It sometimes happens that a body which is more dense than a liquid floats upon it. Thus, a porcelain saucer floats upon water. This arises from its form being such, that it displaces its own weight of water, when only partially immersed. For the same reason iron ships float freely on the ocean.

Illustration of the Principles of Flotation.

90. The principles of flotation may be illustrated by an instrument shown in Fig. 60, which under various forms is sold in the shops as a child's toy.

In the form shown, it consists of a high and narrow glass vessel, surmounted by a brass cylinder, *A*, in which is an air-tight piston that may be raised or depressed by the hand. The vessel is partially filled with water, and contains a light body, as a fish, hollow and of porcelain or glass. The fish is attached to a sphere of glass, *m*, filled with air, and with a small hole, *o*, at its lower side, through which water can flow in or out, as the pressure is increased or diminished.

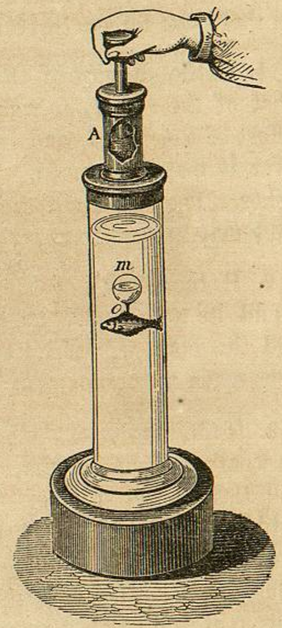

Fig. 60

Under ordinary circumstances the sphere, *m*, with its attached fish, floats at the surface of the water. If the piston is depressed, the air beneath it is compressed, and acting upon the water forces a portion of it into the globe. The apparatus then becomes more dense than the water, and sinks. By relieving the pressure, the air in the globe expands and drives the water out, when it again floats on the surface. The operation may be repeated at pleasure.

Explain the case of a dense body floating on a liquid. (**90.**) *What instrument illustrates the laws of flotation? Explain its use and action.*

Swimming Bladder of Fishes.

91. In many fishes there is a bladder filled with air, situated directly under the backbone. This is called the *Swimming Bladder.*

When the fish wishes to descend, it compresses this bladder by a muscular effort, and then, as the quantity of water displaced is less than before, the weight of the fish prevails over the buoyant effort, and the fish sinks. On relaxing the effort, the bladder expands, the buoyant effort of the water prevails over the weight of the fish, and it rises.


Fig. 61.

Swimming.

92. The human body is lighter than water, especially than the salt water of the ocean, and tends naturally to float when immersed. The only reason why men do not swim naturally, is the difficulty of keeping the head out of water, so as to be able to breathe. The head is the heaviest part of the body, and tends continually to sink into the water.

Many quadrupeds swim naturally, because the head is small in proportion to the body, and is so placed upon the trunk, that it is easy to keep it above the surface.

The safest position for a person in the water, who does not know

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(**91.**) What is the Swimming Bladder of a fish? *Explain its action.* (**92.**) *Explain the phenomenon of swimming. Why do some quadrupeds swim naturally? What is the safest position in the water?*

how to swim, is upon the back. The tendency to raise the arms out of the water should be resisted, as this diminishes the buoyant effort of the fluid without diminishing the weight.

In learning to swim, it is often the custom to place bladders filled with air, or blocks of cork, under the arms, as shown in Fig. 61. These act to increase the buoyant effort of the fluid, without sensibly increasing the weight. It is on this principle that life-preservers are constructed.

Many kinds of birds, as ducks, geese, swans, and the like, swim naturally and without effort. They owe this faculty to a thick layer of down and feathers which are very light and impermeable by water. They, therefore, displace a large volume of water in proportion to their weight, giving rise to a strong buoyant effort.

V.—SPECIFIC GRAVITY OF BODIES.

Definition of Specific Gravity.

93. The SPECIFIC GRAVITY of a body is its *relative weight;* that is, it is the number of times the body is heavier than an equivalent volume of some other body taken as a standard.

It is a matter of daily observation, that some substances are heavier than others under the same volume. Thus, gold is heavier than silver, lead than iron, stones than wood, and so on. In order to compare the relative weights of different bodies, all are referred to a common standard.

Distilled water is generally adopted as a standard, and because water varies in density at different temperatures, it is usual to take it at the temperature of 38°.75 Fahrenheit, water being most dense at that temperature.

In order to find the specific gravity of any body, all that we have to do is, to find how many times heavier any

What is the principle of the life-preserver? Why do some birds swim naturally? (**93.**) What is Specific Gravity? *Illustrate. What is taken as a standard? At what temperature? Why?* What is the process of finding the specific gravity of a body?

given volume of the body is, than an equivalent volume of distilled water at 38°.75 F. This is the method of fixing the specific gravity of solids and liquids; we shall see hereafter how it is possible to fix the specific gravity of gases and vapors.

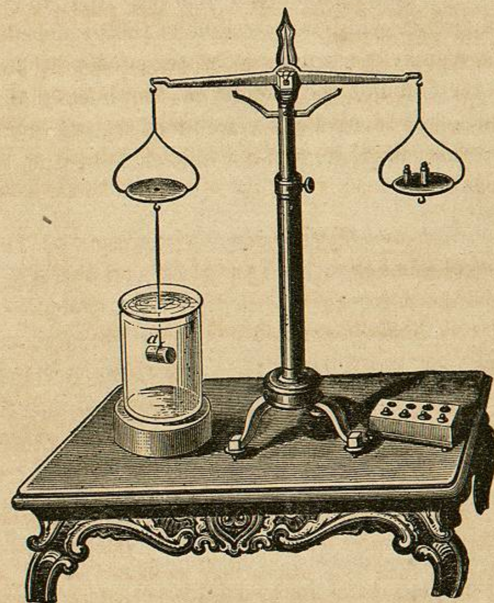

Fig. 62.

Specific Gravity of Solids.

94. The following are some of the methods of determining the specific gravities of solids:

1. *By the Hydrostatic Balance.*—Place the body in one of the scale pans and balance it by known weights in the other pan. These will give the weight of the body in air.

(**94.**) Explain, in detail, the method of finding the specific gravity of a solid by means of the hydrostatic balance.

Next suspend the body in a vessel of distilled water by means of a thread or wire attached to one of the scale pans, as shown in Fig. 62, and balance it by weights placed in the other pan. On account of the buoyant effort of the water, the weight of the body in water will be less than that in air. Subtract the weight of the body in water from that in air, and the difference will be the weight of the displaced water, that is, the weight of a volume of water equal to that of the body. Having found the weight of the body in air, and the weight of an equivalent volume of water, divide the former by the latter, and the result will be the specific gravity required.

2. *By Nicholson's Hydrometer.*—NICHOLSON'S HYDROMETER consists of a hollow cylinder of glass, as shown in Fig. 63, weighted at the bottom by a heavy body, *d*, to make it float erect, and terminating above by a thin stem, *c*, which supports a scale pan, *a*. The instrument is so constructed that when a given weight, say 500 grains, is placed in the pan, it will sink in distilled water to a notch, *c*, on the stem.

The method of determining the specific gravity by means of this instrument is shown in Figs. 64 and 65. Suppose it were required to determine the specific gravity of a small bar of iron weighing less than 500 grains.

The bar is placed in the pan and weights added till it sinks to the notch in the stem as shown in Fig. 64. These weights, subtracted from 500 grains, give the weight of the bar in air. Next place the bar in the cup, *d*, as shown in Fig. 65, and add weights enough to make the instrument sink again to the notch in the stem. The last weights will denote the buoyant effort of the fluid, or the weight of the water displaced by the bar. Divide the weight of the bar in air by the weight of the displaced water, and the result will be the specific gravity sought.

What is Nicholson's Hydrometer? How used for determining the specific gravity of a solid?

3. *By a flask.*—This method is used when a body exists in a state of powder, or in fine particles like sand. A small flask, whose exact weight is known, is first filled with the powder and the whole carefully weighed. The entire weight, diminished by that of the flask, is the weight of the body.

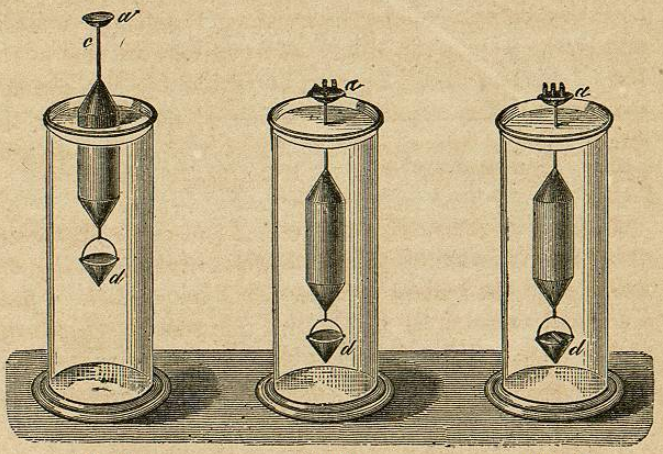

Fig. 63. Fig. 64. Fig. 65.

The flash is then filled with water and weighed. This weight, diminished by that of the flask, is the weight of an equivalent volume of water. Divide the weight of the body by that of its equivalent volume of water, and the result will be the specific gravity required.

Specific Gravity of Liquids.

95. The following are some of the principal methods of determining the specific gravities of liquids:.

1. *By the Hydrostatic Balance.*—Select a heavy body which is not soluble either in water or in the liquid whose

Explain the method by means of a flask. (**95.**) How is the specific gravity of a liquid found by means of the balance?

specific gravity is to be determined, as, for example, a ball of platinum. Weigh this body first in air, then in water, and finally in the liquid in question. Subtract the second and third weights from the first separately; the results obtained will be respectively the weights of a volume of water, and of the liquid, equal to that of the platinum ball. Divide the latter by the former, and the quotient will be the specific gravity required.

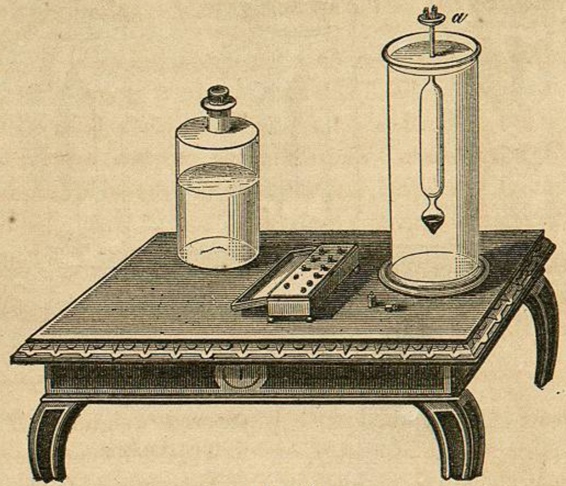

Fig. 66.

2. *By Fahrenheit's Hydrometer.*—FAHRENHEIT'S HYDROMETER consists of a glass cylinder ballasted at the bottom by a small globe filled with mercury, and provided at top with a stem and scale pan as shown in Fig. 66. Its weight is carefully determined.

To use the hydrometer, it is first plunged into distilled water, and weights placed in the scale pan till it sinks to the

Describe Fahrenheit's Hydrometer. How is it used to find the specific gravity of a liquid?

notch filed on the stem. These weights, increased by that of the instrument, will give the weight of the displaced water. The instrument is next plunged into the liquid in question, and weights are placed in the pan till the instrument again sinks to the notch. These weights, added to that of the instrument, give the weight of the displaced liquid. Now the volumes displaced are the same in both cases, each being that of the submerged instrument; hence, if we divide the weight of the displaced liquid by that of the displaced water, the quotient will be the specific gravity required.

3. *By the flask.*—A flask is constructed so as to hold a given weight of distilled water, say 1000 grains. This flask is first weighed when empty, and then when filled with the liquid in question. The difference of these results is the weight of the liquid, and this, divided by 1000 grains, will be the specific gravity required.

The specific gravities of some of the most important substances are given in the following table:

TABLE,

SHOWING THE SPECIFIC GRAVITIES OF SOLIDS AND LIQUIDS.

Platinum	22.07	Mercury	13.60
Gold	19.34	Sulphuric Acid	1.84
Lead	11.35	Milk	1.03
Silver	10.47	Sea Water	1.03
Iron	7.79	Distilled Water	1.00
Zinc	7.00	Bordeaux Wine	0.99
Diamond	3.53	Olive Oil	0.91
White Marble	2.84	Spirits of Turpentine	0.87
Glass	2.49	Absolute Alcohol	0.79
Ivory	1.92	Ordinary Ether	0.71

It will be seen that platinum is the heaviest solid, and that mercury is the heaviest liquid.

How is the specific gravity of a liquid determined by means of a flask? *Which is the heaviest solid? Liquid?*

A knowledge of the specific gravities of bodies is of frequent application. In mineralogy it aids in determining mineral species. The jeweller determines by its aid the precious stones. It enables us to find the weight of a body when we know its volume. Thus, a cubic foot of iron weighs 11.35 times as much as a cubic foot of water; but a cubic foot of water weighs 1000 ounces, hence a cubic foot of iron weighs 11,350 ounces, or about 709 lbs.

Beaumé's Areometer.

96. BEAUMÉ'S AREOMETER consists of a bulb of glass, ballasted at bottom by a second bulb containing mercury, and terminating at top in a cylinder of uniform diameter, as shown in Fig. 67.

When plunged into liquids, it sinks till the weight of the displaced fluid equals that of the areometer. In light fluids it therefore sinks deeper than in heavy ones.

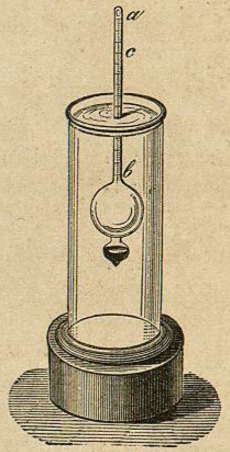

Fig. 67.

The plan of graduating BEAUMÉ'S areometer is as follows. It is ballasted so that in distilled water it will sink to the point *a*, on the stem, which is marked 0. A mixture of salt and pure water is then formed, in the proportion of 15 of the former to 85 of the latter, into which the instrument is plunged. The upper surface then cuts the stem at some point, *c*, which is marked 15. The intermediate space between *a* and *c*, is divided into 15 equal parts, and the division is continued downwards on the stem. The divisions and numbers are on a slip of paper in the interior of the stem.

What are some of the applications of the specific gravity of bodies? (**96.**) Describe BEAUMÉ'S Areometer? How is it graduated?

The use of the instrument thus graduated is to ascertain the amount of salt in any solution of salt in water. It is plunged into the solution in question, and the number to which it sinks, denotes the per-centage of salt in the solution.

Instruments constructed on this principle have been devised for determining the strength of other solutions, whether of acids or salts. Also for determining the strength of saccharine solutions and the like.

The Alcoholometer.

97. The ALCOHOLOMETER is similar in its construction to the areometer just described. It is graduated so as to show the percentage of alcohol in any mixture of alcohol and water.

The instrument is first ballasted so that when plunged in pure water it will float with nearly all of its stem above the water. The line of flotation is marked 0. Mixtures are then formed, containing 1, 2, 3, &c., per cent. of pure alcohol and water, and the instrument is plunged into them in succession. The lines of flotation are marked 1, 2, 3, &c., as in the instrument previously. In this case the numbers run upwards. It is necessary to graduate it throughout by trial, as the divisions are not uniform.

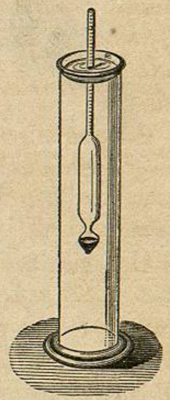
Fig. 68.

To use the instrument, it is plunged into the solution of alcohol in water to be tested, and the per-centage is read off on the paper scale within the tube, or else the scale is scratched upon the stem with a diamond.

What is its use? How used? What other instruments are constructed on the same principle? (**97.**) Describe the Alcoholometer. How is it graduated? How used?

The Lactometer.

98. The LACTOMETER is entirely analagous in principle to BEAUMÉ'S areometer, and is used to determine the purity of milk. The instrument, and the method of using it, are shown in Fig. 69.

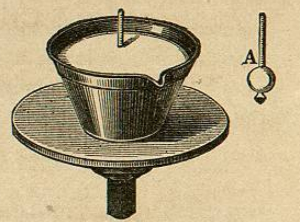

Fig. 69.

It is graduated by trial, using mixtures of milk and water. In the first trial pure water is used, then mixtures containing 10, 20, 30, 40, &c., per cent. of milk. The scale is therefore divided into 10 parts, between pure water and pure milk.

(**98.**) What is a Lactometer? How graduated and used?

CHAPTER III.

MECHANICS OF GASES AND VAPORS.

I.—THE ATMOSPHERE.

General Properties of Gases and Vapors.

99. GASES and VAPORS have been defined to be highly compressible fluids.

The distinction between a gas and a vapor, is not very clear. When a body in a gaseous form can, by moderate pressure, be reduced to a liquid form, it is usually called a vapor. For most of the purposes of Physics the distinction is unimportant.

Besides the property of compressibility, or rather as a consequence of it, gases and vapors continually tend to expand so as to occupy a greater space. The force which they exert in this way, is called their *Tension*, or their *Elastic Force*.

Thirty-four gases are known, thirty of which are compound, and four are simple. The four simple gases are, *oxygen*, *hydrogen*, *nitrogen*, and *chlorine*. Most of the gases are colorless, but some are not so.

Of the thirty-four gases, all but five have been liquefied by pressure, and the application of cold. The five that have thus far resisted are, *oxygen*, *hydrogen*, *nitrogen*, *deutoxyde of nitrogen*, and *carbonic oxyde*.

(**99.**) What are Gases and Vapors? *What is the difference between them?* What is meant by Tension? *How many known gases are there? Which are simple? Which have not been liquefied?*