MEASUREMENT AND MECHANICS

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JOHN SATTERLY

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BY

JOHN SATTERLY, D.Sc., M.A.

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SECTION I.

MEASUREMENT AND MATTER.

CHAPTER I.

THE STATES OF MATTER.

1. Matter.—All bodies which are known to us consist of substances or materials of varying character. These substances or materials are included under the common name of **matter.**

The **quantity of matter** in a body is termed its **mass.**

2. Volume.—One of the fundamental properties of matter with which we are acquainted is that the same portion of space cannot be filled by different portions of matter at the same time; that is, every body occupies a certain portion of space to the exclusion of any other body. The *measure* of such portion of space is termed the **volume** of the body. Thus the volume of a body is the amount of "room" it takes up.

The volume of a body depends upon its **length,** its **breadth,** its **depth,** and its **shape.**

Solids and Fluids.

3. Solids, Liquids, and Gases.—Bodies can be divided into three classes — *solids*, *liquids*, and *gases*. From our everyday experience we get a fairly good idea of the main differences between these. We must now give exact definitions, which may be based on common experience.

We know that a solid body, such as a piece of ice, metal, glass, or wood, always retains the same shape; if put into a

bottle, it does not adapt its shape to that of the bottle. We cannot force a piece of stick into it, nor can we stir it up.

On the other hand, liquids and gases, such as water and air, will flow easily from one vessel into another. If water be poured into a bottle, it adapts itself to the shape of the bottle, and fills the whole of the bottom part. If there is nothing but air in the bottle, there are no empty spaces; the air fills the bottle. Again, water is very easily stirred up with a stick, and air is still more easily stirred, so much so that, when we move about, we experience no perceptible resistance from the air which we displace.

Liquids and gases (*e.g.* water and air) are termed *fluids* on account of their yielding to any force, however small, that tends to change their shape or to produce movements among their parts. They differ in one important respect. If a bottle is half full of water, the water cannot be made to occupy either more or less than half of the bottle. If the bottle is full, we cannot get any more water in by squeezing, nor can we squeeze the water into a smaller space by pushing a cork in or otherwise. On the other hand, any amount of air can be forced into a bottle by pressure, or, again, part of the air in a bottle may be sucked out, and then the remainder will still continue to occupy the *whole* of the bottle. Hence we may distinguish a liquid from a gas by the property that the former cannot, and the latter can, be readily made to occupy a greater or less amount of space. We have thus the following

DEFINITIONS.—**A solid is a body which has definite size and definite shape.** The relative positions of its particles cannot be altered without the application of at least a moderate force. *Examples:* wood, iron, leather.

A liquid is a body which has definite size but no definite shape. It adapts itself to the shape of the containing vessel. Its particles can be separated by the application of a very slight force. *Examples:* water, oil.

A gas is a body which has neither definite size nor definite shape. It tends to increase indefinitely in volume as the pressure confining it within a certain space is removed. It always fills the containing vessel. *Examples:* air, oxygen.

Notice that **gases are distinguished from liquids** by

(i.) Their **compressibility,** in virtue of which they can be compressed into any volume, however small (until they liquefy), by the application of sufficiently great pressure.

(ii.) Their **elasticity,** in virtue of which they expand when the pressure is reduced, so as always to fill the whole volume, however large, of the containing vessel, and exert pressure on its sides.

It is probable that *most* bodies can exist in any one of the three states: solid, liquid, or gaseous. Many we know do so.

Examples.—The liquid, water, when cooled becomes the solid, ice; when heated to 100° C. it becomes the gas, steam.

On the other hand, the gases oxygen and air have been converted into liquids and solids by means of great pressure and low temperature.

4. The Viscous and Plastic States. — A body may exist in such a condition that it is impossible to say that it is solid, liquid, or gas. And when the body can exist either as a solid or liquid or gas, the change from one state to another is frequently gradual. The following experiments illustrate these conditions:—

Exp. 1.—Place on a sheet of glass a drop of water, a small quantity of treacle, and a piece of wax. Slightly tilt the glass. Notice that the water flows down at once, leaving a very *thin* trail. The treacle shows a tendency to *flow;* the wax remains. Incline the glass further. The treacle will flow, leaving a *thick* trail, and the wax will show a tendency to slide.

Now, the trail is due to that portion of the matter, water or treacle, which is in *contact* with the glass; and it is, therefore, the *upper* layers of the matter which *flow over* the lower layers. In other words, *separation* between the upper layers and lower layers occurs in the case of water and of treacle, but not apparently in the case of the wax at ordinary temperature. But there is this difference: the water separates with the greatest ease, the treacle with some difficulty, and the wax not at all.

DEFINITION.—A fluid in which one layer does not easily flow over another is termed a **viscous** fluid, and this property of a fluid is termed **viscosity.**

We may therefore sum up thus:

(*a*) Water *flows* without difficulty, and is a *non-viscous fluid.*

(*b*) Treacle *flows* with difficulty, and is a *viscous* fluid.

(*c*) Wax does *not flow* at ordinary temperatures, and in character approaches very near to a solid.

Exp. 2.—Now gently warm the glass under the wax. After a short time the under layers of wax will melt and spread. Tilt the glass and notice that the upper layers of wax flow over the lower layers. Hence, at higher temperature wax becomes a *viscous fluid*.

It will be found, however, that at intermediate temperatures the wax is neither a solid nor a viscous fluid. It will resemble the treacle in the fact that it is easy to make a dent in either, but the dent in the treacle will be rapidly filled up and disappear, whilst that in the wax will remain for a considerable time, and, it may be, permanently. At these intermediate temperatures wax can be moulded between the fingers.

DEFINITION. — The **plastic** state is a state intermediate between the viscous and the solid state. In this state little force is required to produce change of shape, and such change when produced is to a large degree permanent.

5. Other Properties of Matter. — There are many other qualities of bodies which should be considered. Matter, for example, cannot be destroyed; but the experiments showing this belong rather to chemistry than to mechanics.

Again, bodies of the same size have different weights or masses, *i.e.* some bodies are more dense than others.

For example, we say "Lead is denser than wood, and wood is denser than cork." This property will be described more fully in Chap. VII.

Summary.—Chapter I.

1. The *mass* of a body is the quantity of matter it contains; the *volume* of a body is the space it occupies. (§§ 1, 2.)

2. All bodies may be divided into two classes: *solids* and *fluids*. Fluids may be further divided into *liquids* and *gases*. (§ 3.)

3. Solids and liquids have definite size; but, whereas solids have definite shape, liquids take the shape of the part of the vessel they are in. Gases always fill the containing vessel. (§ 3.)

4. A solid is said to be in the plastic state when it can be easily moulded. A viscous fluid is one in which considerable friction is exerted between its component parts. (§ 4.)