inside. A flask containing 1,000 grains of water will hold 13,568 grains of mercury and 792 grains of alcohol; dividing according to the rule, we find the specific gravity of mercury to be 13.568, and that of alcohol .792.

329. *The Hydrometer.*—The specific gravity of liquids may also be determined by the Hydrometer. This instru-

Fig. 155.

THE HYDROM-ETER.

ment consists of a hollow ball, C, from which rises a graduated scale, A; while to its lower side is attached a solid ball, B, of sufficient weight to keep the instrument in a vertical position.

To find the specific gravity of any liquid, place the hydrometer in it. The rarer the liquid, the farther it descends; and the figure on the scale at the point where it meets the surface, is noted. A table accompanies the instrument, which tells the specific gravity of a liquid when the height to which it rises on the scale is known.

The hydrometer is used by dealers in spirits, oils, and chemicals, to test their strength. The height to which the pure article rises on the scale being known, any different result when a liquid is tested, indicates adulteration.

330. SPECIFIC GRAVITY OF SOLIDS.—The simplest way of finding the specific gravity of a solid would be to take a certain bulk of it (say a cubic inch or cubic foot), ascertain its weight, and divide it by the weight of a like bulk of water. It is so difficult, however, to obtain any given bulk exactly, that other methods have to be resorted to.

331. If the solid sinks in water, weigh it first in air, and then in water by means of a balance prepared for the purpose. Divide its weight in air by the weight it loses in water, and the quotient will be its specific gravity.

This is the same thing as dividing the weight of the solid by that of an equal bulk of water, for we have already seen that a solid weighed in a liquid loses as much weight as the liquid it displaces weighs.

How many grains of mercury will such a flask hold? Of alcohol? What, then, is the specific gravity of mercury and alcohol? 329. What instrument is used for obtaining the specific gravity of liquids? Describe the Hydrometer. How is the specific gravity obtained with this instrument? By whom is the hydrometer chiefly used? How does it indicate adulteration? 330. What would be the simplest mode of finding the specific gravity of a solid? What difficulty stands in the way? 331. How may we find the specific gravity of a solid that sinks in water? Give an

A piece of platinum weighs 22 grains in air, and 21 in water. Dividing 22, the weight in air, by 1, the loss of weight in water, we get 22 for the specific gravity of platinum.

332. To find the specific gravity of a solid that floats on water, attach to it some body heavy enough to sink it. Weigh the two, thus attached, in air and in water; and by subtraction find their loss of weight in water. In the same way, find how much weight the heavy body alone loses in water. Subtract this from the loss sustained by the two, and you get the weight of a volume of water equal to the body under examination. Divide the body's weight in air by this remainder, and you have its specific gravity.

Example. Required the specific gravity of a piece of elm wood weighing 2 ounces. Attach to it 4 ounces of lead.

The combined solids weigh in air 2 + 4 = 6   ounces.
In water we find them to weigh .... 3.15 ounces.

Loss of the combined solids in water, 2.85 ounces.
The lead alone weighs in air............. 4   ounces.
The lead alone weighs in water .... 3.65 ounces.

Loss of the lead in water, ... .35 ounce.

Weight of a volume of water equal to the wood, 2.85 — .35 = 2.50
Specific gravity of elm wood, 2 ÷ 2.50 = .8

333. SPECIFIC GRAVITY OF GASES.—The specific gravity of gases is found by a process similar to that employed for liquids. Air is taken for the standard. A glass flask furnished with a stop-cock is weighed when full of air, and again when exhausted by means of an air-pump; the difference between these weights is the weight of a flask-full of air. The flask is then filled with the gas in question, and again weighed; this weight, less that of the exhausted flask, is the weight of a flask-full of the gas. Divide the weight of the gas by that of the air, and the quotient is the specific gravity required.

334. TABLES OF SPECIFIC GRAVITIES.—The following

example. 332. How may we find the specific gravity of a solid that floats on water? Find the specific gravity of a piece of elm wood weighing 2 ounces. 333. What is taken for a standard in estimating the specific gravity of gases? How may the spe

tables give the specific gravity of some of the most important substances :—

SPECIFIC GRAVITY OF SOLIDS AND LIQUIDS.—*Standard, Distilled Water*, 1.

Iridium 23.000	Iron, cast 7.207	Ice .... .930
Platinum... 22.069	The earth 5.210	Living men.. .891
Gold 19.358	Diamond 3.536	Cork........ .240
Mercury.... 13.568	Parian Marble .. 2.838	Human blood 1.045
Lead....... 11.445	Anthracite coal. 1.800	Milk 1.030
Silver...... 10.474	Bituminous coal. 1.250	Sea water ... 1.026
Copper, cast 8.788	Lignum vitæ.... 1.333	Olive oil .... .915
Tin 7.285	Oak.......... .970	Alcohol ..... .792

SPECIFIC GRAVITY OF GASES.—*Standard, Air*, 1.

Hydriodic Acid 4.300	Air 1.000
Carbonic Acid 1.524	Nitrogen 0.972
Oxygen 1.111	Hydrogen 0.069

335. By examining the above tables, it will be found that solids generally have a greater specific gravity than liquids, and liquids than gases. Among solids, the metals are the heaviest.

The heaviest known substance is the metal iridium, which, bulk for bulk, weighs 23 times as much as water. The lightest substance is hydrogen gas. It would take about 12,000 cubic feet of hydrogen to weigh as much as one cubic foot of water.

Sea-water, being impregnated with salts, is somewhat heavier than fresh water. It is therefore more buoyant; and this every swimmer that has tried it knows. A vessel passing from fresh water to the sea, draws less water in the latter, that is, does not sink to so great a depth.

336. Water is 828 times heavier than air; that is, it would take 828 cubic inches of air to weigh as much as 1 cubic inch of water. Hence, by confining air in tight chambers in different parts of life-boats, they are made so buoyant that they can not sink even when filled with water. Life-preservers act on the same principle. The air confined in them, being 828 times lighter

cific gravity of gases be found? 334. [*Questions on the Tables.*—Which is the densest of the metals? Which is the densest of liquids? Will the wood called *lignum vitæ* float in water? What liquid will it float in? Which weighs more, a cubic foot of water or the same bulk of ice? In which would a boat sink deepest, olive oil, alcohol, or sea-water? Could a man swim in alcohol? Would a balloon rise most easily in hydrogen, carbonic acid, or air? Would a balloon filled with oxygen rise in air?] 335. How do solids, as a general thing, compare with liquids in specific gravity? How do gases compare with liquids? Among solids, what class of bodies are heaviest? What is the heaviest known substance? How does its weight compare with that of water? What is the lightest substance? How many cubic feet of hydrogen would it take to weigh as much as one cubic foot of water? How does sea-water compare with fresh water in specific gravity? In which is it easier to swim? In which does a vessel draw less water? 336. How does air compare with water in specific gravity?

than the same bulk of water, helps to keep up the bodies to which they may be attached. Many species of fish are provided with bladders, which they can fill with air or exhaust at pleasure; they are thus able to increase or diminish their specific gravity instantaneously, and to rise or sink accordingly.

337. The specific gravity of living men is set down at .891, or less than ⁹/₁₀ of that of water. The human body, therefore, will float; and, if the head is thrown back so as to bring the mouth uppermost, there is no danger of drowning, even in the case of those who can not swim. If the air is expelled from the lungs, and water takes its place, the specific gravity is increased; consequently the bodies of drowned persons sink. After remaining under water for a time, they again float; this is owing to the generation of light gases within them, by which their specific gravity is lessened.

338. If we know the specific gravity of a body, we can easily find how much any given bulk of it weighs. A cubic foot of water is found to weigh 1,000 ounces, or 62½ pounds avoirdupois; the weight of a cubic foot of any given substance will, therefore, be equal to 62½ pounds multiplied by its specific gravity.

Example. Required the weight of a cubic foot of gold. The table makes the specific gravity of gold 19.358. Multiplying this into 62.5, we get 1209.875 pounds for the weight required.

339. Two solids of equal bulk will displace equal quantities of a liquid in which they are immersed; but two solids of equal weight will not do so, unless their specific gravity is the same. This principle has been applied in testing the purity of the precious metals.

If, for instance, we wish to find whether a piece of silver is pure, we put it in a vessel even full of water, and catch what overflows: we do the same with an equal weight of what is known to be pure silver. If equal quantities of water are displaced, the article tested is pure, for it has the same specific gravity as pure silver; but if not, it is adulterated.

340. The fact above stated was discovered and first applied by Archimedes. Hiero, king of Syracuse, having purchased a golden crown and suspecting the purity of the metal, asked the philosopher to test it, without injury to its costly workmanship. In vain Archimedes tried to solve the prob-

On what principle are life-boats and life-preservers constructed? How are fish enabled to rise or sink at pleasure? 337. How does the body of a living man compare with water in specific gravity? What follows, as regards danger of drowning? Why do the bodies of drowned persons at first sink, and afterwards rise? 338. If we know the specific gravity of a body, how may we find the weight of any given bulk of it? Give an example. 339. When will two solids immersed in a liquid displace equal quantities? To what has this principle been applied? How, for example, may we find whether a piece of silver is pure? 340. By whom was this principle discovered?

lem; till one day, when bathing, he observed, that, as more and more of his body became submerged, the water rose proportionally higher and higher in the vessel. It at once occurred to him that any body of equal weight and exactly the same density, *but no other*, would cause an equal rise of the liquid; and here was a clue to the solution of the problem that had troubled him. Naked as he was, he rushed home from the bath, shouting *"Heureka!" I have found it!* He immediately procured a quantity of pure gold equal in weight to the crown, and a like weight of pure silver. Then successively plunging the gold, the silver, and the crown, in a vessel brim-full of water, he caught and weighed the liquid displaced in each case. Finding that the crown displaced more than the gold and less than the silver, he inferred that it was neither pure gold nor pure silver, but a mixture of the two. Archimedes afterwards investigated the subject further, and discovered the leading principles connected with specific gravity.

Capillary Attraction.

341. If one end of a fine glass tube be placed in a vessel of water, the other end being left open, the water will rise in the tube above its level. The force that causes the water to rise is known as Capillary Attraction. It is so called from the Latin word *capillus*, a hair, because it is most strikingly exhibited in tubes as fine as a hair.

A liquid will not rise by capillary attraction in tubes that exceed one-fifteenth of an inch in diameter.

342. CAUSE.—The rise of liquids in capillary tubes is owing, it is thought, to the attraction of the inner surface of the solid. In proof of this, we find that the surface of the liquid in the tube is concave, being raised where it comes in contact with the sides of the tube.

Fig. 156.
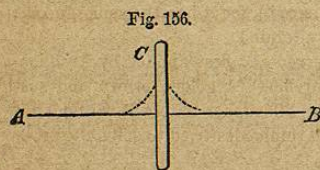
The same thing is seen when a glass plate, C, is placed perpendicularly in water, A B: the surface, instead of maintaining the same level throughout, rises near the glass on both sides, as represented by the dotted lines.

The above experiment seems to show that the attraction of glass for water is sufficiently great to overcome

the gravity of the latter. It is, also, greater than the cohesion subsisting between the particles of water; for, if the glass be removed, some of the liquid will be found adhering to its surface,—that is, it will be *wet*.

343. This attraction, however, does not exist between all solids and liquids; on the contrary, we sometimes find as decided a repulsion.

Let the glass plate, for instance, in the last experiment, be greased, and the water, now acted on by a repelling force, instead of being elevated near the sides, will be depressed, as shown by the dotted lines in Fig. 157. A similar appearance is presented when a glass plate is plunged into a dish of mercury. When this repulsion exists, the liquid does not wet the solid; when the glass plate is drawn out of the mercury, not a particle of the liquid adheres to it.

Fig. 157.
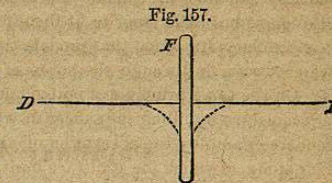
The repulsion just mentioned may be so great as to prevent a solid from sinking in a liquid lighter than itself. A fine needle smeared with grease, if carefully laid in a horizontal position on the surface of still water, will remain floating there. It is thus that insects are able to walk on water; the repulsion between their feet and the liquid prevents them from sinking or even becoming wet.

344. FAMILIAR EXAMPLES.—Examples of capillary attraction meet us on all sides.

If one end of a towel be left in a basin of water, the part outside soon becomes wet, the liquid being drawn up through its minute fibres. The same thing happens if a piece of sponge, of bread, or of sugar, remains in contact with a liquid; the pores of the substance acting like capillary tubes. Blotting paper drinks up ink on the same principle.

The common lamp affords a good illustration of capillary attraction. The oil or burning-fluid is drawn up through the fibres of the wick fast enough to support the flame. There is a limit, however, beyond which capillary attraction does not act; and, therefore, if the oil gets low, the lamp grows dim and finally goes out. To allow a free passage to the oil, the little tubes

must be kept clear; and, as impurities gather in them from the ascending liquid, the wick must be changed from time to time.

Capillary attraction is strikingly exhibited in wood. Water is drawn up into its pores, distending them, and causing a perceptible increase of size. This expansion is turned to practical account in the south of France. A large cylinder of free-stone, several feet in length, has circular grooves made at intervals in its surface. Into these grooves are driven wedges of dry wood, which are then kept wet with water. As the wood absorbs the liquid, it gradually expands, till it rends the solid cylinder into rough mill-stones, which require but little labor to fit them for market.

It is capillary attraction that renders the banks of streams so productive; the water drawn in through the pores of the earth, fertilizes the adjacent parts. On the same principle, a potted plant may be supplied with the necessary moisture by filling the saucer in which it stands with water. Houses are rendered damp by the absorption of external moisture, the pores of the brick or stone, of which the walls are built, acting as capillary tubes.

345. LAWS OF CAPILLARY ATTRACTION.—*Different liquids rise to different heights in tubes of the same size.* Ether, for example, rises about one-half, and sulphuric acid only one-third, as high as water.

The same liquid always rises to the same height in a tube of given size; and this height is proportioned to the fineness of the bore. In a tube $\frac{1}{100}$ of an inch in diameter, water rises $5\frac{3}{10}$ inches.
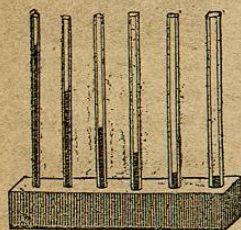
Fig. 158.

Fig. 159.

346. Fig. 158 represents six tubes of different bore, communicating at the bottom with a vessel containing colored water. The water rises according to the fineness of the bore, standing highest in the smallest tube.
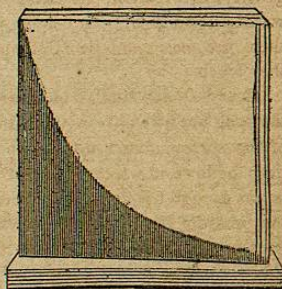
of a lamp supplied with fuel? How is capillary attraction exhibited in wood? What use is made of this principle in France? What is the effect of capillary attraction on the banks of streams? How may a potted plant be supplied with moisture? How are houses made damp? 345. What is the law of capillary attraction, as regards dif-

347. The same principle is illustrated with two glass plates (see Fig. 159), joined at one end and slightly diverging so as to form an angle of about two degrees. Let the plates rest in colored water to the depth of an inch, and the liquid will rise between them, reaching the greatest height where the surfaces are nearest together, and thus forming the curve called the hy-per'-bo-la.

348. INTERESTING FACTS.—If a capillary tube capable of raising water four inches be broken off at three, there will be no overflow, as might be expected. The water will rise three inches to the top of the tube, and there stop. But it will be supplied as fast as evaporation takes place. Hence, to prevent waste in a spirit lamp, an extinguisher is put over the wick when it is not burning.

It is a remarkable fact that no evaporation takes place unless the liquid reaches *the top* of the capillary tube. Tubes containing as much water as they could hold under the influence of capillary attraction, have been hung in the sun for months, without losing any part of their contents by evaporation.

349. FLOATING BODIES.—Motion is produced in bodies floating near each other, by a force resembling capillary attraction. This may be shown with two balls, as represented in Figs. 160, 161, 162.

A and B are cork balls, capable of being wet with water. When they are brought close together, the attraction of their surfaces raises the water around them; the column that separates them becomes thinner and thinner, till at last they touch.

Fig. 160.

C and D are similar balls, greased so that they can not be wet. In this case, the surface of the surrounding water is repelled, forming little hollows in which they rest. Since there is not enough liquid between them to balance the pressure from without, the balls again approach each other.

Fig. 161.

ferent liquids? Give an example. What is the law for the same liquid in a tube of given size? How high does water rise in a tube $\frac{1}{100}$ of an inch in diameter? 346. What does Fig. 158 represent? 347. Describe the experiment with two glass plates. 348. What fact is stated respecting a capillary tube broken off at the top? Why is it necessary to put an extinguisher on a spirit-lamp? What fact is stated respecting evaporation from capillary tubes? 349. How are floating bodies affected by a force resembling capillary attraction? What, for example, is the effect on cork balls capable of being wet? On balls greased so that they can not be wet? On balls, one of
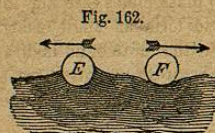
Fig. 162.

E and F are a pair of similar balls, one of which, E, can be wet, while the other, F, can not. The water, attracted by E, rises around it, whereas around F it is depressed. If these balls are placed near together, F, being repelled from the wall of water around E, will recede from it.

350. ENDOSMOSE AND EXOSMOSE.—Two peculiar results of capillary attraction, known as Endosmose and Exosmose, remain to be mentioned.

Endosmose is the inward motion of a fluid, through a membranous or porous substance, into a vessel containing a different fluid. Exosmose is the outward motion of the contained fluid through the same substance.

Fill a vessel with alcohol, tie over the top a bladder that has been soaked in water, and immerse the whole in water. In a few hours it will be found that water has passed into the vessel through the bladder, and that alcohol has passed out into the water. The former movement is called Endosmose; the latter, Exosmose. The inward current is stronger than the outward one. Water passes in faster than alcohol escapes; and consequently the bladder soon becomes puffed out. All membranous and porous substances, such as india rubber, plaster of paris, wood, &c., permit the passage of these currents, which are owing to capillary attraction.

351. Endosmose and exosmose are exhibited in the case of gases, as well as liquids.

If a phial full of air, with a piece of thin bladder tied over its mouth, be placed in a jar of carbonic acid gas, the latter will force its way into the phial while air will pass out. Here, again, the inward current is the stronger; the bladder is puffed out, and finally bursts.

The facility with which gases thus pass in and out through porous substances is proportioned to their rarity. Hydrogen, the rarest of known bodies, exhibits these movements in their greatest perfection. This is the reason why the rose balloons, recently so popular as toys, lose their buoyancy in a few days. They are made of thin india rubber, and filled with hydrogen. When allowed to remain in the air, endosmose and exosmose take place. Hydrogen passes out through the pores of the rubber, and air takes its place. The balloon gradually becomes less buoyant, ceases to rise, and at last, as it loses more of its hydrogen, is carried to the ground by the weight of the india rubber.

which can be wet and the other not? 350. What is Endosmose? What is Exosmose? Show how endosmose and exosmose operate. Through what sort of substances do they take place? 351. What, besides liquids, are affected by these movements? Give an example. What gases most readily pass in and out through porous substances? What gas exhibits endosmose and exosmose most distinctly? What is the

352. The skin being porous, a liquid with which it remains in contact will find its way through by endosmose and be absorbed by the body. If a drop of the powerful poison called prussic acid be placed on the arm, a sufficient quantity to cause death will thus be taken into the system.

353. Endosmose and exosmose enter largely into the operations of nature. They cause the ascent and descent of sap in trees and vines. The inside of living plants consists of minute cells, containing fluids of different densities. These fluids are constantly passing in and out through the porous walls which separate them, under the influence of exosmose and endosmose, modified by the vital action at the same time going on.

EXAMPLES FOR PRACTICE.

1. (*See* § 328.) A phial weighing 4 ounces when empty, weighs 6 ounces when filled with water, and 7 when filled with nitric acid. Required, the specific gravity of the acid.—*Ans.* 1.5.
2. A vessel filled with ether weighs 13.575 ounces; filled with water, 15 ounces; when empty, 10 ounces. What is the specific gravity of ether?
3. An empty jar weighs 7.5 pounds; filled with sulphuric acid, it weighs 12.1125 pounds; and filled with water, 10 pounds. Find the specific gravity of sulphuric acid.
4. A Thousand Grain Bottle is found to hold 870 grains of oil of turpentine, and 1,036 grains of oil of cloves. What is the specific gravity of these oils?
    In which would a cork ball sink the deeper?
5. (*See* § 331.) A piece of crown-glass weighs 5 ounces in the air, and 3 in water. What is its specific gravity?—*Ans.* 2.5.
6. A beef-bone weighs 2.6 ounces in water, and 6.6 ounces in air. What is its specific gravity?
7. What is the specific gravity of a piece of ivory, which weighs 16 ounces in air, and loses 8¾ ounces when weighed in water?
8. (*To solve the next two sums, see* § 332 *and Example. In each case, we may suppose a pound* (16 *ounces*) *of lead, weighing* 14.6 *ounces in water, to be used for sinking the solid.*)
    A piece of wax weighs 8 ounces; when it is fastened to a pound of

effect of these movements on rose balloons? 352. What is their effect, when a liquid is placed on the skin? Give an example. 353. What is the effect of endosmose and exosmose in trees and vines?

lead, the whole weighs in water 13.712 ounces. What is the specific gravity of the wax?—*Ans.* .9.

9. Fastening a piece of ash to a pound of lead, I find their weight in water to be 12.76 ounces. The ash alone weighs 10 ounces in the air. What is its specific gravity?

10. (*See* § 333.) A glass flask, with the air exhausted, weighs 4 ounces; filled with air, it weighs 4.25 ounces; and filled with cy-an'-o-gen, 4.45125 oz. What is the specific gravity of cyanogen?—*Ans.* 1.805.

11. A flask full of chlorine weighs 11.222 ounces. Filled with air, it weighs 10.5 oz., and when the air is drawn out, 10 oz. Required, the specific gravity of chlorine.

12. According to the answers of the last two sums, in which would a balloon rise most easily, air, cyanogen, or chlorine?

13. (*See* § 336.) How many cubic feet of air would it take to weigh as much as 4 cubic feet of water?

14. (*See* § 338, *and Table.*) How much would a cubic foot of gold weigh? How much, the same bulk of silver?

15. What would be the weight of 4 cubic feet of Parian marble?

16. What is the weight of a block of anthracite coal, 6 feet long, 4 feet wide, and 3 feet high? (*To find the number of cubic feet in the block, multiply the length, breadth, and thickness together.*)

17. Suppose a room 10 feet high, long, and wide, to be filled with gold, what would the gold weigh?

CHAPTER XI.

MECHANICS (CONTINUED).

HYDRAULICS.

354. HYDRAULICS treats of liquids in motion, whether issuing from orifices or running in pipes and the beds of streams. It shows how water is applied as a moving power, and describes the machines used for raising liquids.

355. FLOW OF LIQUIDS THROUGH ORIFICES.—If an orifice be made in the side or bottom of a vessel containing a liquid, the latter will escape through it. The particles of liquid near the orifice are forced out by the pressure of those above.

356. *Velocity.*—The velocity of a stream flowing through an orifice depends on the distance of the latter below the surface of the liquid, being equal to the velocity which a body would acquire in falling that distance.

If, for instance, in a reservoir full of water, three orifices be made at depths of $16^1/_{12}$, $64^1/_3$, and $144^3/_4$ feet, the liquid (leaving friction, &c., out of account) will issue from them with velocities of $32^1/_6$, $64^1/_3$, and $96^1/_2$ feet per second, because such, as we have found, would be the velocity of a body falling through the different distances first named.

The distances above mentioned are to each other as 1, 4, 9; the velocities are to each other as the square roots of these numbers, 1, 2, 3. Consequently, *the velocities of streams issuing from different orifices in the same vessel are to each other as the square roots of their respective distances below the surface of the liquid.* Friction, however, and other causes, produce more or less deviation from this rule.

357. As long as the liquid is kept at the same height in the vessel, it issues from a given orifice with the same velocity; but, if the vessel is not replenished, as the liquid gets lower, the pressure diminishes, and the velocity of the stream diminishes with it. It takes twice as long to empty an unreplenished vessel through a given orifice, as it would for the same quantity of water to escape if the liquid were kept at its original level.

358. *The Clepsydra.*—Among the ancients, time was measured by the flow of water through an orifice, in an instrument called the Clepsydra, or Water-clock. It consisted of a transparent vessel with a hole in the bottom that would empty it in a certain time. A scale on the side of the vessel indicated, by figures at different levels, the number of hours which it took the liquid to reach them successively in its descent. As the discharge was most rapid when the vessel was full, the divisions were of course longest at the top of the scale.

The clepsydra was necessarily inaccurate, inasmuch as the flow of the

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354. Of what does Hydraulics treat? 355. What causes a liquid to flow through an orifice in the vessel containing it? 356. On what does the velocity with which a stream issues from an orifice depend? Give an example. What is the law for the velocities of streams issuing from different orifices in the same vessel? 357. What difference does it make, as regards the velocity of a stream through an orifice, whether the vessel is kept replenished or not? 358. What did the ancients use for measuring