Properties of Matter

First Year

Department of Physics

PHYS104

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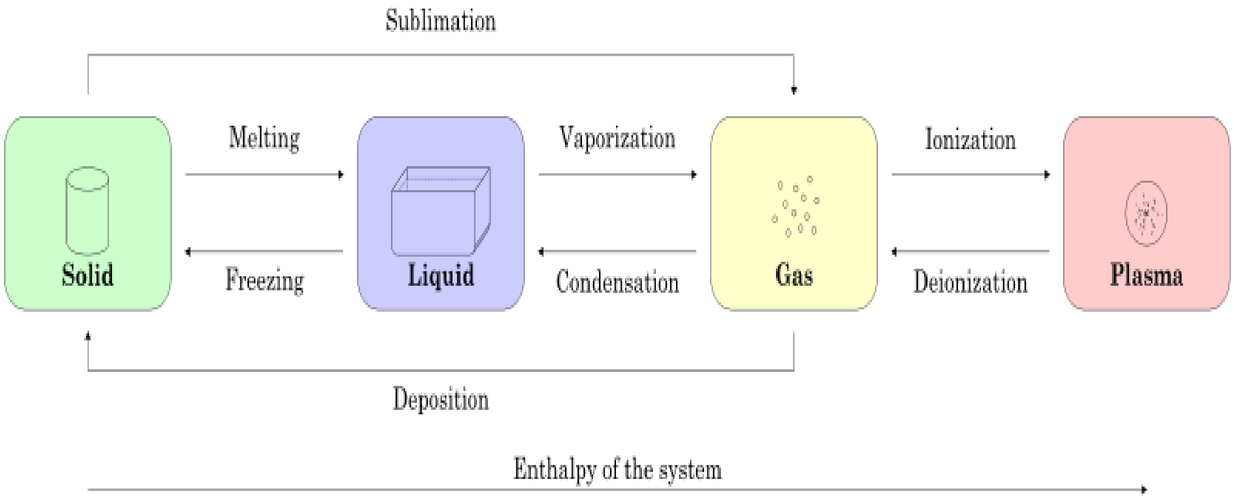
Introduction

Matter is normally classified as being in one of four states: solid, liquid, gas, and plasma. Matter in the solid state maintains a fixed volume and shape, with component particles close together and fixed into place. Matter in the liquid state maintains a fixed volume, but has a variable shape that adapts to fit its container. Its particles are still close together but move freely. Matter in the gas state has both variable volume and shape, adapting both to fit its container. Its particles are neither close together nor fixed in place. Matter in the plasma state has variable volume and shape, but as well as neutral atoms, it contains a significant number of ions and electrons, both of which can move around freely.

A state of matter is also characterized by phase transitions. A phase transitions indicates a change in structure and can be recognized by an abrupt change in particles. The diagram below illustrated transitions between the four fundamental states of matter.



Chapter One

Elasticity

1-1 Elasticity

Elasticity is that property of a body by which it experiences a change in size or shape whenever a deforming force acts on the body. When the force is removed the body returns to its original size and shape.
We shall discuss the elastic properties of solid materials in terms of the concepts of **stress** and **strain**.

Stress is a quantity that is proportional to the force causing a deformation; more specifically, stress is the external force acting on an object per unit cross-sectional area.

$$stress = \frac{force}{area} = \frac{F}{A} \qquad \ldots.\ldots\ldots\ldots..(1-1)$$

The units of stress are: (lb/ft^2), (N/m^2), and (dyn/cm^2).
There are three types of stress:
a) Tension stress

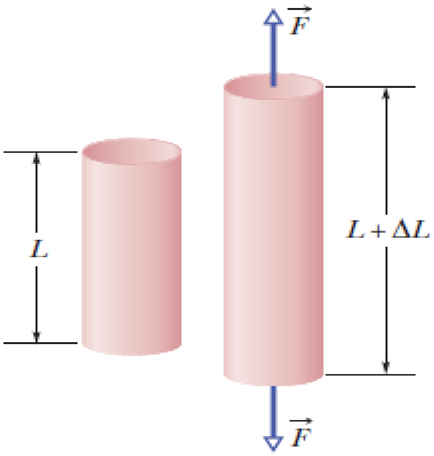


Figure 1-1

b) Compression stress

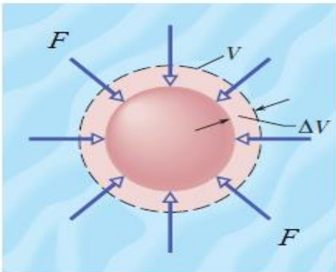


Figure 1-2

c) Shearing stress

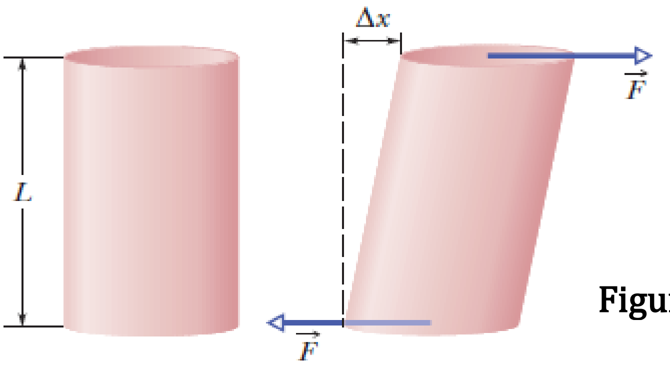


Figure 1-3

<u>Strain</u> is a measure of the degree of deformation; more specifically, strain defined as the ratio of the change in length to the original length of the object.

$$strain = \frac{\Delta L}{L} \qquad \dots\dots\dots\dots\dots\dots(1-2)$$

There are three types of strain:

a) Tension strain

$$strain = \frac{\Delta L}{L} \qquad \dots\dots\dots\dots\dots\dots(1-3)$$

b) Compression strain

$$strain = \frac{\Delta V}{V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1-4)$$

c) Shearing strain

$$strain = \frac{\Delta X}{L} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1-5)$$

It is found that, for sufficiently small stresses, strain is proportional to stress; the constant of proportionality depends on the material being deformed and on the nature of the deformation. We call this proportionality constant the elastic modulus. The elastic modulus is therefore the ratio of the stress to the resulting strain:

$$\text{Elastic modulus} = \frac{\text{stress}}{\text{strain}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots. (1-6)$$

There are three types of deformation and define an elastic modulus for each:

1. Young's modulus, which measures the resistance of a solid to a change in its length

2. Shear modulus, which measures the resistance to motion of the planes of a solid sliding past each other

3. Bulk modulus, which measures the resistance of solids or liquids to changes in their volume.

1-2 Young's Modulus

It is defined as the ratio of the tensile stress to the corresponding tensile strain i.e

$$Y = \frac{tensile\ stress}{tensile\ strain} = \frac{F/A}{\Delta L/L} = \frac{F \times L}{A \times \Delta L} \qquad \ldots\ldots\ldots\ldots\ldots (1-7)$$

The unit of young's modulus are the same as those of stress (lb/ft^2), (N/m^2), and (dyn/cm^2). Young's modulus is typically used to characterize a rod or wire stressed under either tension or compression.

The elastic limit of a substance is defined as the maximum stress that can be applied to the substance before it becomes permanently deformed. It is possible exceed the elastic limit of a substance by applying a sufficiently large stress, as seen in figure (1-4). Initially, a stress-strain curve is a straight line. As the stress increases, however, the curve is no longer straight. When the stress exceeds the elastic limit, the substance is permanently deformed and does not return to its original shape after the stress is removed. Hence, the shape of the substance is permanently changed. As the stress is increased even further, the material ultimately breaks.

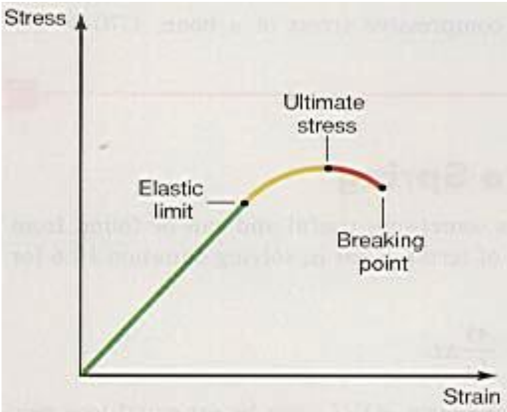


Figure 1-4 stress-strain curve