upper surface in all of the vessels is in the same horizontal plane.

This principle is demonstrated by means of the apparatus represented in Fig. 51. This apparatus consists of a system of glass vessels of different shapes and capacities, all of which communicate by a tube, *ac*. If any amount of water or other liquid be poured

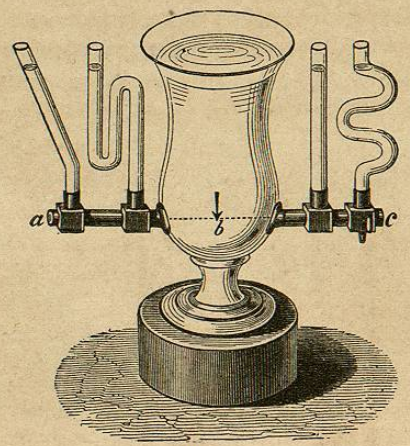

Fig. 51.

into one of the branches and allowed to come to rest, it will be seen that its upper surface in all of the vessels is in the same horizontal plane. The reason of this is, obviously, a necessary consequence of the principle of equal pressures.

Case of Vessels containing Liquids of different Densities.

80. When liquids of different densities are contained in communicating vessels, they will be in equilibrium when the heights of the columns are inversely as their densities.

This principle is demonstrated by means of an apparatus shown in Fig. 52. The apparatus consists of two glass tubes, *A* and *B*, open

How is this demonstrated? (**80.**) What are the conditions of equilibrium in the case of liquids of different densities? *How is this demonstrated?*

at top, and communicating at bottom by a smaller tube. If a quantity of mercury be poured into one of the tubes, it will come to a level in both tubes, according to the principle explained in the preceding article. If a quantity of water be poured into the tube *A*, the level of the mercury in that tube will be depressed, whilst it will be elevated in the tube *B*. The difference of level, *dc*, can be determined by the graduated scales on the tubes. It will be found by measurement, that the column of water, *ab*, is 13.6 times as high as the column of mercury, *dc*, which it supports. It will be shown hereafter, that mercury is 13.6 times as dense as water; hence the principle is proved. Other liquids may be employed with similar results.

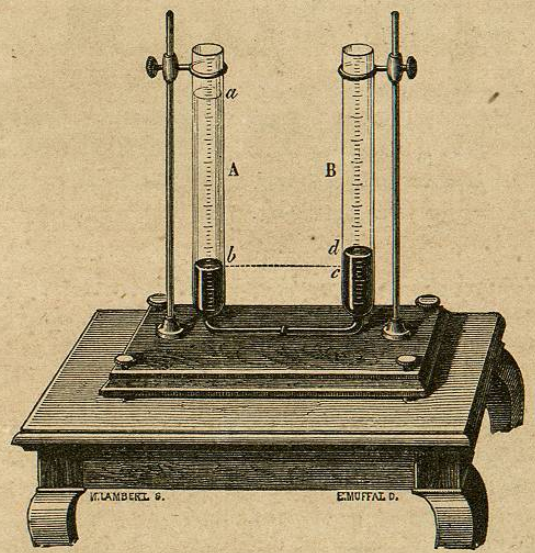

Fig. 52.

Equilibrium of Heterogeneous Liquids.

81. If liquids of different densities, but which do not mix, be poured into a vessel, they will arrange themselves

(**81.**) What are the conditions of equilibrium of heterogeneous liquids?

in the order of their densities, the heaviest being at the bottom, and the upper surface of each will be horizontal.

This is shown by a vial, Fig. 53, containing liquids of different densities, as mercury, water, and oil. If the vial be shaken, the liquids appear to mix, but if allowed to stand, they arrange themselves in horizontal layers, the densest liquid at the bottom.

The vial in the figure is represented as containing four liquids. It was formerly called the *vial of four elements*.

It is in accordance with this principle that cream rises on milk, and oil on water. The principle is often employed to separate liquids of different density by the process of decantation.

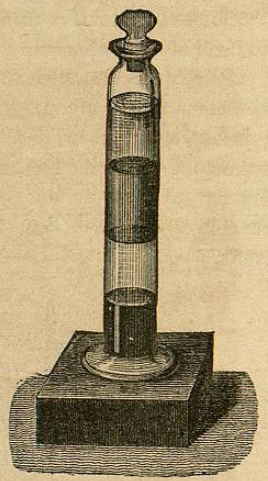

Fig. 53.

III.—APPLICATIONS OF THE PRINCIPLE OF EQUILIBRIUM.

The Water Level.

82. A WATER LEVEL is an instrument employed for determining the difference of level between two points. It consists of a horizontal tube of tin, $2\frac{1}{2}$ or 3 feet in length, into the extremities of which two glass tubes are inserted perpendicular to it. The whole rests upon a three-legged support, called a *tripod*, as shown in Fig. 54. A quantity of water tinged with carmine or other coloring matter is introduced into one of the glass tubes, which, flowing through the horizontal tube, rises to the same level in the other. A visual ray directed along the surfaces of the

How shown? (**82.**) What is a Water Level? Describe it and its use.

water in the two glass tubes will be a horizontal line, or a *line of apparent level*. The use of the instrument is evident from the figure.

Fig. 54.

The Spirit Level.

83. The SPIRIT LEVEL consists of a tube of glass nearly filled with alcohol, and closed at its two extremities. The tube is slightly curved, and when placed horizontally, the

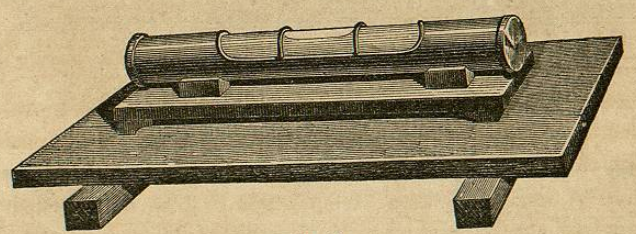

Fig. 55.

bubble of air which it contains rises to the middle of the upper side of the tube. If either end be depressed, the

(**83.**) Describe a Spirit Level. How mounted?

bubble runs towards the other end. When used it is ordinarily mounted in a wooden case.

This form of *level* is much used by masons, carpenters, and other artisans. To ascertain whether a surface is level, the instrument is laid upon it, and the position of the bubble noticed. If the bubble is in the middle of the tube, the surface is level.

This form of level is also attached to many kinds of surveying and astronomical instruments.

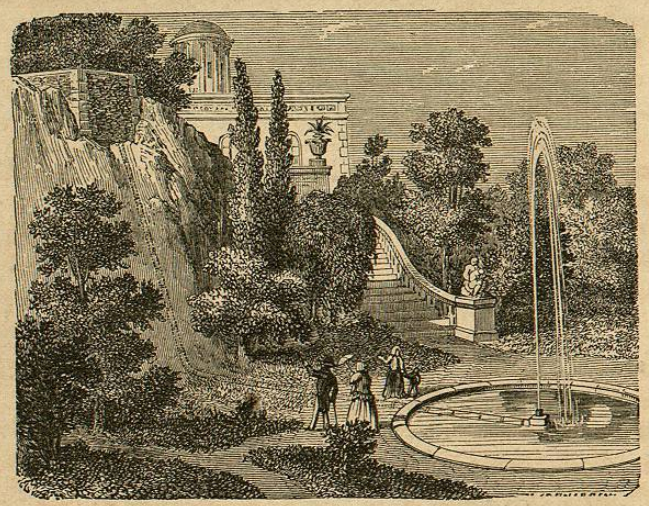

Fig. 56.

Springs. — Fountains. — Rivers.

84. It is the principle of equal pressures that causes water to rise in springs and fountains. The water which feeds them is contained in natural or artificial reservoirs higher than the spring or fountain. These reservoirs communicate with the springs or fountains by natural or artificial channels, and the pressure of the water in them

What are its uses? Applications. (**84.**) What is a Spring? Fountain?

causes that in the spring or fountain to boil up, or sometimes to shoot up in a jet.

Fig. 56 represents a fountain called a *jet d'eau*. The reservoir is on the hill to the left, and the water reaches the bottom of the basin by a pipe represented by dotted lines.

The water of the jet tends to rise to the level of that in the reservoir, and would do so were it not for the resistance of the air, the friction of the water against the pipe, and the resistance offered by the falling particles, all of which combine to render the jet lower than the fountain-head.

The same principle determines the flow of streams from the higher to the lower grounds. The water of lakes, seas, and oceans is continually evaporating to form vapors and clouds. These are condensed in the form of rain, and the particles of water, urged by their own weight, seek a lower level. The rivulets gather to form brooks, and these unite to form rivers, by which the water is once more returned to the oceans and lakes. All of the water does not flow back to the ocean along the surface, but a portion percolates through the porous soils and accumulates in cavities to feed our springs and wells.

Artesian Wells.

85. Artesian Wells are deep wells, formed by boring through rocks and strata of various kinds of earth to reach a supply of water. These wells are named from the province of Artois, in France, where they were first used.

Fig. 57 illustrates the principle of these wells. *H* is the natural surface of the earth. *AB* and *CD* are curved strata of clay or rock which do not allow of the percolation of water. *KK* is an intermediate stratum of sand or gravel, which permits water to penetrate it. When a hole, *I*, is bored down to strike the water-bearing stratum, *KK*, the pressure of the water in the stratum forces it up in a jet. The well of Grenelle, in Paris, is nearly 1800 feet

Explain the jet d'eau? What causes the flow of streams? How are they fed? (**85.**) What are Artesian Wells? *Explain their action? How deep is that at Paris?*

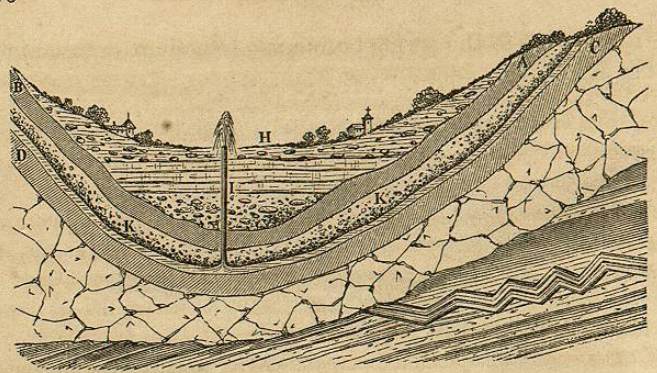

Fig. 57.

deep, and is fed by water coming from the hills of Champagne, which are much higher than Paris. The supply of water from this well is immense.

Many Artesian wells have been sunk in our own country.

IV. — PRESSURE ON SUBMERGED BODIES.

Principle of Archimedes.

86. If a body is submerged in a fluid, it will be pressed in all directions, but not equally.

To illustrate, suppose a cube immersed in water, as shown in Fig. 58. The lateral faces, *a* and *b*, will be equally pressed and in opposite directions. The same will be true for the other lateral faces. Hence, the horizontal pressures will exactly neutralize each other. The upper and lower faces, *c* and *d*, will be unequally pressed, and in opposite directions. The face, *c*, will

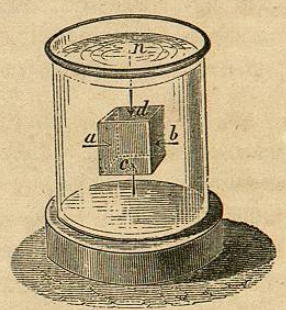

Fig. 58.

(86.) Are submerged bodies pressed equally in all directions? *Illustrate in detail.*

be pressed upwards by a force equal to the weight of a column of the liquid whose cross-section is that of the cube, and whose height is the distance of *c* from the surface of the fluid. The face, *d*, will be pressed downwards by the weight of a column of the liquid, having the same cross-section as the cube, and a height equal to the distance of *d* from the surface of the liquid; the resultant of these two pressures is an upward force, equivalent to the weight of a volume of the liquid equal to that of the cube. This upward pressure is the *buoyant effort* of the fluid.

The principle just explained is called the *Principle of Archimedes*. It may be expressed by saying that, *a submerged body loses a portion of its weight equal to that of the fluid displaced by it.*

Hydrostatic Balance.

87. A Hydrostatic Balance is a balance having a hook attached to the lower face of each scale pan, and so constructed that the beam may be raised or lowered at pleasure.

Fig. 59 represents a hydrostatic balance. The cylinder, *c*, is solid, and fitted to slide up and down in the hollow cylinder, *d*. The cylinder, *c*, may be confined in any position by means of a clamp screw, *n*.

Cylinder and Bucket Experiment.

88. The principle of Archimedes may be illustrated by what is called the *Cylinder and Bucket Experiment*, as shown in Fig. 59. A hollow cylinder or bucket, *b*, of brass, is attached to the hook of one of the scale pans, and from it is suspended a solid cylinder of brass, just large enough to fill the bucket, and the two are balanced by weights placed in the opposite scale pan. A glass vessel

Enunciate the principle of Archimedes. (87.) What is a Hydrostatic Balance? *Explain its construction.* (88.) Explain the Cylinder and Bucket Experiment.

having been placed beneath the cylinder, water is gradually poured into it, until the cylinder is immersed. The opposite scale pan will descend, showing that the cylinder is

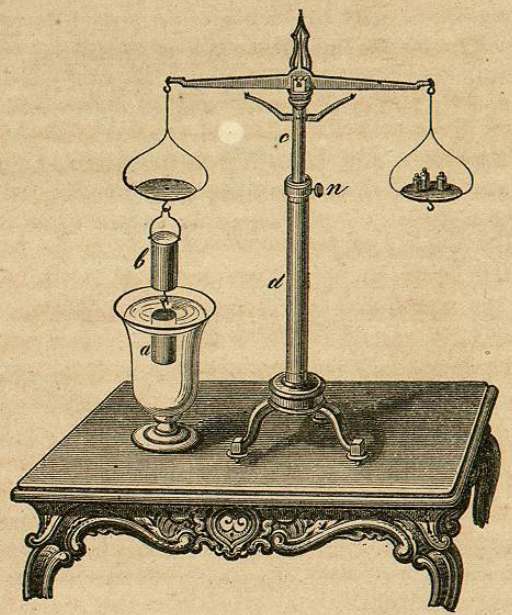

Fig. 59.

buoyed up by some force. If we now fill the bucket, *b*, with water, the equilibrium will be restored, and the beam will come to a level. Because the water poured into the bucket is equal to that displaced by the cylinder, we infer that the buoyant effort is exactly equal to the weight of the displaced fluid.

The principle of ARCHIMEDES is so called, because it was first discovered by the illustrious philosopher of that name. He was led to the discovery in an attempt to detect a fraud, perpetrated upon

Why is the principle of ARCHIMEDES *so called?*

HIERO of Syracuse, by a goldsmith, whom he had employed to make a golden crown. The artisan mixed a portion of silver with the gold that was given him for making the crown, but by means of the principle above explained, ARCHIMEDES was able to determine the exact amount of each material employed.

Floating Bodies.—Principles of Flotation.

89. When a body is plunged into a liquid, it is urged downward by its proper weight, and upward by the buoyant effort of the liquid, and, according to the relative intensities of these two forces, three cases may arise:

1. If the density of the immersed body is the same as that of the liquid, its weight will be equal to the buoyant effort of the liquid, and it will remain in equilibrium wherever it may be placed. This is practically the case with fishes. They maintain themselves in any position in which they may happen to be, without effort.

2. If the density of the body is greater than that of the liquid, its weight will be greater than the buoyant effort, and the body will sink to the bottom. This is what happens when a stone or piece of iron is thrown into water.

3. If the density of the body is less than that of the liquid, its weight will be less than the buoyant effort, and the body will rise to the surface. The body will continue to rise until the weight of the displaced liquid equals that of the body, when it will come to rest. It is then said *to float*. Thus, a piece of wood floats upon water, and in like manner a piece of iron floats upon mercury.

When a floating body comes to rest on a liquid, the plane of the upper surface of the liquid is called the *Plane of Flotation.*

Explain the method of its discovery. (**89.**) When a body is plunged into a liquid, what three cases may arise? Explain the first case. The second case. The third case. What is the Plane of Flotation?