \) is a constant, called the force constant or spring constant of the material. For the material above, \( k = \frac{F}{x} = \frac{10N}{0.1m} = 100N/m \).

- If I pull on the rod hard enough, many bonds may rupture and the rod will break.

- The important quantity in determining the amount of deformation, and whether it will break, is the force per unit area in the rod. (It is not just the force, it also depends on the cross sectional area of the rod. The larger the cross-sectional area, the greater the force required to stretch it a given amount.) The force per unit area is the stress or pressure. Pressure = Force/Area. It is actually the amount of stress, or force per unit area, that determines how much the material deforms.