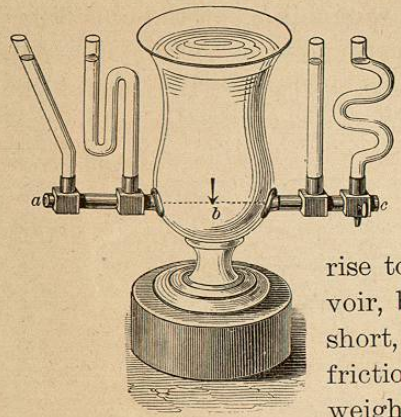
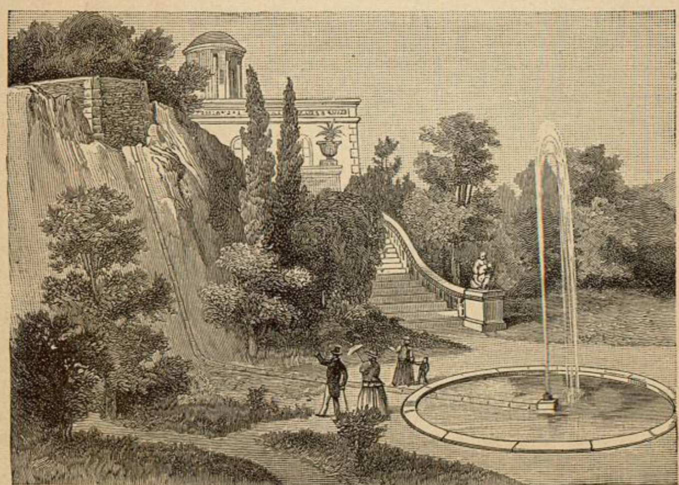
must be unequally pressed from opposite sides, and must move until equilibrium is attained. In Fig. 77 a tank is situated on a hill, whence the water is conducted underground through a pipe to the fountain. In theory the jet will rise to the level of the reservoir, but in practice it falls short, owing chiefly to the friction in the pipe, the weight of the falling drops, and the resistance of the air.

Fig. 76.



Water in Communicating Vessels.

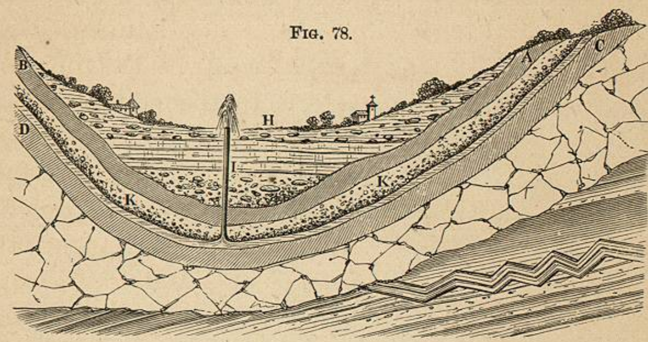
Fig. 77.



Construction of a Fountain.

*Artesian Wells.**—Let *A B* and *C D* represent curved strata of clay impervious to water, and *K K* a layer of gravel. The rain falling on the hills filters down to *C D*, and collects in this basin. If a well be bored at *H*, as soon as it reaches the gravel the

Fig. 78.



Artesian Well.

water will rush upward, under the tremendous lateral pressure, to the surface of the ground, often spouting high in air.†

Wells.—Of the rain which falls on the land, a part runs directly to the streams and part soaks into the soil. The latter portion may filter down to an im-

* They are so named because they have long been used in the province of Artois (Latin, Artesium), France. They were, however, early employed by the Chinese for the purpose of procuring gas and salt water.

† The famous well at Grenelle, Paris, is at the bottom of a basin which extends miles from the city. It is about 1,800 feet deep, and furnishes 656 gallons of water per minute. The two wells of Chicago are about 700 feet deep, and discharge daily about 432,000 gallons. Being situated on the level prairie, the force with which the water comes to the surface indicates that it may be supplied perhaps from Rock River, 100 miles distant. There are also valuable artesian wells at Louisville, Kentucky, and at Charleston, South Carolina. When the water comes from a great depth, it is generally warm.

permeable layer of rock or clay, and then run along till it oozes out at some lower point as a spring; or, if it can not escape, it will collect in the ground. If a well be sunk into this subterranean reservoir, the water will rise in it to the level of the source.*

(2.) RULES FOR COMPUTING PRESSURE.—I. *To find the pressure on the bottom of a vessel.* Multiply the area of the base in square feet by the vertical height in feet, and that product by the weight of a cubic foot of the liquid.

FIG 79.

The Curvature of a Water Level.

II. *To find the pressure on the side of a vessel.* Multiply the area of the side in square feet by half

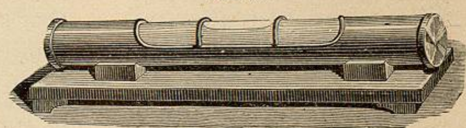
* "From a forgetfulness of this principle the company which dug the Thames and Medway Canal, England, incurred heavy damages. Having planned the canal to be filled at high tide, the salt water spread immediately into all the wells of the surrounding region. Had the canal been dug a few feet lower, the evil would have been avoided."—ARNOTT.

of the vertical height in feet,* and that product by the weight of a cubic foot of the liquid. The pressure on the bottom of a cubical vessel of water is the weight of the water; on each side, one half; and on the four sides, twice the weight; therefore, on the five sides the pressure is three times the weight of the water.

(3.) WATER-LEVEL.—The surface of standing water is said to be level—*i. e.*, horizontal to a plumb-line. This is true for small sheets of water, but for larger bodies an allowance must be made for the spherical form of the earth (Fig. 79). The curvature is 8 inches for the first mile, and increases as the square of the distance.†

The *spirit-level* is an instrument used by builders for leveling. It consists of a slightly-curved glass tube nearly full of alcohol, so that it holds only a bubble of air. When the level is horizontal, the bubble remains at the center of the upper side of the tube.

FIG. 80.



The Spirit-level.

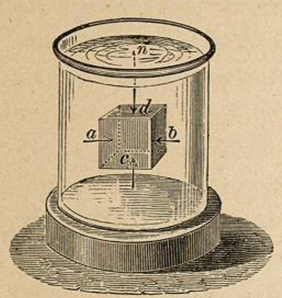
(4.) SPECIFIC GRAVITY, or relative weight, is the ratio of the weight of a substance to that of the

* This clause of the rule holds only when the center of gravity of the side is at half the vertical height. In general, the depth of its center of gravity below the surface should be used as the multiplier.

† For two miles it is 8 inches $\times 2^2 = 32$ inches. If one's eye were at the level of still water, he could barely see the top of an object 67 feet high at a distance of 10 miles in a perfectly clear atmosphere.

same volume of another substance taken as a standard. Water is taken as the standard* for solids and liquids, and air for gases. A cubic inch of sulphur weighs twice as much as a cubic inch of water; hence its specific gravity = 2. A cubic inch of carbonic-acid gas weighs 1.52 times as much as the same volume of air; hence its specific gravity = 1.52.†

Fig. 81.



Immersed Cube.

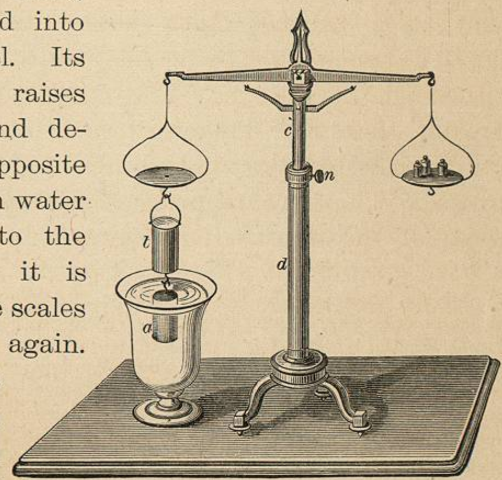
Buoyant Force of Liquids.—The cube *a b c d* is immersed in water. The lateral pressure at *a* is equal to that at *b*, because both sides are at the same depth; hence the body has no tendency toward either side of the jar. The upward pressure at *c* is greater than the downward pressure at *d*, because its depth is greater; hence the cube has a tendency to rise. This upward pressure is called the buoyant force of the water. *It is equal to the weight of the liquid displaced.* For the downward pressure at *d* is the weight of a column of water whose area is that of the top of the cube, and whose vertical height is *n d*, and the upward pressure at *c* is equal to the weight of a column of the same size whose vertical height is *n c*. The difference between the two, or the buoyant force, is the weight of a volume of water equal to the size of the cube.

* "The water must be at 39.2° F., its greatest density. In all exact measurements, especially of standards, it is necessary to know the temperature. For the scale that is a foot long to-day may be more or less than a foot long to-morrow; the measure that holds a pint to-day may hold more or less than a pint to-morrow. Nay, more, these measures may not be the same in two consecutive moments. When a carpenter takes up his rule and applies it to some object, the size of which he wishes to determine, it becomes in that instant longer than it was before; when a druggist grasps his measuring glass in his hand to dispense some of his preparations, the glass increases in size. A person enters a cool room, and at once it becomes more capacious, for its walls, ceiling, and floor, because of the heat he imparts, immediately expand."—Draper.

† The term density is often used in the same sense as specific gravity, especially in relation to gases.

The same principle is shown in the "cylinder-and-bucket experiment." The cylinder *a* exactly fits in the bucket *b*. When the glass vessel in which the cylinder hangs is empty, the apparatus is balanced by weights placed in the scale-pan. Next, water is poured into the glass vessel. Its buoyant force raises the cylinder and depresses the opposite scale-pan. Then water is dropped into the bucket; when it is exactly full, the scales will balance again. This proves that "a body in water is buoyed up by a force equal to the weight of the water it displaces." This is called Archimedes' law.

Fig. 82.

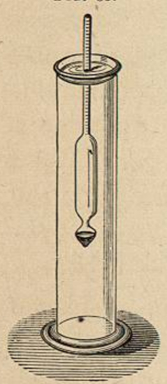


Cylinder-and-bucket Experiment.

To find the specific gravity of a heavy solid. Weigh the body in air, and in water; the difference is the weight of its volume of water; divide its weight in air by its loss of weight in water; the quotient is the specific gravity. Thus, sulphur loses one half its weight when immersed in water; hence it is twice as heavy as water, and its specific gravity=2.*

To find the specific gravity of a liquid by the specific-gravity flask. This is a bottle which holds exactly 1,000 grains of water. If it will hold 1,840 grains of sulphuric acid, the specific gravity of the acid is 1.84.

Fig. 83.



Hydrometer.

To find the specific gravity of a liquid by a hydrometer. This instrument consists of a glass tube, closed at one end and having at the other a bulb containing mercury. A graduated scale is marked upon the tube. The *alcoholometer*, used in testing alcohol, is so balanced as to sink in pure water to the zero point. As alcohol is lighter than water, the instrument will descend for every addition of spirits.

* In careful measurements an allowance is made for the weight of the air displaced by the body, so that its weight in a vacuum becomes known. Strictly, it is the weight in a vacuum that has to be compared with the loss of weight in water. If the body will not sink in water, attach it to a heavy body. 1. Weigh the lighter body in air (A). 2. Weigh the heavy body in water (B). 3. Weigh both together in water (C). Now C is less than B because the light body buoys up the heavy one; *i. e.*, its weight A is more than balanced, and is replaced by an upward or lifting force$=B-C$. Therefore the loss of the light body in water$=A+B-C$ $\therefore$ spec. grav.$=\frac{A}{A+B-C}$.

The degrees of the scale indicate the percentage of alcohol. Similar instruments are used for determining the strength of milk, acids, etc.

To find the weight of a given volume of any substance. Multiply the weight of one cubic foot of water by the specific gravity of the substance, and that product by the number of cubic feet.—*Example:* What is the weight of three cubic feet of cork? *Solution:* 1,000 oz. × .240* = 240 oz.; 240 oz. × 3 = 720 oz.

To find the volume of a given weight of any substance. Multiply the weight of a cubic foot of water by the specific gravity of the substance, and divide the given weight by that product. The quotient is the required volume in cubic feet.—*Example:* What is the volume of 20,000 oz. of lead? *Solution:* 1,000 oz. × 11.36 = 11,360; 20,000 ÷ 11,360 = 1.76 + cu. ft.

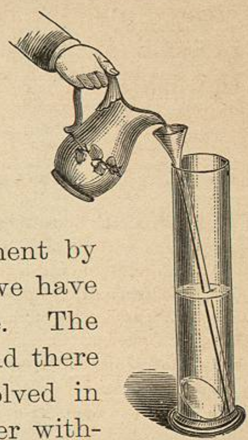
To find the volume of a body. Weigh it in water. The loss of weight is the weight of the displaced water. Then, as a cubic foot of water weighs 1,000 oz., we can easily find the volume of water displaced. — *Example:* A body loses 10 oz. on being weighed in water. The displaced water weighs 10 oz. and is $\frac{1}{100}$ of a cubic foot; this is the exact volume of the body.

* Table of Specific Gravity. (See "Chemistry," p. 288.)

Iridium	21.80	Zinc	7.15	Pine Wood	.66
Platinum	21.53	Diamond....about	3.50	Cork	.24
Gold	19.34	Flint Glass	2.76	Sulphuric Acid	1.84
Mercury	13.59	Chalk	2.65	Water from Dead Sea	1.24
Lead	11.36	Sulphur	2.00	Milk	1.03
Silver	10.50	Ice	.93	Sea-water	1.03
Copper	8.90	Potassium	.86	Absolute Alcohol	.79
Cast-iron	7.21	Quicklime	.80		

Floating Bodies.—A body will float in water when its weight is not greater than that of an equal volume of the liquid, and its weight always equals that of the fluid displaced. An egg dropped into a glass jar half full of water (Fig. 84) sinks directly to the bottom. If, by means of a funnel with a long tube, we pour brine beneath the water, the egg will rise. We may vary the experiment by not dropping in the egg until we have half filled the jar with the brine. The egg will then fall to the center, and there float. Almost any solid, if dissolved in water, fills the pores of the water without adding much to its volume. This increases its density and buoyant power. A person can therefore swim more easily in salt than in fresh water.*—An iron ship will not only float itself, but also carry a heavy cargo, because it displaces a great volume of water.—A body floating in water has its center of gravity at the lowest point, when it is in stable equilibrium.†—Fishes have air-bladders, by which they can rise or sink

Fig. 84.



Egg in Water.

* Bayard Taylor says that he could float on the surface of the Dead Sea, with a log of wood for a pillow, as comfortably as if lying on a spring mattress. Another traveler remarks, that on plunging in he was thrown out again like a cork; and that on emerging and drying himself, the crystals of salt which covered his body made him resemble an "animated stick of rock-candy."

† Herschel tells an amusing story of a man who attempted to walk on water by means of large cork boots. Scarcely, however, had he ventured

at pleasure.* By compressing the air-bladder, the fish diminishes the volume of its own body. The buoyant effect of the water is correspondingly decreased and the fish descends. By relaxing the compression on the bladder, the air in it expands and the fish rises.

PRACTICAL QUESTIONS.

1. Why can housekeepers test the strength of lye by trying whether or not an egg will float on it?
2. How much water will it take to make a gallon of strong brine?
3. Why ought a fat man to swim more easily than a lean one?
4. Why does the firing of a cannon sometimes bring to the surface the body of a drowned person? *Ans.* Because by the concussion it shakes the body loose from the mud or any object with which it is entangled.
5. Why does the body of a drowned person generally come to the surface of the water after a time? *Ans.* Because the gases which are generated by decomposition in the body makes its specific gravity less.
6. If we let bubbles of air pass up through a glass of water, why will they become larger as they ascend?
7. What is the pressure on a canal lock-gate 14 feet high and 10 feet wide, when the lock is full of water?
8. Will a pail of water weigh any more with a live fish in it than without?
9. If the water filtering down through a rock should collect in a crevice an inch square and 250 feet high, opening at the bottom into a closed fissure having 20 square feet of surface, what would be the total pressure tending to burst the rock?
10. Why can stones in water be moved so much more easily than on land?
11. Why is it so difficult to wade in water when there is any current?

out ere the law of gravitation seized him, and all that could be seen was a pair of heels, whose movements manifested a great state of uneasiness in the human appendage below.

* It was formerly thought that a fish in water has no weight. It is said that Charles II. of England once asked the philosophers of his time to explain this phenomenon. They offered many wise conjectures, but no one thought of trying the experiment. At last a simple-minded man balanced a vessel of water, and on adding a fish, found it weighed just as much as if placed on a dry scale-pan.

12. Why is a mill-dam or canal embankment small at the top and large at the bottom?

13. In digging canals, ought the engineer to take into consideration the curvature of the earth?

14. Why does the bubble of air in a spirit-level move as the instrument is turned?

15. Can a swimmer tread on pieces of glass at the bottom of the water with less danger than on land?

16. Will a vessel displace more water in a fresh river than in the ocean?

17. Will iron sink in mercury?

18. The water in the reservoir in New York is about 80 feet above the fountain in the City Hall Park. What is the pressure upon a single inch of the pipe at the latter point?

19. Why does cream rise on milk?

20. There is a story told of a Chinese boy who accidentally dropped his ball into a deep hole where he could not reach it. He filled the hole with water, but the ball would not quite float. He finally thought of a successful expedient. Can you guess it?

21. Which has the greater buoyant force, water or oil?

22. What is the weight of four cubic feet of cork?

23. How many ounces of iron will a cubic foot of cork float in water?

24. What is the specific gravity of a body whose weight in air is 30 grs. and in water 20 grs.? How much is it heavier than water?

25. Which is heavier, a gallon of fresh or one of salt water?

26. The weights of a piece of syenite-rock in air and water were 3941.8 grs. and 2607.5 grs. Find its specific gravity.

27. A specimen of green sapphire from Siam weighed in air 21.45 grs. and in water 16.33 grs.; required its specific gravity.

28. A specimen of granite weighs in air 534.8 grs., and in water 334.6 grs.; what is its specific gravity?

29. What is the volume of a ton of iron? A ton of gold? A ton of copper?

30. What is the weight of a cube of gold 4 feet on each side?

31. A cistern is 12 feet long, 6 feet wide, and 10 feet deep; when full of water, what is the pressure on each side?

32. Why does a dead fish always float on its back?

33. A given volume of water weighs 62.5 grs., and the same volume of muriatic acid 75 grs. What is the specific gravity of the acid?

34. A vessel holds 10 lbs. of water; how much mercury would it contain?

35. A stone weighs 70 lbs. in air and 50 in water; what is its volume?

36. A hollow ball of iron weighs 10 lbs.; what must be its volume to float in water?

37. Suppose that Hiero's crown was an alloy of silver and gold, and weighed 22 oz. in air and $20\frac{1}{2}$ oz. in water. What was the proportion of each metal?

38. Why will oil, which floats on water, sink in alcohol?

39. A specific gravity bottle holds 100 gms. of water and 180 gms. of sulphuric acid. Required the density of the acid.

40. What is the density of a body which weighs 58 gms. in air and 46 gms. in water?

41. What is the density of a body which weighs 63 gms. in air and 35 gms. in a liquid of a density of .85?

II. HYDRODYNAMICS.

Hydrodynamics treats of liquids in motion. In this, as in Hydrostatics, water is taken as the type. In theory, its principles are those of falling bodies, but in practice they can not be relied upon except when verified by experiment. The discrepancy arises from changes of temperature which vary the fluidity of the liquid, from friction, the shape of the orifice, etc.

1. Rules Concerning a Jet.—(1.) The velocity of a jet is the same as that of a body falling from the surface of the water. We can see that this must be so, if we recall two principles: First, "a jet will rise to the level of its source;" and second, "to elevate a body to any height, it must have the same velocity that it would acquire in falling that distance." It follows that the velocity of a jet depends on the height of the liquid above the orifice.

(2.) To find the velocity of a jet of water, use the 4th equation of falling bodies, $v^2 = 2gh$, in which h is the distance of the orifice below the surface of the water.—*Example:* The depth of water