so highly ductile, that it may be spun into fine threads and woven into fabrics. Many of the metals, as iron, gold, silver, and copper, are ductile at ordinary temperatures, and are capable of being drawn out into fine wires, by means of wire-drawing machines.

The following metals are arranged in the order of their ductility: *platinum, silver, iron, copper, gold, zinc, tin, lead.*

Malleability.

67. MALLEABILITY is the property of being flattened or rolled out into sheets, by forces of compression.

This property often augments with the temperature; every one knows that iron is more easily forged when hot than when cold. Gold is highly malleable at ordinary temperatures. Gold is reduced to thin sheets by being rolled out into plates by a machine; these plates are cut up into small squares, and again extended by hammering until they become extremely thin. They are then cut up again into squares, and hammered between membranes, called gold-beater's skins. By this process gold may be wrought into leaves so thin, that it would take 282,000, placed one upon another, to make an inch in thickness. These leaves are employed in gilding metals, woods, paper, and the like. Silver and copper are wrought in the same manner as gold.

The following metals are amongst the most malleable under the hammer: *gold, silver, platinum, iron, tin, zinc, copper, lead.*

When metals are alloyed, they are generally harder and less malleable, as well as less ductile.

Is gold ductile? When? Give examples of ductile metals. (**67.**) What is Malleability? *Effect of temperature? How is gold formed into sheets? What is the order of malleability of metals? Effect of alloying.*

CHAPTER II.

MECHANICS OF LIQUIDS.

I.—GENERAL PRINCIPLES.

Definition of Hydrostatics and Hydrodynamics.

68. THE Mechanics of Liquids is divided into two branches: HYDROSTATICS, which treats of the laws of equilibrium of liquids, and HYDRODYNAMICS, which treats of the laws of motion of liquids.

Properties of Liquids.

69. The following properties are common to all liquids:

1. The molecules of liquids are extremely movable, yielding to the slightest force.

There is very little cohesion between the molecules of liquids, whence their readiness to slide amongst each other. It is to this principle that they owe their fluidity.

2. Liquids are only slightly compressible.

Liquids are so slightly compressible, that for a long time they were regarded as absolutely incompressible. In 1823, ERSTED demonstrated, by an apparatus which he contrived, that liquids are slightly compressible. He showed that for a pressure of one atmosphere, that is, of 15 lbs. on each square inch of surface, water is compressed the $\frac{49}{1000000}$th of its original volume. Slight as is

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(**68.**) Define Hydrostatics. Hydrodynamics. (**69.**) What is the first property of Liquids. *Illustrate.* Second property? *Illustrate.*

the compressibility of water, it is nevertheless ten times as compressible as mercury.

3. Liquids are porous, elastic, and impenetrable, like other bodies.

That liquids are porous, has already been shown (Art. 9). That they are elastic, is shown by their recovering their volume after the compressing force is removed. It is also shown by the fact that they transmit sound. Their impenetrability is shown by plunging a solid body into a vessel filled with a liquid. If there is no imbibition, a volume of water will flow over the vessel just equal to that of the solid introduced.

Upon these three properties of liquids depends their property of transmitting pressures in all directions.

Transmission of Pressures.—Principle of Pascal.

70. Let a bottle be filled with water and corked, as represented in Fig. 43. If the cork be pressed inwards, the pressure will be transmitted to the molecules in contact with it; these molecules will in their turn press upon the neighboring ones, and so on until the pressure is finally transmitted to every point of the interior surface of the bottle.

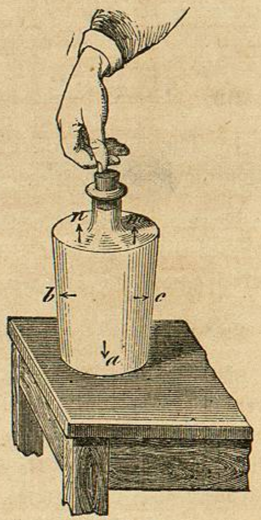

Fig. 43.

It is shown by experiment that the pressure thus transmitted is equal to that applied to the cork; that is, the pressure upon each square inch of

Third property? *Illustrate.* (**70.**) What is the Principle of Pascal?

the interior surface of the vessel is equal to that upon a square inch of the cork. The pressure is everywhere perpendicular to the surface, as shown by the arrow-heads.

This principle is called the *Principle of Pascal*, because it was first demonstrated by BLAISE PASCAL in the seventeenth century. Upon it depends the whole theory of Hydrostatics.

Pressure due to the Weight of Liquids.

71. If a cylindrical vessel is filled with a heavy liquid, its weight produces a pressure upon the walls of the vessel. If we suppose the liquid divided into horizontal layers of equal thickness, it is plain that the second layer from the top supports a pressure equal to the weight of the first, the third layer supports a pressure equal to the weight of the second and first, and so on to the bottom. Hence, *the pressure upon any layer is proportional to its depth below the upper surface, and is equal to the weight of the column of fluid above it.*

In consequence of the principle of PASCAL, this pressure is transmitted laterally, and acts against the sides of the vessel with an equal intensity. Hence, *every part of the surface is pressed with a force equal to the weight of a column of liquid whose base is the surface pressed, and whose height is equal to the distance from that surface to the upper level of the fluid.*

The same principle holds, whatever may be the form of the vessel.

Why so called? How illustrated? (**71.**) What is the measure of the pressure on any horizontal layer of a liquid? How shown? How is it transmitted? What pressure is exerted on the surface of a containing vessel?

Lateral Pressures.—Reaction Wheel.

72. The fact that liquids exert lateral pressures upon the walls of vessels, is demonstrated by means of the reaction wheel. This wheel is shown in Fig. 44; it consists of a vertical cylindrical tube *C*, turning freely in a ring, *n*, near its upper extremity, and resting upon a pivot at its lower extremity. Just above the pivot, the tube terminates in a cubical box, from the faces of which project four tubes, having their ends curved, as shown in the figure. Water is supplied from a cistern through the funnel *D*. When the water is admitted, it flows down the tube *C*, and escaping through the curved tubes at the bottom, the wheel is turned in the direction indicated by the arrow-head.

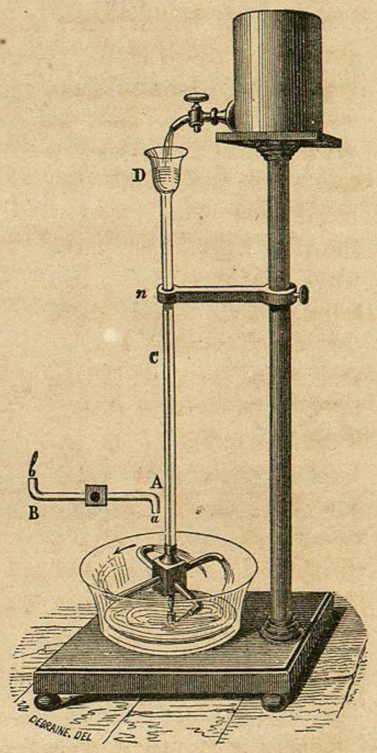

Fig. 44.

The reason of this will be plain from a consideration of the small figure *ab*, which is a plan of two of the tubes. The weight of the water causes a pressure upon *A*, which, were

(**72.**) How is the lateral pressure demonstrated? Describe the reaction wheel. *Explain its action.*

a closed, would be exactly counterbalanced by the pressure upon it; but *a* being open, the pressure upon *A* is not counterbalanced, but acts from *a* towards *A*, producing rotary motion. The reactions in all of the tubes conspire to produce rotation in the same direction.

Pressure upwards.

73. That liquids exert a pressure upwards is demonstrated by means of the apparatus shown in Fig. 45. It consists of a tube of glass, with a movable disk, *a*, ground so as to fit the bottom of the tube. The disk being held closely against the tube by a string, *b*, the whole is plunged into a vessel of water. In this state, the disk, though heavier than water, does not fall to the bottom, showing that it is held in place by an upward pressure. If water now be poured into the tube in a gentle stream, the disk will adhere till the latter is filled to the level of the fluid on the outside. This shows that the upward pressure is equal to the weight of a column of water whose base is that of the tube, and whose altitude is its distance below the upper surface of the fluid.

Fig. 45.

The upward pressure of fluids is called their *Buoyant Effort*. It is in consequence of their buoyant effort that fluids sustain lighter bodies on their surfaces. The same principle causes fluids to buoy up bodies of all kinds, diminishing the weight of heavy ones, and causing light ones *to float*.

(**73.**) How is upward pressure demonstrated? *What is the Buoyant Effort? Its effect on bodies?*

Pressure on the Bottom of a Vessel independent of its Shape.

74. The pressure on the bottom of a vessel, arising from the weight of a liquid, is entirely independent of the shape of the vessel, as well as of the quantity of liquid which it contains. It depends only on the size of the surface pressed, and its distance below the upper surface of the liquid.

This principle may be demonstrated by means of an apparatus, shown in Fig. 46. The apparatus consists of a tube, *o*, firmly attached to the cover of a glass vessel, *P*. By means of a screw joint, different shaped vessels, *A*, *B*, *C*, may be attached to the upper end

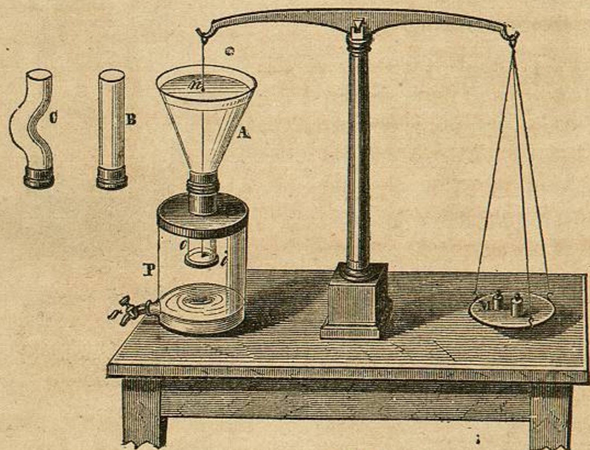

Fig. 46.

of the tube. A disk, *i*, of ground glass is held in contact with the lower end of the tube by a string, which is secured at its upper extremity to an arm of a balance.

The vessel, *A*, is screwed on, and filled with water until the downward pressure exactly counterpoises a given weight in the

(**74.**) Does the pressure on the bottom of a vessel depend upon the shape of the vessel? *How shown? Explain the experiment in detail.*

scale-pan, *M*, when the upper surface of the water is marked by a sliding bead, *n*. The other vessels, *B* and *C*, are successively screwed on, and filled with water up to the level, *n*; if any more water is poured into either, the downward pressure overcomes the weight, *M*, and the water escapes into the vessel, *P*.

This principle of pressure on the bottom of vessels is sometimes called the *Hydrostatic Paradox*. It is so called, because the same pressure may be obtained by using very different quantities of the same liquid.

Pascal's Experiment.

75. The following experiment was made by PASCAL, in 1647. He fitted into the upper head of a strong cask a tube of small diameter and about thirty-four feet in length, as shown in Fig. 47. The cask being filled with water, he succeeded in bursting it by pouring a comparatively small quantity of water into the tube. In this case, the pressure exerted laterally was the same as though the tube had been throughout of the same diameter as the cask, or even greater.

Fig. 47.

Hydraulic Press.

76. The principle of equal pressures has been applied in the construction of a press, by means of which a single man may exert an enormous power. This press is shown in perspective in Fig. 48, and in section in Fig. 49, the letters in both figures corresponding to the same parts.

What is this principle of pressure called? Why? (**75.**) *Explain Pascal's experiment.* (**76.**) What is the principle of the Hydraulic Press?

The press consists of two cylinders, *A* and *B*, of unequal diameters. In the cylinder, *B*, is a solid piston, *C*, which rises as the water is forced into *B*, and thus forces up a platform, *K*. The cylinder, *A*, forms the barrel of a pump by means of which water is raised from a reservoir, *P*, and forced into the cylinder, *B*. This pump is worked by a lever, *O*, attached to a solid piston, *a*. When the piston, *a*, is raised, a vacuum is formed behind it, which is filled by water from

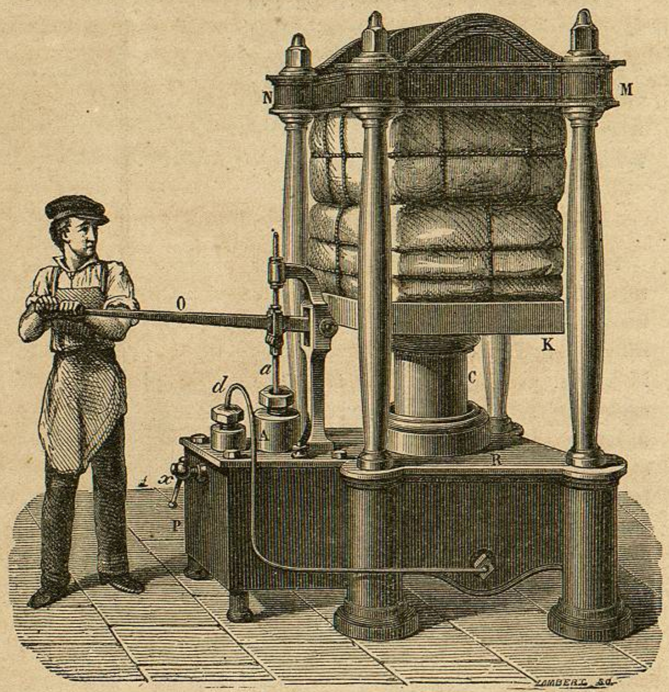

Fig. 48.

the reservoir, *P*, which enters by opening the valve, *S*. When the piston is depressed, the valve, *S*, closes, the valve, *m*, is opened, and a portion of the water is forced through the pipe, *d*, into the cylinder, *B*. By continuing to work the piston, *a*, up and down, additional quantities of water are forced into the large cylinder.

Describe the press in detail. Explain its action.

In consequence of the principle of *equal pressures*, the force applied to the piston, *a*, is transmitted through the tube, *d*, and is finally exerted upwards against the piston, *C*, its effect being multiplied by the number of times that the section of the piston, *C*, is greater than that of the piston, *a*. For example, if the section of *C* is 150 times as great as that of *a*, every pound of pressure on the latter will produce 150 lbs. of pressure on the former. This effect is further multiplied by means of the lever, *O*. The pressure exerted upon *C*, forces up the platform, *K*, with an energy that may be utilized in compressing any substance placed between it and the top of the press, *MN*. This upward pressure may also be used for raising heavy weights.

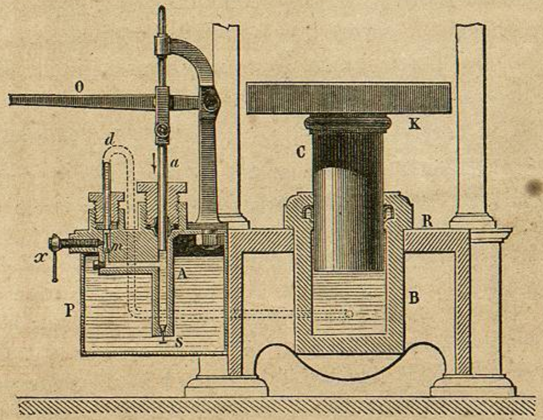

Fig. 49.

By varying the relative dimensions of the parts of the machine, an immense power may be exerted. In the arts, presses of this kind are constructed capable of exerting a force of more than a hundred thousand pounds.

The hydraulic press is used in compressing seeds to obtain oils, in packing hay, cotton, and other goods for shipment, in pressing books for the binder, and in a great variety of other operations. The immense tubular bridge over the Menai Straits was raised from the level of the water to the top of the piers by means of presses of this

Illustrate its power by an example. What are its uses?

description. The hydraulic press was also used in launching the Great Eastern, the heaviest movable structure ever constructed by man.

II.—EQUILIBRIUM OF LIQUIDS.

Conditions of Equilibrium.

77. A solid body is in equilibrium when its centre of gravity is supported, because the particles of the body are held together by cohesion. In liquids the particles do not cohere, and unless restrained they would flow away and spread out indefinitely. A liquid can only be in equilibrium when restrained by a vessel, or something equivalent. Furthermore, each particle must be equally pressed in all directions, which requires that the free surface should be level, that is, everywhere perpendicular to the force of gravity.

In saying that the free surface must be level, we suppose that the liquid is only acted upon by the force of gravity, which is the ordinary case. If, however, it is acted upon by other forces, the free surface must, at every point, be perpendicular to the resultant of all the forces acting at that point; for if it were not so, this resultant might be resolved into two components, one perpendicular to the surface, and the other parallel to it. The former would be resisted by the reaction of the liquid, and the latter, being uncompensated, would produce motion, which is contrary to the hypothesis of equilibrium.

Level Surface.

78. The surface of a liquid is LEVEL when it is everywhere perpendicular to the direction of gravity. Small level surfaces coincide sensibly with horizontal planes. Large level surfaces are curved so as to conform to the general form of the earth's surface. That the surface of the ocean is curved is shown by the phenomena presented by a

(**77.**) Explain the difference between equilibrium of solids and liquids. When is a liquid in equilibrium? *How is the upper surface when other forces than gravity act? Why?* (**78.**) What is a level surface? Nature of a small level surface? Of a larger one? Illustrate.

ship sailing from the shore, as exhibited in Fig. 50. As the vessel sails away, we first lose sight of her hull, then her lower sails disappear, then her higher sails, until at last the entire vessel is lost to view.

Fig. 50.

In defining a level surface, we said that it was everywhere perpendicular to the direction of gravity; more strictly speaking, it is perpendicular to the resultant of gravity and the centrifugal force due to the earth's rotation on its axis. Were it not for the centrifugal force, the surface of the ocean would be perfectly spherical, but in consequence of that force, it is ellipsoidal; that is, the oceans are elevated about the equator and depressed about the poles.

The general level of the ocean is called the *true level;* a horizontal plane at any point is called the *apparent level.*

Equilibrium of Liquids in Communicating Vessels.

79. When a liquid is contained in vessels which communicate with each other, it will be in equilibrium if its

Explain the effect of the centrifugal force on the form of a level surface. What is a true level? An apparent level? (**79.**) What are the conditions of equilibrium in communicating vessels?