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 above the orifice is 49 feet; required the velocity. Substituting, $v=\sqrt{2 \times 32 \times 49}=56$ feet.

(3.) To FIND THE QUANTITY OF WATER DISCHARGED IN A GIVEN TIME, multiply the area of the orifice by the velocity of the water, and that product by the number of seconds.—*Example:* What quantity of water will be discharged in 5 seconds from an orifice having an area of $\frac{1}{2}$ sq. foot at an average depth of 49 feet? At that depth, $v=\sqrt{2 \times 32 \times 49}=56$ feet per second; multiplying by $\frac{1}{2}$, we have 28 cubic feet discharged in one second and 140 cubic feet in five seconds.* In practice, much less than this can be realized.

2. Effect of Tubes.—If we examine a jet of water, we see its size is decreased just outside the orifice to about two thirds that at the opening. This neck is called the *vena contracta*, and is caused by the water producing cross currents as it flows from different directions toward the orifice. If a tube of a length twice or thrice the diameter of the opening be inserted, the water will adhere to the sides so that there will be no contraction, and the flow be increased to about 80 per cent. of the theoretical amount. If the tube be conical, and inserted with the large end inward, the discharge may be augmented to 95 per cent.; and if the outer end be

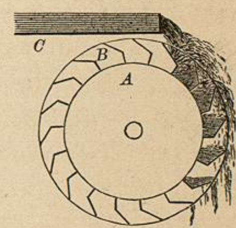
* If, at a foot below the surface, an opening will furnish 1 gallon per minute, to double that quantity the opening must be 4 feet below the top. Again, if a certain power will force through a nozzle of a fire-engine a given quantity of water in a minute, to double the quantity the power must be quadrupled.

flaring, it may reach 98 per cent. Long tubes or short angles, by friction, diminish the flow of water.

3. Flow of Water in Rivers.—A fall of three inches per mile is sufficient to give motion to water, and produce a velocity of as many miles per hour. The Ganges descends but 800 feet in 1,800 miles. Its waters require a month to move down this long inclined plane.* A fall of three feet per mile will make a mountain torrent. The current moves more swiftly at the center than near the shores or bottom of a channel, since there is less friction.

4. Water-wheels are machines for using the force of falling water. By bands or cog-wheels the motion of the wheel is conducted from the axle into the mill.†

Fig. 85.



The Overshot Wheel.

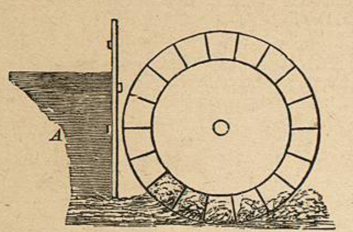
The OVERSHOT WHEEL has on its circumference a series of buckets which receive the water flowing from a *sluice*, *C*. These hold the water as they descend on one side, and empty it as they come up on the other. Overshot wheels are valuable where a great fall can be secured, since they require but little water. If *W* denotes the weight of the water and *h* the distance it

* "The fall of 800 feet would theoretically give a velocity of more than 150 miles per hour. This is reduced by friction to about three miles."

† The principle is that of a lever with the *P* acting on the short arm. In this way the movement of the slow creaking axle reappears in the swiftly buzzing saw or flying spindle.

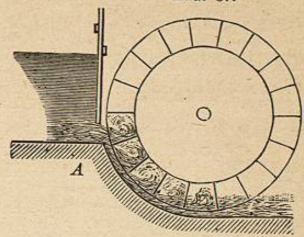
falls, then the total work $= Wh$. Of this amount, 75 per cent. can be made available under good conditions.

Fig. 86.



Undershot Wheel.

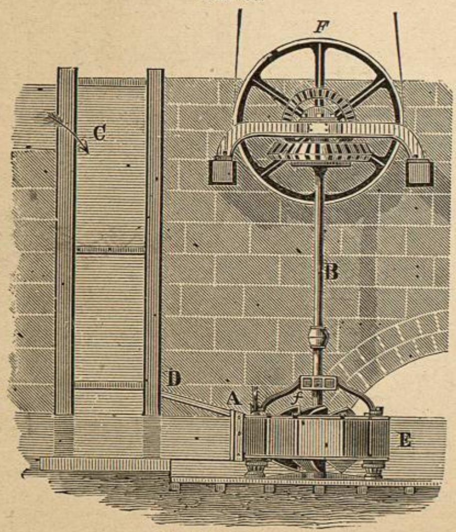
Fig. 87.



Breast wheel.

The Undershot Wheel has projecting boards, or *floats*, which receive the force of the current. It is of use where there is little fall and a large quantity of water. It utilizes not more than 25 per cent. of the energy of the water.

Fig. 88.



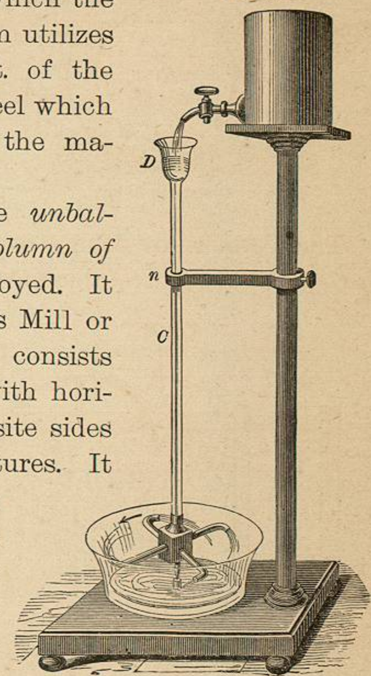
Turbine Wheel.

The Breast-wheel (Fig. 87) is a medium between the two kinds already named.

The Turbine Wheel is placed horizontally and immersed in the water. In Fig. 88, C is the dam and DA the spout

by which the water is furnished. E is a scroll-like casing encircling the wheel, and open at the center above and below. The axis of the wheel is the vertical cylinder B, from which radiate plane-floats against which the water strikes. This form utilizes as high as 90 per cent. of the energy. F is a band-wheel which conducts the power to the machinery.

Fig. 89.



Barker's Mill.

The principle of the *unbalanced pressure of a column of water* may also be employed. It is illustrated in Barker's Mill or Reaction-wheel.* This consists of an upright cylinder with horizontal arms, on the opposite sides of which are small apertures. It rests in a socket, so as to revolve freely. Water is supplied from a tank above. If the openings in the arms are closed, when the cylinder is filled with water the pressure is equal in all directions and the machine is at rest. If now we open an aperture, the pressure is relieved

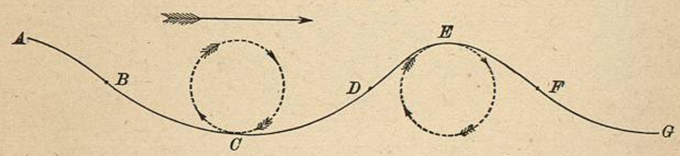
* Revolving fire-works and the whirligig, used for watering lawns and as an ornament in fountains, are constructed on the same principle.—An ingenious pupil can easily construct a Reaction-wheel of straws or quills, pouring the water into the upright tube by means of a pitcher, or admitting it slowly through a siphon from a pail of water placed on a table above.

on that side, and the arm flies back on account of the unbalanced pressure of the column of water above.

5. Waves are produced by the friction of the wind against the surface of the water. The wind raises the particles of water and gravity draws them back again. They thus vibrate up and down, but in deep water the liquid mass does not advance. The forward movement of the wave is an illusion. The *form* of the wave progresses like the apparent motion of the thread of the screw which we turn in our hand, or the undulations of a rope or carpet which is shaken, or the stalks of grain which bend in billows as the wind sweeps over them.

The corresponding parts of different waves are said to be *like phases*. Thus, in Fig. 90, *A* and *E*,

Fig. 90.

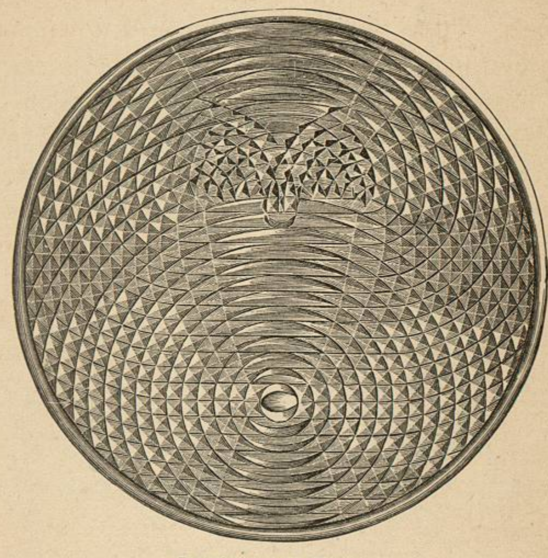


B and *F*, *C* and *G* are like phases. The distance between two like phases, or between the crests of two succeeding waves, is called a *wave-length*. Thus the distance *AE*, or *BF*, or *CG* is a wave-length. Opposite phases are those parts which are vibrating in opposite directions, as *E* and *C*, or *B* and *D*. The successive particles of water move each in an ellipse, and in regular succession, so that when a particle at

E is moving forward, one at *C* is moving backward, one at *B* upward, and one at *D* downward. This is easily observed at sea.*

Composition of Wave Motion.—A tide-wave may be setting steadily toward the west; waves from

Fig 91.



Interference of Waves.

distant storms may be moving upon this; and, above the whole, ripples from the breeze then blowing may diversify the surface. These different systems will be

* Near the shore the oscillations become shorter; the lower particles being checked in their elliptic motion by the friction on the sandy beach, the front becomes well-nigh vertical, and the upper part curls over and falls beyond. The size of "mountain billows" has been exaggerated. Along the coast in a gorge they may reach 90 feet, but in the open sea the highest wave, from the deepest "trough" to the very topmost "crest," rarely measures over 30 feet.

distinct, yet the joint effect may be very peculiar. If any two systems coincide with *like phases*,—the crest of one meeting the crest of the other, and the furrow of one meeting the furrow of the other,—the resulting wave will have a height equal to the *sum of the two*. If any two systems coincide with opposite phases,—the hollow of one striking the crest of another,—the height will be the *difference of the two*. Thus, if in two systems having the same wave-length and height, one is exactly half a length behind the other, they will destroy each other. This is termed the *interference* of waves.*

The manner in which different waves move among and upon one another, is seen by dropping a handful of stones in water and watching the waves as they circle out from the various centers in ever-widening curves. In Fig. 91 is shown the beautiful appearance these waves present when reflected from the sides of a vessel.

* "In the port of Batsha the tidal-wave comes up by two distinct channels so unequal in length that their time of arrival varies by six hours. Consequently when the crest of high water reaches the harbor by one channel, it meets the low water returning by the other, and when these opposite phases are equal, they neutralize each other, so that at particular seasons there is no tide in the port, and at other times there is but one tide per day, and that equal to the difference between the ordinary morning and evening tide."—*Lloyd's Wave Theory*.

Another striking example of interference of tide-waves is seen in the immediate neighborhood of New York. The tide-wave from the ocean, coming from the south-east, divides, a part passing up New York Bay, and another part sweeping around and turning westward through Long Island Sound. The meeting-place of these two branches is at Hell Gate, the narrowest ship-channel between Long Island and New York. If a wall were built across Hell Gate, the water on one side would sometimes be five feet above that on the other. In the absence of such a wall, the current surges with great rapidity under the Brooklyn Bridge, alternately in opposite directions.

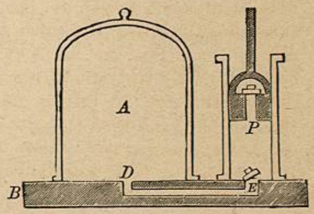
PRACTICAL QUESTIONS.

1. Two faucets, one 8 feet and the other 4 feet below the surface of the water in a cistern, are kept open for a minute. How many times as much water can be drawn from the first as the second?
2. How much water will be discharged per second from a short pipe having a diameter of 4 inches and a depth of 48 feet below the surface of the water?
3. When we pour molasses from a jug, why is the stream so much larger near the nozzle than at some distance from it?
4. Ought a faucet to extend into a barrel beyond the staves?
5. What would be the effect if both openings in one of the arms of Barker's Mill were on the same side?

III. PNEUMATICS.

Pneumatics treats of the general properties and the pressure of gases. Since the molecules move among themselves more freely even than those of liquids, the conclusions which we have reached with regard to transmission of pressure, buoyancy, and specific gravity apply also to gases. Since air is the most abundant gas, it is taken as the type of the class, just as water is of liquids.

Fig. 92.



The Air-pump.

1. The Air-pump is shown in its essential features in Fig. 92. *A* is a glass receiver standing on an oiled pump-plate. The tube *D* connecting the receiver with the cylinder, is closed by the valve *E*, opening upward. There is a second valve, *P*, in the piston, also opening upward. Suppose the piston is at the bottom and both