

wheels and pinions is such, that there is a constant increase of velocity and a corresponding loss of power. The great wheel, which begins the train, revolves once in four hours; the balance, which closes it, revolves in one-fifth of a second; but the force of the spring becomes so attenuated by the time it reaches the balance, that the slightest additional resistance there, a particle of dust or even a thickening of the oil used to prevent friction, deranges, and may stop, the action of the whole.

## CHAPTER X.

### MECHANICS (CONTINUED).

#### HYDROSTATICS.

298. **HYDROSTATICS** and **Hydraulics** are branches of **Mechanics** that treat of liquids.

**Hydrostatics** is the science that treats of liquids at rest.

**Hydraulics** is the science that treats of liquids in motion, and the machines in which they are applied.

299. The principles of **Hydrostatics** and **Hydraulics** are equally true of all liquids; but it is in water, which is the commonest liquid, that we most frequently see them exhibited.

Water abounds on the earth's surface. It covers more than two-thirds of the globe, and constitutes three-fourths of the substance of plants and animals.

300. **NATURE OF LIQUIDS.**—Liquids differ from solids in having but little cohesion.

of a watch consist? What is said of the arrangement of the wheels and pinions? What is the comparative velocity of the great wheel and the balance? What is said of the force of the spring by the time it reaches the balance?

298. What sciences treat of liquids? What is **Hydrostatics**? What is **Hydraulics**? 299. What is said of the principles of **hydrostatics** and **hydraulics**? How much of the globe is covered with water? How much of the substance of plants and animals consists of water? 300. In what respect do liquids differ from solids? What shows

Cohesion is not entirely wanting in liquids, as is proved by their particles' forming in drops; but it is so weak as to be easily overcome. Thick and sticky liquids, like oil and molasses, have a greater degree of cohesion than thin ones, like water and alcohol.

301. Liquids were long thought to be incompressible, but experiment has proved the reverse. Submitted to a pressure of 15,000 pounds to the square inch, a liquid loses one-twenty-fourth of its bulk. Were the ocean at any point a hundred miles deep, the pressure of the water above on that at the bottom would reduce it to less than half its proper volume.

302. To distinguish them from the gases, liquids are often called non-elastic fluids; yet they are not devoid of elasticity.

To prove this, after compressing a body of water, remove the pressure, and it will resume its former bulk. Again, if a knife-blade be brought in contact with a drop of water hanging from a surface, the drop may be elongated by slowly drawing away the blade; but it immediately returns to its original shape, if the blade is entirely removed without detaching the drop from the surface.

#### Law of Hydrostatics.

303. *Water at rest always finds its level.*

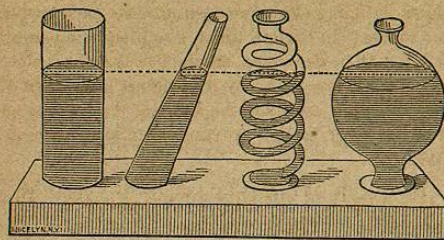
No matter what the size or shape of a body of water may be, its surface has the same level throughout; that is, it is equally distant at every point from the earth's centre. Accordingly, the surface of the ocean is spherical; and this we know to be the case from always seeing the mast of a vessel approaching in the distance before we see the hull. In small masses of liquids, no convexity is perceptible; and we may consider their surfaces as perfectly flat.

304. The tea-pot affords us a familiar illustration of this law. The tea always rises as high in the spout as in the body of the pot; and, if the body is higher than the spout, it will pour out from the latter when the pot is filled.

So, let there be a number of vessels having communication at their bases, as shown in Fig. 141. If water be poured into any of them, it will rise to

that cohesion is not entirely wanting in liquids? What liquids have the most cohesion? 301. What is said respecting the compressibility of liquids? If the ocean were a hundred miles deep, what would be the consequence of the pressure? 302. What are liquids often called, to distinguish them from gases? Is the name strictly correct? Prove that liquids are elastic? 303. What is the great law of **Hydrostatics**? What do we mean, when we say that a body of water has the same level throughout? What sort of a surface must the ocean have? What evidence is there of this? How may we regard the surfaces of small bodies of liquids? 304. Show how the tea-pot illus-

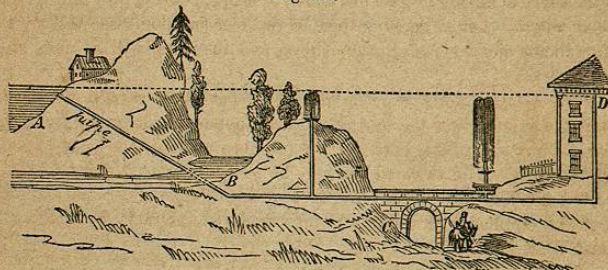
Fig. 141.



neously with that in the river.

305. We take advantage of this law in supplying cities with water from elevated ponds or streams. The water may be conveyed in pipes any distance, and when released from the pipe at any point will rise to the level from which it started.

Fig. 142.



Thus, in Fig. 142, the pond A is made to supply the house D with water by means of pipes carried down into the valley, under the stream B and over the bridge C. In the house it will reach the level of the pond from which it was taken, shown by the dotted line.

Fountains formed by tapping the pipe at any point, rise, theoretically, to the same level, as seen in the plate, but are prevented from quite reaching it by the resistance of the air and the check which the ascending stream receives from the falling drops.

306. The ancient Romans appear to have known that water conducted in pipes will find its level; yet so difficult did they find it to make water-

trates this law. Illustrate it with Fig. 141. How does this law apply in the case of pools connected with tide-water? 305. To what practical purpose is this principle applied? Illustrate this with Fig. 142. How high will fountains formed by tapping the pipe rise? 306. How did the ancient Romans convey their supplies of water?

the same level in all, no matter how they may differ in shape or size. In like manner, if there be subterranean connection between a river affected by the tide and pools near its banks, the water in the pools will rise and fall simulta-

tight joints, that, instead of employing pipes, they conveyed their water through vast level aqueducts, bridging at an immense expense such ravines and valleys as lay in their course. In modern times, iron pipes laid beneath the surface, however much it may be depressed, accomplish the same object with much less cost, the water always rising to its original level when allowed to do so. The lower the pipes are sunk, the stronger they should be; for the upward pressure of the water, tending to resume its level, increases in proportion to the depth.

307. *Artesian Wells.*—It is on this principle, also, that Artesian Wells are made. They are so called from the province of Artois [*ahr-twah'*], in France, the first district of Europe where they were extensively introduced, though known to the Chinese for centuries.

The outer crust of the earth consists of different strata, or layers; some of which (rock and clay, for instance) are impervious to water, and others not (such as gravel and chalk). If a stratum which allows water to flow through it is enclosed, after leaving the surface, between two impervious layers, and thus descends to a lower level, the water received by this stratum at the surface, unable to pass out above or below, collects in it throughout its whole length. Let an opening then be made at any point into this reservoir through the impervious stratum above, and the water will at once rise to find its level.

Such openings are Artesian wells. They have been carried in some cases a third of a mile below the surface; and so abundant is their supply of water that a single well of this kind at Paris has been computed to yield 14,000,000 gallons daily. The elevated end may be several hundred miles distant; it matters not how far. It is thought that the deserts of Arabia and Africa might be supplied with water, and thus rendered habitable, by means of Artesian wells.

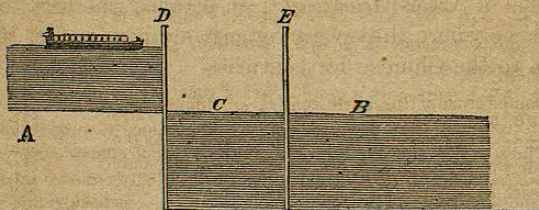
308. *Springs.*—Springs have a similar origin. The rain drunk up by the earth's surface gradually sinks, till it reaches an impervious stratum. Along this it runs, receiving additions as it goes, till it finds vent in some natural opening.

In ordinary wells, the water does not rise to the earth's surface, because it does not come from an elevated stratum.

Why did they not employ pipes? What precaution must be taken, in consequence of the upward pressure of the water? 307. What wells are made on this principle? Why are Artesian Wells so called? Explain their working. How low have they been carried? How much water does the well at Paris supply? How far off may the elevated end of the stratum be? What is thought respecting the deserts of Arabia and Africa? 308. Explain the origin of springs. Why does not the water rise in

309. *Locks.*—We are enabled to run canals through uneven tracts by taking advantage of the fact that water always finds its level. If the bottom of the canal were not of a uniform grade, the water would run towards the lower end and inundate the surrounding country. When, therefore, the ground is uneven, the canal is built in sections, each level in itself, but of a different grade from the one next to it, with which it is connected by a compartment called a Lock.

Fig. 143.



Let A B represent a canal, the upper section of which, A, is fifteen feet higher than the lower section B. A boat is passed from one to the other by means of the lock C, which communicates with either section, as may be desired, by opening sliding valves in the lock-gates D, E. When a boat is going down, the gate E is closed and D is opened till the water in the lock assumes the same level as in A. The boat is then brought into the lock; the gate D is closed and E is opened. The water, gradually sinking in the lock, bears the boat along with it till it reaches the same level as in B. In going up, the operation is reversed. The boat having passed from B into the lock, E is closed and D opened. The water rushes in to find its level, and the boat is raised till it stands at the same height as the water in A.

310. *The Spirit Level.*—The Spirit Level, an instrument much used by surveyors, masons, and others, operates on this same principle. It consists of a glass tube (see Fig. 144) nearly filled with colored alcohol, just enough air being allowed to remain in it to form a bubble. The tube is then closed, and fixed in a wooden or metallic case.

Fig. 144



THE SPIRIT LEVEL.

On being applied to a surface, if the latter is perfectly level, the air-bubble will rest midway of the tube, in its highest point which has been found

ordinary wells? 309. How are we enabled to run canals through uneven tracts of country? With the aid of Fig. 143, show the workings of a Lock. 310. What is the

by previous experiment and marked. If the bubble rests in any other place, it shows that one end of the tube is higher than the other, and consequently that the surface on which it rests is not level.

The tube is sometimes made of a different form, and nearly filled with water instead of alcohol; the instrument is then known as the Water Level.

### Pressure of Liquids.

311. *FIRST LAW.*—*Liquids, subjected to pressure, transmit it undiminished in all directions.*

Solids transmit pressure only in the line in which it is exerted; liquids transmit it in every direction. This is proved by experiment.

In Fig. 145, A represents a glass vessel of water, to the neck of which a piston, B, is tightly fitted. Tubes are inserted at intervals through orifices in the sides. As the piston is driven down, the pressure is felt alike at all points of the vessel, as is shown by the flow of the water from the tubes.

Fig. 145.



312. *SECOND LAW.*—*Liquids, influenced by gravity alone, press in all directions.*

Bore a hole in the bottom of a pail filled with water; the water rushes out—this proves its downward pressure.

Bore a hole in the side of the same pail: the water rushes out—this proves its lateral pressure.

Bore a hole in the bottom of a boat; the water rushes in—this shows its upward pressure.

313. *THIRD LAW.*—*The pressure of liquids in every direction is proportioned to their depth.*

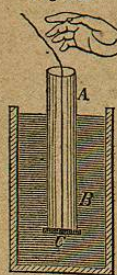
The downward pressure of liquids increases with their depth. To prove this, take four tubes of equal diameter, and over one end of each tie a piece of very thin india rubber. Fill them with water to different heights, say 5, 10, 20, and 30 inches. The india rubber will be distended the most in the one containing the greatest depth of liquid.

The lateral pressure of liquids increases with their depth. Hence dams

Spirit Level? Of what does it consist? How is the spirit level used? What is the Water Level? 311. What is the first law relating to the pressure of liquids? What is the difference between solids and liquids in this respect? Illustrate this law with Fig. 145. 312. What is the second law relating to the pressure of liquids? Prove the downward pressure of liquids. Prove their lateral pressure. Prove their upward pressure. 313. What is the third law relating to the pressure of liquids? What experiment proves that the downward pressure of liquids is proportioned to their depth?

and sea-walls should increase in strength towards their bases. On the same principle, barrels holding liquids should be more securely hooped at bottom than at top.

Fig. 146.



The upward pressure of liquids increases with their depth. This is shown by the experiment represented in Fig. 146. AB is an open tube, ground perfectly smooth on the lower end. C is a plate of lead attached to a string. Pass the string through the tube, and with it keep the lead plate close against the ground end; then introduce the whole into a deep vessel of water. When it has descended an inch or two, let go the string, and the lead will sink. Let it go near the bottom of the vessel, and, as shown in the Figure, the lead will be supported by the water. The upward pressure has therefore increased with the depth.

314. At great depths the pressure of water becomes immense; neither divers nor fish can endure it. Strong glass bottles, empty and tightly corked, are often let down with cords at sea, and the pressure is generally sufficient to break them at a depth of 60 feet. If the bottle does not break, either the cork is driven in or water enters through its pores. The hardest wood, sunk to a great depth, has its pores so thoroughly filled with water as to become incapable of rising. Hence, when a ship goes down at sea, her timbers are never seen again.

Fig. 147.



315. This law leads to wonderful results. Effects almost incredible may be produced by an insignificant body of liquid so disposed as to have considerable depth.

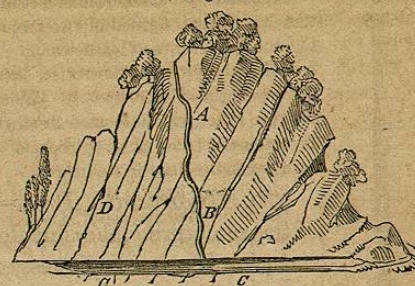
We may, for example, burst a stout cask with a few ounces of water. Having filled the cask with water and inserted in its top a long tube communicating with the inside, we may force the staves asunder, however tightly hooped, by simply pouring water into the tube.

316. Similar effects are often produced in nature. Let D (see Fig. 148) be a mass of rock through which runs a long crevice, AB, communicating with C, a large cavity below, full of water, and having no outlet. When a shower fills the crevice, so great a pressure may be generated as to rend the rock in fragments. It is in this way that many of the great convulsions of nature are produced.

What should be the strongest part of dams, sea-walls, and barrels,—and why? Describe the experiment which proves that the upward pressure of liquids increases with their depth. 314. What is said of the pressure of water at great depths? What experiment is often made with strong glass bottles? What is the effect of this pressure on wood sunk to a great depth? 315. How may wonderful effects be produced by an insignificant body of liquid? How, for example, may a cask be burst? 316. What similar effect is produced in nature? 317. What is meant by the Hydro-

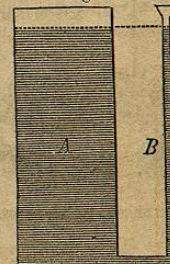
317. *Hydrostatic Paradox.*—Pressure being proportioned to depth alone, a very small quantity of liquid may balance any quantity, however great. This principle is called the Hydrostatic Paradox. Improbable as it appears at first, its truth is proved in various ways.

Fig. 148.



In Fig. 149, let A be a vessel holding 50 gallons, and B a tube of the same height, communicating with A, and having a capacity of one gallon. Water poured in either rises to the same height in both. When both are full, the pressure of the one gallon in the tube must be as great as that of the 50 gallons in the vessel; otherwise, the latter would force its way into the tube and cause the water there to overflow.

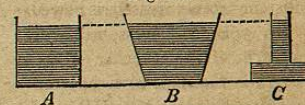
Fig. 149.



318. *Rule for finding the Pressure on the Bottom of a Vessel.*—To find the pressure of a body of liquid on the bottom of the vessel containing it, multiply its height into the area of the vessel's bottom.

According to this rule, different quantities of liquid may produce equal pressure. In Fig. 150, let A, B, and C be three vessels having equal bases, and containing the same depth, though different quantities, of liquid; then the pressure on their bottoms will be equal.

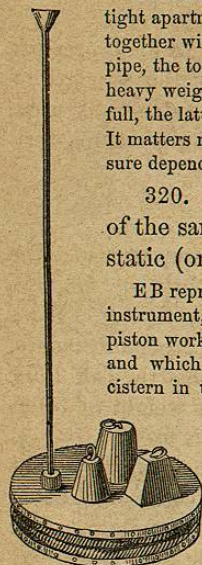
Fig. 150.



319. *Hydrostatic Bellows.*—Interesting experiments may be performed with the Hydrostatic Bellows, represented in Fig. 151.

static Paradox? Prove the truth of the paradox with the apparatus represented in Fig. 149. 318. What is the rule for finding the pressure of a body of liquid on the bottom of the vessel containing it? Explain how different quantities of liquid may produce equal pressure. 319. Describe the Hydrostatic Bellows, and the experiment

Fig. 151.



HYDROSTATIC BELLOWS.

connect-  
ing E B  
with the  
large cyl-  
inder C,  
to which  
is fitted  
a smaller  
wrought-  
iron cylinder D, free to move up  
and down within it. D has a plat-  
en, H H, attached to it, between  
which and the top of the frame,  
the cotton, hay, cloth, or other  
substance to be pressed, is placed.

To work the press, raise the  
long arm of the lever A. Water  
is by this means drawn up from  
the cistern into the tube E B; and,  
when A is lowered and the piston  
thus made to descend, being pre-  
vented from returning to the cis-  
tern by a valve which closes, it is  
forced through the tube F G into  
the lower part of the cylinder C. D being thus driven up and with it the  
platen, whatever is confined between the latter and the top of the frame is

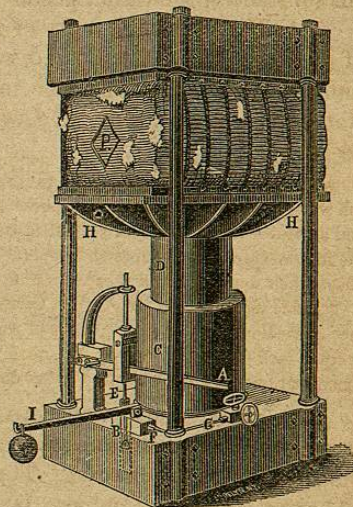
performed with it. How great a weight will it support? 320. Describe the Hydrostatic  
Press, with the Figure. How is it worked? How great pressure may be obtained

A metallic pipe, about four feet long, is screwed into a water-  
tight apartment, formed of two circular pieces of board fastened  
together with a broad leather band. As water is poured into the  
pipe, the top of the bellows rises, and with such force as to lift  
heavy weights placed upon it. When both pipe and bellows are  
full, the latter will support from three to four hundred pounds.  
It matters not how small the bore of the pipe may be; the pres-  
sure depends solely on its height.

320. *Hydrostatic Press.*—A useful application  
of the same principle is made in Bramah's Hydro-  
static (or Hydraulic) Press, exhibited in Fig. 152.

E B represents a forcing-pump worked by the lever A. This  
instrument, which is fully described on page 188, consists of a  
piston working within a small tube to which it is tightly fitted,  
and which descends, as shown by the dotted lines, into a  
cistern in the bottom of the frame of the press. F G is a tube

Fig. 152.



HYDROSTATIC PRESS.

subjected to pressure, greater or less according to the quantity of water  
forced into C.

With the Hydrostatic Press any degree of pressure  
may be obtained that is not too great for the strength of  
the materials employed. The machine is extensively used,  
not only for pressing, but also for extracting stumps, test-  
ing cables, and raising vessels out of water.

### Specific Gravity.

321. If we weigh a cubic inch of water, and then the  
same bulk, or volume, of silver, and of cork, we find the  
silver heavier than the water, and the cork lighter. If we  
proceed to compare the weights of various other substances,  
taking a cubic inch of each, we shall find that they all differ  
more or less. To express the comparative weight of differ-  
ent substances, the term Specific Gravity is used.

322. The Specific Gravity of a substance is the weight  
of a given bulk of it compared with the weight of an equal  
bulk of some other substance taken as a standard. The  
standard employed is distilled water at the temperature of  
60 degrees.

A standard of this kind must be invariable. Hence the temperature of  
the water is fixed; for at a higher degree of heat it would become rarer,—  
and at a lower degree, denser. Distilled water is taken, because it is pure;  
the intermixture of vegetable and mineral matter in spring and river water  
affects their density, and makes them unfit for a standard.

A cubic inch of silver weighs  $10\frac{1}{2}$  times as much as a cubic inch of wa-  
ter; accordingly, the specific gravity of water being 1, that of silver is  $10\frac{1}{2}$ .  
A cubic inch of cork weighs  $\frac{24}{100}$  as much as the same bulk of water; the  
specific gravity of cork, therefore, is set down at  $\frac{24}{100}$  or .24.

323. Fluids that do not mix, when brought together,  
arrange themselves in the order of their specific gravities,  
the heaviest at the bottom. Thus, if mercury, water, and  
oil be thrown into a tumbler, the mercury will settle at the

with the hydrostatic press? For what is this machine used? 321. If we weigh equal  
bulks of different substances, what do we find? What term is used to express the  
comparative weight of different substances? 322. What is Specific Gravity? What  
is taken as a standard? Why is the temperature of the water fixed? Why is dis-  
tilled water taken? What is the specific gravity of silver, and why? What is the  
specific gravity of cork, and why? 323. How do fluids that do not mix, when brought

bottom, because its specific gravity is greatest; next will come the water; and on top, the oil, which is the lightest of the three.

Cream rises on milk, because its specific gravity is less than that of milk. For the same reason, the oily particles of soup float on the top.

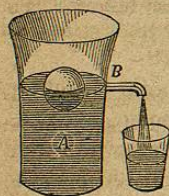
The negroes in the West Indies take advantage of this law of specific gravity. When they want to steal rum out of a cask, they introduce through the hole in its top the neck of a bottle filled with water. The water descends on account of its greater weight, and rum takes its place in the bottle.

324. Gases, like liquids, differ in their specific gravity. Smoke rises, because it is lighter than air. Hydrogen is so much inferior to air in specific gravity, that it not only rises itself, but also carries up a loaded balloon. Carbonic acid gas, on the other hand, is somewhat heavier than air; it is therefore found at the bottom of wells and mines, where its poisonous properties sometimes prove fatal to those who descend.

325. If a solid floats on a liquid, like cork on water, its specific gravity is less than that of the liquid; if it sinks, like lead, its specific gravity is greater. If solid and liquid have the same specific gravity, the solid will remain stationary at any depth at which it is placed, without rising or sinking.

That a solid may float, it is not essential that, in a compact mass, it weigh less than a like bulk of the liquid. A solid may therefore float or sink in the same liquid, according to the form it is made to assume. A cubic inch of iron weighs  $7\frac{1}{4}$  times as much as a like bulk of water, and will therefore sink in the latter; but, if beaten out into a vessel containing more than  $7\frac{1}{4}$  cubic inches, this same iron will float, because then it is lighter than an equal bulk of water. It is on this principle that iron ships float.

Fig. 153.



326. A floating solid displaces its own weight of liquid.

To prove this, fill the vessel A with water up to the opening B. Drop in a ball of wood. As it becomes partially immersed, it raises the water and causes it to flow through B. Catch the water thus displaced, and it will be found to weigh exactly the same as the ball.

327. A body immersed in water is

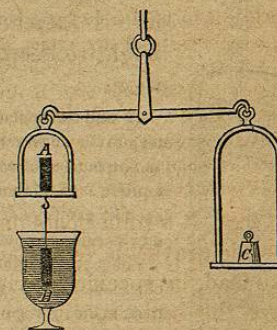
together, arrange themselves? Give an example. Why does cream rise on milk? What use do the negroes in the West Indies make of this principle? 324. What is said of the specific gravity of gases? Why does smoke rise? How does hydrogen compare with air in specific gravity? Carbonic acid? 325. When will a solid float on a liquid, when sink, and when remain stationary without rising or sinking? How may a solid which in a compact mass is heavier than water, be made to float?

buoyed up, and loses as much weight as the water it displaces weighs.

A boy can bring up from the bottom of a pond a heavy stone which he could not lift on land. In raising a bucket from a well, we find it become heavier the moment it leaves the water. In each case, the weight of the object, while in the water, is diminished by its upward pressure.

That the weight thus lost equals that of the water displaced, is shown with the apparatus represented in Fig. 154. From one side of a balance suspend a solid cylinder B, and on the same scale place a hollow cylinder A, which just contains the other. Balance the whole with a weight C in the opposite scale. If, now, we immerse B, still suspended, in a vessel of water, C will be found to outweigh A B, but the difference is exactly made up by filling A with water; and as A just holds B, it is evident that it holds as much water as B displaces.

Fig. 154.



328. SPECIFIC GRAVITY OF LIQUIDS.—The specific gravity of a body is simply its weight compared with that of a like bulk of water. Hence the specific gravity of a liquid may be easily obtained in the following way: Fill a glass vessel, whose weight is known, with water up to a certain mark, and weigh it; subtract the weight of the vessel, and you have the weight of the water alone. Then fill the vessel to the same height with the liquid in question, weigh it again, and subtract the weight of the vessel as before. To find the specific gravity of the liquid, divide its weight by that of the water.

A flask that will hold 1,000 grains of water, called the Thousand Grain Bottle, is often used for this purpose. A glass stopper, with a narrow opening running lengthwise through it, is fitted to the neck. The flask being filled, this stopper is inserted; as it descends, it forces out the excess of liquid through its opening, and thus always ensures the same volume of liquid

Give an example. 326. How much liquid does a floating solid displace? Prove this with Fig. 153. 327. How much weight does a body immersed in water lose? Give some familiar examples of this loss of weight. Prove, with the apparatus represented in Fig. 154, that the weight lost equals that of the water displaced. 328. How may the specific gravity of a liquid be obtained? What is the Thousand Grain Bottle?