Weighelmann's Companion
to the air pump

A

COMPANION

TO THE

AIR PUMP,

WITH A DESCRIPTION OF

CLAXTON'S IMPROVED SINGLE CYLINDER LEVER AIR PUMPS,

AND A DESCRIPTIVE EXPLANATION OF A GREAT VARIETY OF

APPARATUS AND EXPERIMENTS,

MANY OF WHICH ARE ORIGINAL.

BY JOSEPH M. WIGHTMAN,

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PHILOSOPHICAL INSTRUMENT MAKER,

No. 33 CORNHILL, BOSTON.

BOSTON:

PRINTED BY GEORGE W. LIGHT.

1839.

ADVERTISEMENT.

The following little manual has been prepared with the primary object of assisting the experimenter in the use of the Improved Lever Pumps, and the experiments which have been adapted to them. It is believed, however, that it will be an interesting "Companion" to those who have other forms of the Air Pump, as presenting a greater variety of experiments than are usually found together. Many hints and suggestions are given which are not commonly noticed in works on the Science, especially in the *mechanical* part of the experiments, which are not sufficiently described to suffer the teacher to overcome any little difficulty in the manipulation, the design of the Text Book being to convey the *principle*, without particular reference to the success of the experiment.

Besides, there are many illustrations copied from book to book, without the author inquiring whether they can be readily performed, or are correct in the details. A few common experiments thus circulate through the Text Books, imposing the duty upon the teacher of collecting his experiments from a great variety of sources, which duty, it is hoped, the "Companion" will in some measure relieve. The writer's frequent communication with our most eminent professors and scientific men, has furnished him with many valuable hints in the performance of experiments, which he would gratefully acknowledge; and he trusts that his endeavor thus to diffuse their ideas and render them more useful, will be as acceptable to them as it is pleasing for him to acknowledge them.

JOSEPH M. WIGHTMAN.

33 Cornhill.

TESTIMONIAL.

The following is the Report of the Judges on Philosophical Apparatus, at the Mechanics' Fair held in this city, Sept., 1837.

No. 568. CLAXTON & WIGHTMAN, BOSTON. Sectional model of a Steam Engine; Pneumatic Apparatus for Schools; Table Air Pump and Apparatus; Large Air Pump and Apparatus; Orreries. These articles are thoroughly made and well finished.

The Sectional Model illustrates the mechanism of the high and low pressure steam engines. The Pneumatic Apparatus for schools, furnishes the means of performing in a satisfactory manner, all the common experiments in this branch of natural philosophy, at a small expense. The Table Air Pump is simple in construction. It has a single barrel, which is worked upon its piston in a vertical direction by means of a lever. This arrangement is thought to give the instrument several advantages over that of the common construction. *This pump is also easily kept in repair, and for general use, is considered superior to any that has fallen under the notice of the Committee.*

Claxton & Wightman deserve great credit for the improvement they have introduced in the manufacture of Philosophical Apparatus. Many of their articles have been either invented or greatly improved by them.

A SILVER MEDAL.

GEO. B. EMERSON, AARON BREED,
S. P. MILES, EBEN. BAILEY, } JUDGES.
PROF. ANDREWS,

THE AIR PUMP.

In its primitive form, the Air Pump was composed of a smooth tube, fitted with a piston and two valves, very similar to the present construction of the common water pump. Its first application was by Otto de Guericke, a Burgomaster of Magdeburgh, in Germany, in the year 1654, who exhausted the air from two hollow brass Hemispheres, twelve inches in diameter, the edges of which were ground air tight.

His object was to exhibit the pressure of the air, in which he succeeded; for the combined efforts of twelve horses, pulling in opposite directions, were unable to overcome the power with which they were held together.

This experiment, so imposing in effect, was well calculated to attract the attention of philosophers; and the minds of many of them were directed to the eliciting of new facts and experiments. In a short time, the combined talent thus brought into the field, produced not only improvement in the science, but also in the form and convenience of the machine. The syringe, as used by Guericke, in the Magdeburgh experiment, was now attached to a stand, and by means of a flat brass plate, was adapted for a glass receiver, in which an experiment could be enclosed, and the effect seen.

This form, with some modification, has been much used to the present time on account of its simplicity; but it is subject to the radical defect of the labor *increasing* in proportion as the receiver is exhausted, and the operator fatigued—owing to the pressure on the top of the piston becoming greater, as the air is removed from the under side.

A limit being thus given to the size of the Single Barrel Pump, with the simple application of the hand direct to the piston, not being sufficient to overcome the resistance, and its power in some experiments frequently being insufficient, led to the invention of the Double Barrel Pump; in which the piston rods have teeth upon them, and are moved alternately in the cylinders by a geared wheel attached to a crank, and thus produce double the effect by the new combination.

Although the anticipated increase of effect was produced, yet the increased number of joints and valves, and the general complication of parts, are such, even with the present improvements, as to render them frequently liable to derangement, and more difficult of repair, except by a manufacturer. It is somewhat remarkable, although too common to be singular, to what an extent the complication of philosophical instruments is encouraged; and this too by those who of all others should be governed by more correct principles. Those who are constantly illustrating the beautiful *simplicity* of science, will yet prefer to do it with so complicated an instrument, as frequently to mar the effect, if they do not prevent it from being understood. An Air Pump, most beautifully finished in every part, was imported from London at a cost of nearly $500, for a scientific society of this city, a few years since; and so completely was this principle of complication carried out, that whenever a lecture was attempted with it, the power of two strong men was required to exhaust even a small receiver; whereas the entire experiments of the evening,

were repeatedly performed with ease and success, when the plain and simple Lever Air Pump was used.

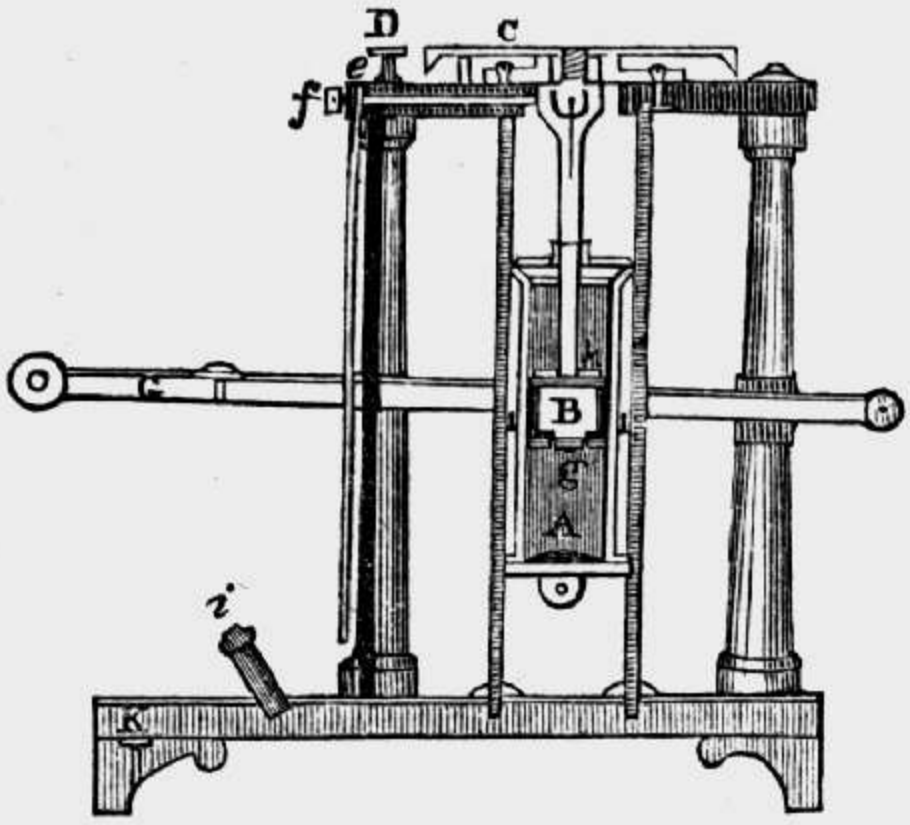
It is true, this is but a single instance; yet does it not forcibly illustrate the folly of complication in instruments? That there are Double Barrel Pumps which operate satisfactorily, we do not question; but that they have equal advantages with the Improved Lever Pump, we believe is contrary to nature; is contrary to the Mechanical axiom—that power is *lost*, *not gained*, by complication; that to exhaust a vessel of given dimensions, requires a certain amount of power, and therefore, *the apparatus by which the power can be applied in the most direct and convenient manner, and with the least friction, is the best.* The application of the Lever to the Single Barrel in the present form, is peculiar; it causes the *resistance to occur at the downward* strokes, which being perpendicular, suffer the muscles of the arm to operate with *less fatigue*, and *more advantage*, than in the geared circular motion; and with the simple lever, *two* strokes can be given with the same power, and in about the same time, required for *one* with the Double Barrel form. Besides, its simplicity permits the teacher at a distance, to be able to keep his Pump in good order himself, with but little trouble.

The gain of two Barrels over one in the rapidity of exhaustion, is merely imaginary; if aught *is* gained, it is by the Single Barrel; for by increasing the diameter of the cylinder from $1\frac{1}{2}$ *to* 2 *inches, it will at each stroke, exhaust one eighth more air than two cylinders of* $1\frac{1}{2}$ *inches, and the friction will be increased but one half;* because the area increases according to the square of the diameter, but the friction in a simple ratio.

With these radical advantages, we are confident that, founded as it is, upon true mechanical principles, the Improved Lever Pump will produce a revolution in the form of the instrument; and in time, entirely supersede the present Double Barrel Pump.

PORTABLE LEVER AIR PUMP.

Fig. 1.



Description.—This Pump, of which a section is represented at Fig. 1, consists of a mahogany stand, upon which is the Pump, supported by four turned pillars. Within this frame, the cylinder A slides between two polished steel guide-rods. The cylinder is moved by means of the lever G, upon the piston B, which is connected by the piston rod to a triangular brass plate, fastened by three brass screws under the Pump-plate to the top board. C, is a brass plate, ground very flat and true, upon which the receivers are placed for exhaustion.

D, is a screw to a lmit the air to the receiver.

e, is the Guage, with an ivory scale at the back, fastened to a piece of mahogany, to prevent the Guage from being easily broken.

f, is a screw to fasten the Guage in its place. If the tube should be broken, a small block of wood, with a piece of leather, may be fitted in the place of the guage, and made tight by the screw *f*, and the Pump used as before.

g, *h*, are the valves.

i, is an elastic cushion to receive the force of the Lever in the downward stroke.

K, is a brass staple, by which the whole is firmly clamped to the table.

When it is necessary to take the Pump apart to repair the valves or piston, a few directions will be useful.

First. Carefully remove the Guage by loosening the screw *f*.

Second. Unscrew the Pump-plate C, under which are three screws; when these are removed, the triangular plate, with the piston attached, can be drawn out of the Barrel, and the piston, with all the valves attached, unscrewed and repaired.

There are two valves, both attached to the piston; viz., the valve *g*, on the bottom of the piston, by which the air passes through the piston-rod from the receiver to the cylinder; and *h*, by which the air passes from the cylinder to the open air. These valves are composed of fine calf-skin, and are very durable, and but little liable to get out of order.

If the piston is too loose, turn down the leather packing, and wind a little worsted or thread on the brass under it, which will enlarge the packing at pleasure.

Observe if all the *leather washers* are in place and in order; there are three attached to the Pump; viz., under the Pump-plate C,—on the screw D, for admitting the air—and on the Guage, where it is fastened to the Pump. These should be examined, and with the joints about the Lever, and steel guide-rods, oiled occasionally. Always keep a little sweet or good sperm* oil upon the top of the piston; but none is required in the hole in the plate C, except new valves have been added, and then but a *very little*.

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* I find that sperm oil does not thicken and clog the valves so much as olive oil.

Use a *very* little lard or oil on the Pump-plate C, and between the ground surfaces of all the brass and glass apparatus, to assist in keeping them tight, and prevent scratching.

While performing experiments, keep a cloth or rag at hand to wipe the edges of the receivers *every* time they are taken from the table to be used, and likewise the Pump-plate, to remove any grit or broken glass that might accidentally get upon it. Frequently, from the want of a little care in this respect, the plate and receivers are seriously injured. Make a practice of rubbing the receiver, when put on the plate, as it will render it much tighter. In all experiments with mercury, such as the Torricellian, extreme care is required to prevent any of the metal getting into the Pump; for if suffered to remain, it would amalgamate and injure it. If it should get in by accident, it should be immediately taken apart, and the mercury cleared entirely away. A small quantity may be intercepted by the small cup placed in a cavity under the Pump-plate, to prevent any thing entering the Pump through the hole on the top. On unscrewing the ground-plate, a looped string will easily remove the cup.

In the closed end of the glass Guage tube, is a small portion of air, which indicates, by its *expansion*, the degree of exhaustion in the receiver. Our object in this construction, is to be able to calculate with a short guage, the *first* portions of air, as they are removed from the receiver. In the usual syphon guages, only the latter part of the exhaustion is indicated. The calculation for this Guage is this;—when the air in the tube has expanded to *twice* its *bulk*, one half of the air is removed from the receiver; to 3 times its bulk, two thirds; 4 times, three quarters; 6 times, five sixths; 8 times, seven eighths; 20 times, nineteen twentieths, and so on. This is the kind of guage we have usually put to this Pump; but if the guage has no air in the closed end, the vacuum is shown

by the difference of level in the two parts of the tube; thus, if the difference is one quarter of an inch, there is but one hundredth of the air in the receiver; if one tenth, there is but one three hundredth.

Never suffer any one to admit the *air suddenly by removing the finger*—and always let the air in by the screw D, or the sudden rush of the air is liable to break the Guage, or separate the mercury column. If the mercury should be thus separated, the Guage should be taken out, and the column shaken together.

As improvements are constantly being made in the *form* of the parts, the rules and directions here given must be taken in a general sense; but with these, a person can undoubtedly understand how to repair a Pump; and the old valves and packing will always be guides for new. I would also caution persons against the frequent *new* valving and packing of an Air Pump; as this should *only* be done, when the leather is decayed or worn out; it is always better to clean and put them on again, than to put new, as the pores of the leather become filled with thick oil, and it is generally better after six months, than when first put on. Generally, a Pump, well packed and valved with leather, will not require renewing for a number of years. Particles of dust, &c. may get under the valves, and the packing become loose; but the first may be cleared away, and a few turns of yarn under the leather packing will render it better than new. A serious difficulty in the performance of accurate experiments, next to the good operation of the Pump, exists from the adhesion on the ground edge of the receiver, of small particles of dust or brass, rubbed from the plate, which, if not removed, will, although scarcely perceptible without careful examination, prevent the success of accurate experiments, particularly those requiring a good vacuum like the experiment for freezing of water, by its own evaporation. This difficult experiment, which but very few Double

Barrel Pumps will perform, I have recently successfully tried with the Portable Lever Pump, and produced ice in a watch crystal placed over sulphuric acid, in less than two minutes, and doubt not that subsequent improvements may be made to produce it even in less time. This experiment, which requires at least an exhaustion of ninety-nine one hundredths of the air from the receiver, to succeed to be performed by a Single Barrel of 1½ inches diameter, and 6 inches long, conveniently arranged for power and durability, at a cost of $30, is, we believe, without a parallel in the history of the science. Yet this has been produced by simplifying the valves—using leather instead of oiled silk—reducing the number of joints as far as practicable—and by the adoption of a simple lever applying the power to the best advantage.

Whenever new washers, valves, or packing are required, observe never to *wet* the leather; but it is well always to *oil* them. It is well to mention also that after performing experiments in which *water* is contained under the receiver, the vapor rising from the water is diffused in very minute particles through all parts of the Pump, and the operator will generally fail in any delicate experiment, unless the Pump is carefully cleared. This is best done by exhausting the largest receiver you have, and then letting the air in. If this is done several times, the vapor is much more effectually removed, than if air were simply drawn through the Pump without the receiver. If you make a practice of covering the experiment with as small a receiver as practicable, much labor will be saved which is otherwise needlessly expended.

EXPERIMENTS.

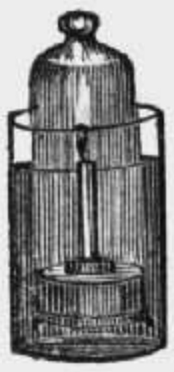
In treating of the Experiments with an Air Pump, it is usual to divide them into classes, illustrating the peculiar properties of the Atmosphere, such as its Materiality, Weight, Pressure, Expansion, Elasticity, and Resistance, which are called the *Mechanical Properties* of the Air, because they are rendered evident by the action of a *Machine*, independent of heat, or other *Chemical* or compound agent.

THE MATERIALITY OF THE AIR.

In speaking of the properties of the Air, it is necessary to illustrate, first, that it is a material substance, and subject to the laws of matter with regard to space—that although its bulk may be reduced by force, yet no force is sufficient to annihilate it.

Experiment 1.—Fill a bladder or silk bag with air, and tie the neck to prevent its escape. Weights may be added, or pressure applied, but it will merely be compressed, and resume its former bulk as soon as the force is removed.

Fig. 2.

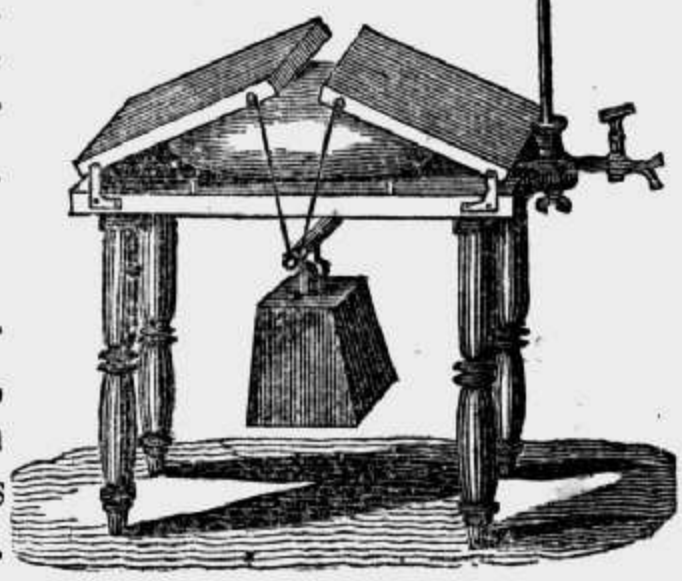


Exp. 2.—Take a bell receiver, or a tumbler, invert it in a jar of water, and press it down some distance, as in Fig. 2. The inside will be found to be perfectly dry, proving that the air has prevented the water from entering. If a small taper made to float on a piece of cork, be placed under the bell glass, it may be sent down the whole depth of the water, and may be brought to the

surface again, still burning, if the experiment be *quickly* performed. If it is not, the oxygen will be consumed, and the flame extinguished. This beautiful experiment illustrates the principle of the Diving Bell, and the taper the individuals; and as the flame is extinguished by the consumption of the oxygen, so if the individual is not furnished with fresh supplies of air, he will soon fall a victim to his temerity.

Observation.—The invention of the Diving Bell is ascribed to the 16th century. Taisner relates, that at Toledo, in Spain, in 1538, he saw, in the presence of the emperor Charles V., two Greeks let themselves down under water in a large inverted kettle, with a burning light, and rise up again, without being wet. But to Dr. Halley we are indebted for many improvements in this machine. He substituted glasses in the top of the Bell for the lamp that had been used, and suggested the use of air-barrels, which were sent down by weights to supply the change of air necessary for respiration. Diving Bells, when made of wood, are usually five feet high, four feet broad at the top, and six feet at the bottom, and loaded with sufficient weight to cause them to descend: if of iron, they are more frequently made to resemble the lower half of a cone. The one used at Howth, near Dublin, is an oblong iron chest, six feet long, four broad, and five high, and weighs about four tons. It has two seats, and will hold four persons.

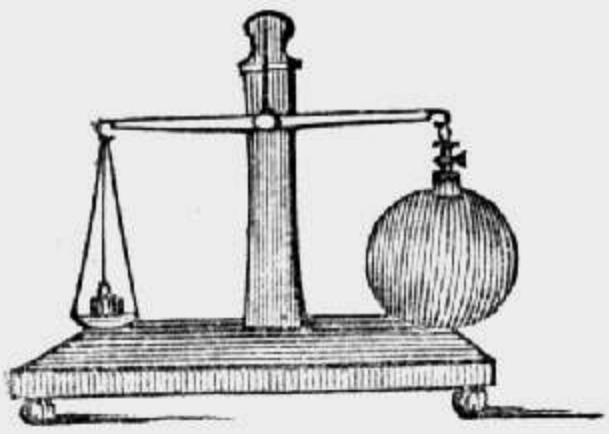
Fig. 3.



Exp. 3—The *Hydrostatic Bellows*, when inflated, forms a pleasing illustration of this property of the air, as the weight is sustained by it.

WEIGHT OF THE AIR.

Fig. 4.



Exp. 4.—Balance the Glass Globe with the small stop cock open, as in Fig. 4; then take it from the scales, and *by means of a large stop cock as a connector*, attach it to the Pump, and exhaust it. On returning it to the scales, it will be found to have lost some of its weight, (which may be ascertained if desired;) and when the air is admitted, it will be again in equilibrium. A quart of air weighs about 17 grains. The weight of a column of air 45 miles high and 1 inch square, is 15 pounds.

Exp. 5.—Take the copper air chamber, Experiment 52, screw a cock in the nut at the side, and also on the top—shut the side cock, and by means of a hollow brass piece fitting the screws of the cocks and pumps, called a *Connector*, attach a condensing syringe to the cock on the top of the chamber, and let a quantity of air be forced in—then shut the cock—remove the condenser and connector, and by a loop or string suspend the chamber to the arm of the balance and weigh it, and the weight will be increased in proportion to the air forced in.

PRESSURE OF THE AIR.

The air being proved a substance, and possessed of weight, we naturally infer that any thing having these properties will, as a necessary consequence, possess pressure also; and the experiments in this branch of the science are pleasing and numerous.

Fig. 5.

Exp. 6.—*The Hand Glass.*—Place the large end of the conical Hand Glass (Fig. 5) upon the Pump Plate, and apply the palm of the hand to the other. Exhaust the air, and the pressure will be felt fastening the hand to the glass, so that it cannot be removed but by admitting the air by the screw.

Obs.—The air being removed from the under part of the hand, causes it to sustain the whole weight of the column above it. This experiment shows that the *flesh* contains air, by its expanding and swelling downwards into the glass.

Fig. 6.

Exp. 7.—*The Sucker.*—A circular piece of leather, having a brass handle with a small hole through it, illustrates a pleasing fact in the natural application of the pressure of the atmosphere. When the leather is wet and pressed flat on a smooth board or stone, if the hole in the handle be closed, it will adhere so firmly, that a stone of several pounds may be raised; if the hole be opened, the air is admitted to the centre, and they immediately separate.

Obs.—The common Fly, the Gecko, a species of lizard, and the Sucking fish, all employ similar apparatus in attaching themselves to smooth surfaces.

Exp. 8.—*The Inverted Jar.*—If the mouth of a jar or tumbler, *filled* with water, be covered with a piece of writing paper and held in place by the palm of the hand while it is inverted—the pressure of the air will sustain the water in the jar after the hand is removed.

Exp. 9.—*The Magic Bottle, from which the water will run through the bottom when the stopper is removed.*—In the bottom of a glass-stopped bottle, several small holes are drilled. Immerse it in water with the mouth open, and when full, put in the stopper with a little tallow round it. The pressure of the air will sustain the water while the top is kept tight; but as soon as the stopper is removed, it will flow, by its gravity, through the holes.

Exp. 10.—*The Cemented Receiver.*—A receiver, placed upon the pump and the air exhausted, will be pressed to it with such force that the Pump may be lifted from the table by it.

Fig. 7.

Exp. 11.—*The Brass Hemispheres.*—Put the Brass Hemispherical Cups together with a little tallow on the edges to keep them tight —screw them by the stop-cock to the Pump, and exhaust them; turn the cock to prevent the air from getting inside, and it will require great force to separate them; but if the air be let in again, they will fall asunder by their own weight. Be careful that the persons pulling the cups apart, do not fall and bruise them; because the edges would not come together and be tight without refitting, which is very troublesome. One handle of the hemispheres may be attached to a fixed hook; and the other to a steelyard or scales, and the pressure shown safer and more correctly.

Fig. 8.

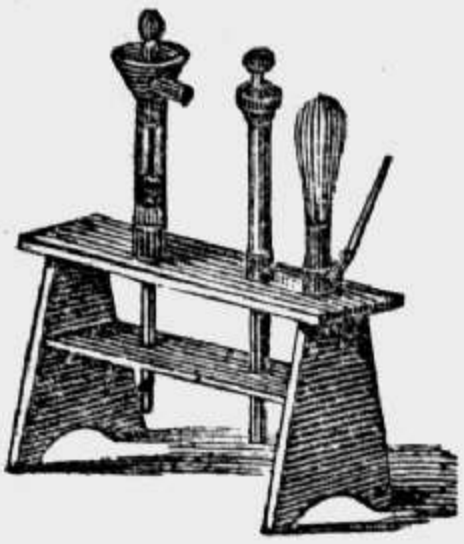
Exp. 12.—*The Bladder Glass.*—Over the large open end, stretch a piece of wet calf's or other *thin* bladder—tying it firmly over the edge, and let it be thoroughly dried. If it is then placed upon the Pump and the air exhausted, it will be broken by the pressure of the air with a loud report.

If the bladder be too strong to yield to the pressure, the point of a pin or penknife applied near the edge while the air is exhausted, will always perform the experiment.

Exp. 13.—*The India Rubber Glass.*—If instead of the bladder a piece of india rubber be used, it will not break but yield to the pressure, and nearly fill the glass vessel.

Exp. 14.—*Water Tube.*—Screw the long glass tube to the exhausting syringe—immerse the lower end in water —and on moving the piston, a vacuum will be formed, and the water rise in the tube by the pressure of the external

Fig. 9.



air—illustrating how water is raised *to* the boxes or valves of the common water pumps. The further operation of the air in raising the water is exhibited by working models of the lifting and forcing Pumps, as Fig. 9, having glass barrels and air vessels, so that the action of the valves, &c. can be seen in operation.

These models furnish very beautiful illustrations, not only for the science of Pneumatics, but Hydraulics, also.

Fig. 10.

Exp. 15.—*The Fountain in Vacuo.*—Screw the stop-cock and straight jet into the fountain glass, and attach it to the Pump by the other end of the cock—exhaust the air—shut the cock—remove it from the Pump—immerse and open the cock in a bowl of water, when, the air not being suffered to enter the glass, will force the water in a pleasing jet until the space before occupied by the air, is supplied with water. The same stop cock and jet is also used with the fountain in Exp. 52.

Fig. 11.

Exp. 16.—*The Crushed Bottle.*—If the breaking cube with the brass cap and oiled silk valve be placed with the wire guard over it, under a receiver, and the air exhausted; when the air is admitted, the square form of the bottle will not sustain the pressure, but be crushed. The cap may then be removed from the broken neck by warming, and cemented to another. Care should be taken that the valve is good and the little valve-hole clear of cement. Be careful, in this experiment, to wipe all the small pieces of glass off the Pump-plate to prevent injury.

Fig. 12.

Exp. 17.—*The Weight Lifter.*—Upon the mahogany stand with three legs, place the glass apparatus; and to the hook, suspend 50 *or* 100 *pounds*—attach the exhausting syringe, or Pump, (if you have a flexible tube) exhaust the air—and the weight will be raised. By having a hole bored through the table and a rod pass through to which a scale may be suspended, a small boy may be raised instead of the weight.

The improved India rubber cloth is used in this apparatus instead of a bladder, and forms a very imposing experiment on the upward pressure of the air. It illustrates that the air not only presses downwards, as in the bladder, Exp. 12, but with equal force upwards and in all directions, like any other fluid.

Fig. 13.

Exp. 18.—*Torricellian Experiment.*—Fill the small tube with mercury—place the finger over the end, and invert it into the glass cup containing a little of the metal to prevent the air entering, when the finger is removed—place the receiver over the whole; and as the air is exhausted, the mercury sinks in the tube; thus proving that the principle of the Barometer is correct; for when the atmosphere is damp and light, the column falls—when clear and heavy, it rises.

Obs.—This experiment is so named from Torricelli, the pupil of Galileo, as it proves the correctness of his discovery of the barometer, and the principles by which it is governed. The space between the top of the mercury and the tube, is called a Torricellian vacuum—and is presumed to be the most perfect vacuum (or void space) we can produce, by artificial means.

Exp. 19.—*The Artificial Halo.*—We have said in the preceding experiment that when the atmosphere is *damp*, it is *light*, and the Barometer falls. This, from the

fact that water is heavier than air, is frequently doubted by those not versed in the sciences, because it is said, how can the air be rendered lighter by the addition of a heavier fluid. It cannot be, nor is it. The air is not rendered lighter by *water* which is heavier, but, by steam or vapor of water, which, it is well known, is lighter and rises because the pressure of the atmosphere is reduced. This may be shown by experiment. Take a bulb receiver—place a shallow dish or saucer of water under it on the Pump—place a light on the outside of the receiver on the opposite side to the audience; as the air is rarified in the receiver, the vapor rises, and causes the light to appear surrounded with a halo, like the moon of a hazy night.

Exp. 20.—*The Glass Leech.*—Light a small piece of dry paper, or a little alcohol in a wine glass, and immediately place the fleshy part of the hand over it, by which it will be extinguished. If done without fear, there is no danger of being burned, and the hand will be held to it with considerable force. This is owing to the heat expelling the air, and the hand preventing its return. This experiment is frequently practiced by physicians in cupping.

Fig. 14.

Exp. 21.—*The Pump in Vacuo.*—Take the small Pump, or the syringe for exhausting, with a ground plate on the lower part. Screw in the long glass tube used in Experiment 14. Place a jar of water on the large pump-plate; then cover it with the guinea and feather, or other tall receiver open at the top, through which the tube may pass into the jar of water, and the plate of the syringe rest air-tight upon the upper edge of the glass. If the piston of the syringe be raised, the water will rise in the tube while the air remains in the receiver; but if the receiver be exhausted with the large Pump, the fluid cannot be made to ascend by any "suction" produced by the small Pump; proving that there is no "suction" independent of the pressure of the air.

Exp. 22.—*Suction Tube.*—Take a glass syphon or bent tube, and having inverted it to hold water, fill it nearly full—turn it so that the water fills one leg entirely, and apply the finger to exclude the air—then apply the mouth to the other leg and attempt to withdraw the water by "suction;" if the finger be held tight, no sucking power will be sufficient, unless there is a portion of air between the water and the finger, which may, by its expansion, suffer the water to be drawn from the tube. This is a very simple but convincing experiment, as there are no instruments used to perform it.

Fig. 15.

Exp. 23.—*The Syphon in Vacuo.*—After showing that the water will begin and continue to flow from the syphon cup until it is exhausted, if water be poured into it till it is above the bend of the tube—place it nearly filled upon a jar, and cover it with the tall open top receiver—place the plate and funnel filled with water and the cock shut upon the top—exhaust the receiver, and then by opening the cock, let sufficient water in from the funnel to fill the cup above the bend, and the syphon will not operate, because the pressure of the atmosphere is removed.

Fig. 16.

Exp. 24.—*The Hemispheres in Vacuo.*—After the Hemispheres have been exhausted, and their pressure shown, one of the handles may be unscrewed, and the wood part rescrewed in its place: then suspend the Hemispheres by the sliding hook in a receiver, so that the foot is raised about a fourth of an inch from the plate of the Pump—exhaust the air,and the pressure being thus removed, the Hemispheres will fall asunder. With a little practice and care, they may again be put together, and when the air is let into the receiver, they

will be as firmly pressed together as before. It requires rather more exhaustion of the receiver than the Hemispheres, to overcome the adhesion of the tallowed edges. A small clamp on the sliding rod will prevent the weight of the Hemispheres from drawing it through the plate.

Fig. 17.

Exp. 25.—*The Mercurial Shower.*—This is a beautiful illustration of the pressure of the air, and the porosity of wood. The cup and plate with the piece of wood, is to be placed on the top of an open receiver: mercury being poured into the cup and the air exhausted, it will be forced through the pores of the wood in a beautiful metallic shower: and if the weather be dry and the receiver clear, it will appear luminous in the dark—the metal being electrically excited by the friction of passing through the pores.

Fig. 18.

Exp. 26.—*The Air Shower.*—This is a similar experiment to the preceding, except that in the present, air is forced through the pores of the wood instead of mercury. The lower end of the wood is immersed in a jar of water to render the air visible. The thumb may be placed over the top of the wood to prevent the air entering sooner than is desired. This experiment shows not only the pressure of air, but that wood is pervious to the air, and that the course of the vessels is lengthwise.

Exp. 27.—Take a Florence oil flask partly filled with water—boil it and put it by for a few minutes to reduce the temperature—then place it under a receiver of the Air Pump, and a few strokes of the lever will cause it to boil again rapidly. Water, at the surface of the earth, requires a temperature of 212° Fahr. to boil it; whereas by the Air Pump, or on the top of a high mountain, it will boil at 130°. A Thermometrical Barometer has been devised on this principle for measuring the altitude, by observing the temperature at which water boils at different elevations.

Exp. 28.—*Boiling and Freezing at the same time.*—Place under a bell receiver a shallow dish or cup containing a small quantity of sulphuric ether; in this dish of ether, place a thin watch-glass containing water—exhaust the air, and the evaporation of the ether will be so rapid as to produce ebullition; and as it is an axiom in chemistry, that all evaporation is attended with a great absorption of heat, and so much is required, that the ether draws a supply from the water in the watch-glass, it will thus be forced to part with so much of its latent heat, as to leave it not enough to remain a liquid, but change it to ice.

Note.—This experiment must never be performed with a pump for accurate exhaustion, as the vapor of the ether will remain in the piston, leathers and valves for some time.

Exp. 29.—*The Pneumatic Paradox.*—A pleasing experiment is performed by cementing a circular piece of stiff card, 2 or 3 inches diameter, to a piece of quill, a hole being made through the centre of the card to admit the quill: cut a similar piece of card and pass a common pin through the centre and place it on the former; the object of the pin being to project into the quill, and prevent the upper disk from sliding off. Any attempt to blow off the upper card by blowing through the quill, will be unsuccessful, owing to the adhesion produced by the current passing between the discs. This apparatus may be had very neat, of brass.

The foregoing experiments illustrating the pressure of the air, prove that there is a pressure of 15 pounds on every square inch; and if the human body presents a surface of 11 square feet, it must sustain a pressure of more than 20,000 pounds! The reason we are not sensible of this great weight is, we are so constituted by nature, that we are insensible of its power from the effect of habit, and the pressure of the internal fluids *outwards*, is at the surface of the earth, exactly equal to the external pressure *inwards*, thus rendering the forces equal.

Exp. 30.—To illustrate this by experiment: take a square bottle as used in Exp. 16—cork and seal the mouth of it—attach a weight, or otherwise sink it several feet under water. If it is tight, the pressure of water on the sides will break it. But let it be filled with water, and no depth, however great, will be sufficient to crush it while in the fluid; because, as with the body, the internal and external fluids are equal to each other.

EXPANSION OF THE AIR.

When the pressure of the atmosphere is removed by the Air Pump, air exposed to the reduced pressure, expands. To show that it does so, we are obliged to confine or enclose it so that it may not be removed with that which we wish to exhaust.

Exp. 31.—*The Expanded Bladder.*—Enclose a small portion of air in a bladder—tie the neck tight—cover it with a receiver, and as the air is exhausted, the bladder will be distended and entirely filled by the expansion of the small portion of air enclosed.

Exp. 32.—*Expansion of India Rubber.*—The India rubber glass, usually sent for pressure, as in Exp. 13, is a shallow glass vessel, with a brass cap, having a fine screw fitting the inside hole of the stop cocks; if this be attached to a stop cock *shut*, and placed under a receiver, as the air is exhausted from the receiver, that enclosed in the rubber glass will expand, and cause the rubber to swell afterwards, in proportion as the receiver is exhausted.

Exp. 33.—*The Wilted Fruit Restored.*—A shrivelled apple or fig, if the skin is moist and not broken, will, while under an exhausted receiver, appear plump and fresh.

Exp. 34.—*Expanded Bubbles.*—Place some strong white *soap suds* in a shallow dish under a receiver—as the air is removed, the bubbles will expand and exhibit

the prismatic colors—but if they are thus made extremely thin, the colors disappear, and the bubbles are *black.*

Sir Isaac Newton discovered that air or any other transparent substance might be made so inconceivably thin, that it would cease to reflect a single ray of light, and consequently appear black.

Fig. 19.

Exp. 35.—*The Bolt-Head.*—Take the long-necked globe with brass plate, and place it on an open top receiver, as in Fig. 19. Let the neck be immersed in a jar of colored water; and while the receiver is being exhausted, the air will be seen to expand in the globe and escape in bubbles through the water. When the air is again let into the receiver, as it cannot rise into the globe, it will force the colored water in its place, and the exact expansion of the air may be thus determined. In this and other experiments where water is used, it is difficult to be seen unless it is colored, which may very readily be done by the addition of a few drops of red ink.

Exp. 36.—*The Exploded Bottle.*—Take a square bottle, as in Exp. 16, and seal the neck tight—place over it the wire guard and a receiver—exhaust the air, and the air enclosed in the bottle will expand with such force as to break it in pieces. The brass cap usually sent, may be warmed and applied with cement to other bottles. *Wipe the pump-plate.*

Fig. 20.

Exp. 37.—*The Exhausted Egg.*—In the large end of an egg between the skin and the shell, there is a portion of air enclosed; if a small hole be made in the small end of the shell, and the egg placed in a wine glass with the hole down, and held in its position by the sliding rod, as in Fig. 20, the exhausting of the air will cause *that* in the egg to expand, and expel the contents from the shell. If the shell be kept in place when the air is let into the receiver, the egg will return to its former position. It is well to support

the egg on 3 small sticks or pieces of wire, that the contents of the shell may have room to issue. A better way would be, to suspend the egg with a string to the hook, and then raise or lower it as desired.

Exp. 38.—If a glass of warm beer be placed under a receiver, and the air exhausted, the air or gas will expand, and rise in rapid bubbles, causing the beer to foam and run over the glass. If the beer be afterwards tasted, it will be found to have lost its flavor, and become flat.

Fig. 21.

Exp. 39.—*Brass Stand with Weights for Expansion.*—That air expands with force, is shown by placing the cylinder with weights on the piston, as in Fig. 21; as the pressure is removed from the receiver, a small portion of air between the piston and bottom of the cylinder expands, and forces the piston and the weight upon it, to rise. The apparatus may be inverted and suspended by a ring in the base to the sliding hook, when, as the air is exhausted, the weights will sink, and when the air is let in again, they will rise.

Fig. 22.

Exp. 40.—*Stand with Weights for Expansion.*—The mahogany stand with weights resting on a bladder, or an India rubber bag partly filled with air, is placed under a receiver, and a similar experiment performed. This apparatus is rather more simple than the preceding, but more liable to be out of repair, unless India rubber bags are used instead of a bladder.

Exp. 41.—*The Guage for showing the force of Expansion.*—A small glass globe on a foot is mounted with a vertical glass tube, reaching to the bottom of the globe, and extending about 20 inches above it. This tube, by means of a brass cap, is made to screw air tight on the top of the globe. If the globe be half filled with mercury,

the tube screwed in, and placed under the Torricellian receiver, the exact force of the expanded air will be shown by the mercury rising to successive divisions of the tube, as the air is exhausted from the receiver.

Fig. 23.

Exp. 42.—*The Balloon.*—Put the small balloon in a tall jar filled with water—cover it with a receiver—and as the air is exhausted, bubbles of air will rise from the balloon; when the air is admitted, sufficient water should enter the balloon to cause it to sink to the bottom, containing part air and part water. If the pump be then operated, the air will expel the water from the balloon, and it will rise; and if the air is let in, it will sink; and it may be thus lowered or raised at pleasure.

Fig. 24.

Exp. 43.—*The Lungs Glass*—Shows rather imperfectly the effect of a vacuum on the lungs of an animal. In the apparatus, the glass represents the *chest*, and the bladder the *lungs*, which as the air is exhausted, are caused to contract by the expansion of the air contained in the chest. This apparatus will explain the principle quite as well, if not better, than a living animal, upon which it is not generally useful to try the experiment; for as the fact has been satisfactorily proved, it is cruelty to repeat it for mere curiosity, and has a tendency to destroy those feelings in the mind of the pupil which should be cultivated. It *was* necessary, in laying down the principles of the science, that these experiments should be tried, and once proved. It is best to illustrate them, if possible, without pain to any creature. The experiment, as tried by the learned Boyle, one of the first experimenters with the air pump, may be interesting.

He took a newly caught viper, placed it under a small glass receiver, and extracted the air. It first began to swell; a short time after, it gasped and opened its jaws;

then resumed its former lankness, and began to move up and down in the receiver, as if to seek for air. After a while it foamed a little, leaving the foam sticking to the side of the glass; soon after, the body became prodigiously swelled, and a blister appeared on its back. Within an hour and a half the viper moved, being yet alive, though its jaws remained quite stretched, its black tongue reaching beyond its mouth, which had also become black on the inside. It remained thus for three hours. The air was then admitted; the viper's mouth closed, but soon after opened again; and these motions continued for some time, as if there were still some remains of life.

Live fishes put into a jar of water under a receiver, will, as the air is exhausted, rise to the surface, without being able to go down to the bottom—because the air in their air-bladder is expanded against their will, making them specifically lighter than the water. Sometimes the air-bladder breaks, when they sink to the bottom and rise no more. Fishes, frogs, &c., which live in the water, will not die by exhausting the air from the receiver, because they extract the air they respire from the water itself. A whale, however, would be killed as soon as a man, if deprived of the atmospheric air, because it is obliged to rise to the surface at every respiration.

Fig. 25.

Exp. 44.—*Improved Fountain by Expansion.*—Exhaust the vessel for fountain in vacuo (Exp. 15)—screw the pipe into the stop-cock where it was screwed to the pump—half fill the glass globe with water—attach the exhausted fountain glass—open the cock, and the expansion of the air in the globe will force the water, in a beautiful jet, into the fountain glass. This Globe may also be used for the condensed air fountain, instead of the copper air chamber, (Exp. 52,) by removing the vessel for fountain in vacuo, and applying the Condensing Syringe by means of a Brass Connector, and condensing air upon the surface of the water.

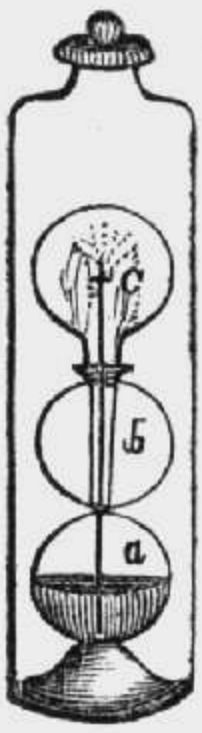
Exp. 45.—*Air in Wood.*—If a block of wood be sunk by a weight in a jar of water under a receiver, as

the air is exhausted, that contained in the pores of the wood will expand and rise in rapid bubbles to the surface. It is the air in the pores of all kinds of wood which causes it to float. Mr. Claxton succeeded in sinking all kinds of wood except cork, by simply cutting a thin slice *across* the *grain* and laying it on the surface of the water.

Exp. 46.—*The Animated Sawdust.*—This is a pleasing experiment, and is thus performed. Put some dry sawdust in a vessel of water, under a receiver—exhaust the air, and when it is re-admitted, many of the particles will sink, having been deprived of the air which rendered them buoyant.

But although sunk, each particle has still a small portion of air left, which will, if the receiver be again exhausted, act as a little balloon, and buoy up the wood like a car to the surface.

Fig. 26.



Exp. 47.—*Transfer of Liquids.*—Half fill the globe *a*, with colored water—put in the brass jet-pipe, and top globe—cover the whole with a tall receiver. As the receiver is exhausted, the two globes, *b* and *c*, are also; and the air in the globe *a* will expand, forcing the liquid through the jet pipe into the globe *b;* and when the air is re-admitted to the receiver, the fluid is forced by the pressure into the globe *c*, to supply the vacuum before made. The liquid is thus transferred from *a* to *b*, by *expansion*, and *b* to *c* by *pressure*.

Fig 27.

Exp. 48.—*Bacchus.*—A Figure is represented on the top of a miniature cask, having two compartments. A portion of colored liquid is put into one, through the screw at the end, (not more than half filled;) when the apparatus is placed under an exhausted receiver, the expansion of the air on the liquid will cause it to ascend a glass tube, leading from the bottom of the cask to the mouth of the figure, and

convey it into the other compartment, which is exhausted (through a small hole) with the receiver, giving the figure the appearance of drinking. When the air is admitted, the liquid returns. To render the experiment more striking, a bladder partly filled with air, is concealed under the loose silk dress, which expands also, and adds to the deception and illustration.

Exp. 49.—*The Mercurial Rod.*—Cut a piece of dry stick even at each end with a sharp knife and sink it in a cup of mercury; as the air is exhausted from the receiver, it will expand and come out of the wood—when the air is re-admitted to the receiver, it forces the mercury into the pores of the wood to possess the place of the air. If the stick be weighed, it will be found much heavier than before, and if cut transversely, the metal will be seen to glitter in every part of it.

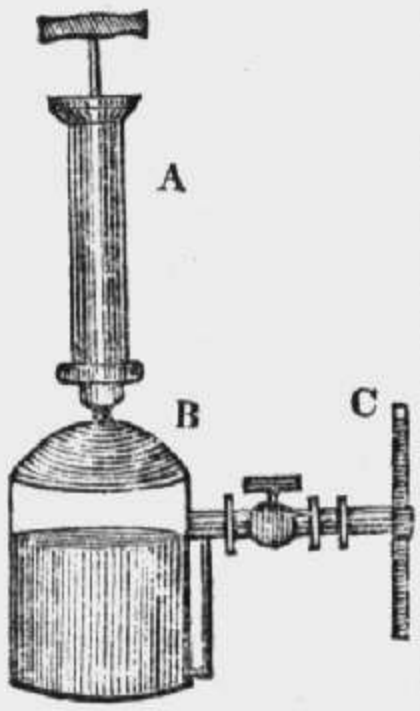
Exp. 50.—*Vegetable Air Bubbles.*—Sink a small branch of a tree with its leaves, or a small plant in a jar of water—cover it with a receiver and exhaust the air. When the pressure of the external *air* is taken off, the spring of that in the *air vessels* of the plant, will cause little silvery bubbles to rise upon the orifices of all the vessels, and produce a beautiful appearance—illustrating the great quantity of air contained in vegetable substances. An apple, a pear, an orange, or any fruit placed under water in a jar, as above, will afford very pleasing appearances.

ELASTICITY OF THE AIR.

This is one of the most singular properties of the air. For however much it may be compressed, even the air contained in a large room, into a nut-shell, yet the instant it is relieved, by its perfect elasticity, it springs to the same bulk as before; and this, too, without any regard to the time it has been confined. No compression has yet

been sufficient to change it to the liquid state as with some of the gases; and nothing in nature has yet been discovered possessing this property in such perfection.

Fig. 28.



Exp. 51.—*The Condensing Syringe.*—The experiments in this branch of the science are usually performed with a Condensing syringe; but as it is frequently convenient to have an Exhausting syringe likewise, as in Exps. 17 and 21, the syringe contrived for this purpose combines the two requisites in one apparatus. At the bottom of the syringe A, is a piece screwed so that either end may be inserted. Upon one end is a valve, and another is on the piston. If it is required to be used as a *condenser*, the *valve* at the *bottom* is to be turned *outwards*, and that end of the piston marked C, to be attached to the piston rod. If as an *exhauster*, the *valve* and *piston* are to be *reversed.*

Exp. 52.—*The Air Chamber.*—Half fill the copper fountain B, Fig. 28, with clean water—to the side-screw attach the stop cock and straight jet from the fountain in vacuo, Fig. 10, and the syringe, as a condenser, to the top. The air may thus be forced in upon the surface of the water, which will, when the cock is opened, be thrown out in a jet 14 or 15 feet. This is a good illustration of the cause of a continuous stream from the pipe of a fire-engine; for without the air chamber, the water would be thrown by jerks, and but a small portion reach its destination.

Exp. 53.—*Revolving Jet, or Barker's Mill.*—Unscrew the straight jet from the stop cock, and attach in its place the Revolving jet C, Fig. 28—condense the air—open the cock, and the action of the water on the arms will cause it to revolve with great rapidity, forming a beautiful vertical wheel of water in the air. This effect was long explained on the principle of the resistance of the air to

the jets on the opposite sides of the arms; but it is now proved to be produced by the force of reaction of water on the sides of the arms, opposite to the jets; for as the water is forced into the tubes, an equal pressure is sustained by all parts, and this pressure being relieved on one side by the jet hole, the arm is caused to revolve in a contrary direction by the pressure against the side of the tube opposite to the jet.

Exp. 54.—*Revolving Jet in Vacuo.*—To prove that the action of the jet is not caused by the *resistance* of the air—screw the jet and stop cock into the pump-plate—cover it with a receiver, and exhaust it—when the air is admitted, it will pass through the jet, which will revolve quite as rapidly where there is *no* air to resist it, as where there is.

Exp. 55.—*The Air Gun.*—A simple illustration is afforded by screwing a brass tube, or the long glass tube, Exp. 14, to the cock of the air chamber, dropping a few peas or shot into the tube and suddenly turning the cock round, by which the condensed air will escape, and the shot be thrown a considerable distance. The air gun, as usually made, differs from a common gun, in having a hollow ball of 3 or 4 inches diameter, into which air is condensed, and then screwed to the lower end of the barrel. This ball or air chamber is charged by a condenser about 2 feet long and three-fourths of an inch diameter—which by a cross handle is forced down upon the piston, held securely by the feet resting upon the handle. When sufficient air has been condensed, the chamber is removed from the syringe and attached to the gun, which is then ready to receive the ball. This is forced into the barrel, surrounded with a small piece of linen to make it fit the bore of the barrel perfectly. In discharging the gun, the force of the lock is directed against a small steel piston, moving through a collar to the valve of the chamber. A portion of air instantly escapes—rushes into the barrel—and drives out the ball. By the construction of the lock, only a certain portion of the air is suffered to escape, so that after once charging the chamber, 40 or 50 balls may be discharged in rapid succession with surprising force.

There is a very common error respecting the report or noise produced by the discharge of an air gun; and those who are ignorant of the principle, suppose that a ball from an air gun is a *silent* messenger of death. This leads to the impression, that the report is something inherent in the gun-powder; but it is not so. The noise is produced by the sudden *expansion* and *collapsing* of the air, and perhaps, in some degree, by the particles being pressed against each other by the passing of the ball through them; and in the air gun is as much in *proportion* to its force as in the powder gun. But the air has never been condensed to more than a *fifteenth* of the force of ignited powder. The noise produced by clapping the hands suddenly together, is a perfect illustration of the principle; and the discharge of the electric fluid, united probably with a combustion of gases in the atmosphere, produces such instantaneous expansion as to cause, by this simple principle, the awful roll of echoing thunder.

It is a curious fact that the air gun, so nearly allied to the air pump in the arrangement of its valves, should have existed so long antecedent to it. For it is recorded than an air gun was made for Henry IV, in 1408, and another preserved in the armory of Schmetau, dated 1474, more than 200 years before the experiment of Guericke. These guns, however, discharged but one ball, after a tedious process of condensation, and thus would not compare with the modern instruments.

Fig. 29.

Exp. 56.—*The little Æronaut.*—This is a glass balloon, having a car and a beautiful little glass figure of a man enclosed in a tall glass jar (filled with proof-spirit to prevent freezing) and the top covered with sheet India rubber. The balloon, when placed in the fluid, is much too light to sink by the pressure, unless it were first balanced, so as just to float at the surface, by introducing portions of the fluid through a small hole at the bottom. If the balloon be prepared in a wide mouth vessel, in which it can readily be tried till the specific gravity is right, there will be but little danger of breaking. When prepared, if the hand is pressed upon the

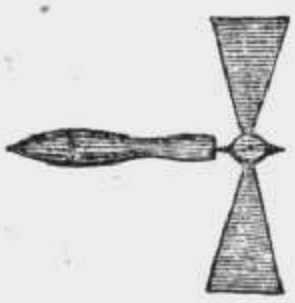
cover, the balloon sinks; because the pressure of the hand is communicated by the air under the elastic cover to the fluid, and by the fluid to the air contained in the balloon, which is thus compressed, and more fluid forced in, which renders the balloon specifically heavier, and it sinks. When the pressure is removed, the elasticity of the air in the balloon drives out the fluid, it becomes of its original gravity, and rises to the surface. If the balloon be prepared in summer, as the weather becomes colder, it will probably sink, and remain at the bottom in consequence of the condensation of the air by the change of temperature. It will operate, however, if carried into a warm room, or it may be taken out and adjusted for the winter, by expelling a little of the fluid from the balloon.

RESISTANCE OF THE AIR.

This is the sixth mechanical property of the air; and the experiments prove, that a body in passing through the air, is resisted in its passage, according as the *surface* presented is *increased*, and the *weight* in proportion to the surface is *decreased*.

Exp. 57.—*The Floating Paper.*—Take a sheet of writing paper and cut it into two pieces of equal size; take one in each hand and let them fall, when, after floating in the air, they will reach the floor at the same time. But if one piece be rolled into a ball, the surface and the resistance is less, and it will fall much more rapidly than the other.

Fig. 30.



Exp. 58.—*The Revolving Fans.*—This is a simple and pleasing apparatus, and consists of two thin metal fans fastened to a brass ball having two centres, so that it may be revolved either flatwise or edgewise; if the broad surface be presented to the air, and they are turned rapidly with

the finger, they will soon stop because of the resistance; but if turned edgewise, the surface is much decreased, and they will, with the same force, revolve much longer. It is upon this principle that windmills, fans, and fan-wheels for drying cotton yarn and other purposes, are constructed. The striking part of a clock is also regulated by a contrivance of this kind.

Fig. 31.

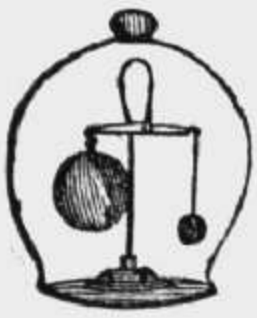
Exp. 59.—*Guinea and Feather Experiment*, (*English form.*)—Upon *each* of the drop stages, place a piece of money and a feather, or piece of light tissue paper. While the air is in the receiver, the money will fall much faster than the feather; but if the air be exhausted, the resistance to the feather will be removed, and they will both fall at the same time. There are two stages to allow of *two* illustrations with *one* exhaustion—and are *not* intended to fall together, with the money on one, and the feather on the other stage, as is erroneously supposed to be the use of the two stages or falls. A little lard should be put on the brass plate before placing it on the top of the receiver. The money and feather should be placed side by side so as not to interfere in their descent.

Fig. 32.

Exp. 60.—*Guinea and Feather Experiment*, (*French form.*)—This form of the experiment differs from the preceding, in having the piece of money and feather enclosed in a long glass tube, fitted at one end with a brass cap and stop cock. The effect is shown by turning the tube before and after exhaustion. The advantage of this arrangement is, that the experiment may be tried a *number* of times with once exhausting; whereas, in the English, the illustrations are limited by the number of drop stages: but on the other hand, the tall receiver of the latter, is very useful for other purposes. The stop cock of this apparatus must not be used for any *wet* experiment, as it may soil the tube.

Exp. 61.—*Guinea and Feather Experiment, (American form.)*—This is a third variety of this experiment; and from its *perfect effect* and *simplicity*, is superior to the foreign forms. Take a piece of money, (suppose a half a dollar) and laying it upon writing paper, cut a piece out exactly the size of the money; then take the paper in one hand and the money in the other, and drop them at the same time—the money will fall to the floor, but the paper will be much longer in its descent. Now take the *paper*, and, placing it *upon* the money, let them fall together—when it will be found that the *two* reach the floor at the same time; because the resistance to the paper, which prevented its falling, is removed by the passage of the coin, which, in fact, forms a vacuum through which the paper descends.

Fig 33.



Exp. 62.—*A pound of Feathers heavier than a pound of Lead.*—This pleasing experiment is upon the principle, that the resistance is in proportion to the surface. For convenience, we use instead of the feathers, a light hollow glass globe, which is counterpoised at one end of a small delicate balance, by a solid lead or brass ball placed at the other end; these are exactly balanced in the air by small rings of card, which may be shipped on at pleasure. Thus balanced, it is to be placed under a receiver, and as the air is exhausted, the glass globe (or feathers) will be seen to descend, appearing to have become heavier. This is however owing to the glass globe having been resisted or buoyed up more by the air than the lead; and therefore, when the support is removed, the glass globe is affected by it in proportion as its surface is greater than the lead ball.

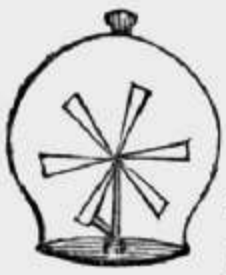
Exp. 63.—*The Water Hammer.*—This consists of a glass tube, partially filled with water, and from which the air has been as perfectly excluded as possible, by boiling the water in the tube, and sealing it while filled with steam. When the steam is condensed, there is a better vacuum in the tube than is usually obtained with the air-

pump; and if the tube be turned over endways, the water falling in the vacuum, and meeting with no resistance, strikes the glass, and itself with a noise as sharp as the concussion of two pieces of glass. In those which are well made, simply turning the tube is sufficient, and rapid shaking would probably break them. This illustrates the effect of rain, were it not for the resistance of the atmosphere; and also the action of water in the tubes of a pump, if attempted to be raised by the pressure of the air more than 32 feet.

With the water hammers of the best kind, another pleasing experiment may be shown. Turn the tube so that the water will fill the bulb at one end—then incline it just sufficient to prevent the water from flowing out. If the other end of the tube be grasped with the warm hands, a little vapor will be produced, and force itself through the water in the bulb, which, being cold, will condense the vapor instantly, and cause a ticking, loud in proportion as the water is colder in the bulb. This effect of the condensation of vapor can only be shown when the tube is of considerable size, and well exhausted.

The water hammer, often used in a warm room, sometimes ceases to operate. It should then be immersed a few moments in some cold water.

Fig. 34.



Exp. 64.—*The Wheel in Vacuo.*—This consists of a wheel with vanes, which is put in motion by a jet at the base. Apply the jet to the mouth, and cause the wheel to revolve as rapidly as possible by blowing; when you cease, note how soon it is stopped by the resistance of the air. Now attach it by the screw to the pump-plate, and covering it with a bulb receiver, exhaust the air as perfectly as possible: open the screw for admitting the air, and let in just sufficient to set the wheel in motion, when it will be noticed to revolve much longer.

Exp. 65.—*The Rocket.*—The common Sky Rocket is a beautiful illustration of this property of resistance. It consists of a cylinder of paper, about six inches long, and

one and a half in diameter, filled with gun-powder, and connected with one end of a stick, three or four feet long, to act as a rudder in preserving its direction. The mouth or open end of the Rocket being lighted, the only exit for the powder is downward, which being resisted by the air as it rushes out, or rather by the reaction, as explained in Exp. 53, causes the tube to ascend, if its weight be not greater than the resistance, and to continue its flight until its power is consumed.

MISCELLANEOUS.

Under this caption will be noticed those experiments not immediately connected with either of the foregoing properties, and which are not so strictly mechanical in their illustration.

Exp. 66.—*The Refraction of the Air.*—Place in the bottom of an earthen bowl a piece of money, or a small earthen figure is better, so that the pupils can just see the top of the head—fill the bowl with water, and the refraction will cause the figure to appear to rise in the water with a very pleasing effect.

Fig. 35.

Exp. 67.—*The Bell in Vacuo.*—If a *perfect* vacuum was produced, and the Bell *perfectly* insulated from all sonorous bodies, there would be no sound. But as this is impracticable, we can only approximate so near as to produce a *vast difference* in vibrations within and out of the receiver. Some of the bells screw directly to the plate of the pump, and ring by a cord attached to the sliding rod, which conducts the vibrations so perfectly, that little or no difference is perceptible. My present form is believed to be as free from these objections as practicable. The base is of wood, resting upon woollen, to insulate it from the plate of the pump. The bell is rung by depressing the

sliding hook upon a pin with a cup on the top, which raises the hammer lever, and then suddenly withdrawing the hook, the hammer falls, and the bell is left to vibrate without any contact with the hook or receiver.

Exp. 68.—*The Taper in Vacuo.*—That air is necessary to combustion, is shown by a taper or candle being extinguished when placed in an exhausted receiver.

Fig. 36.

Exp. 69.—*Flint and Steel in Vacuo*, will not emit sparks, in consequence of the absence of oxygen to support the combustion of the steel. The gun-lock is to be removed from the wood foot and screwed into the pump-plate—it is then arranged so that the sliding hook will depress the lever which acts upon the trigger, and by which it may be fired. When the receiver *is well exhausted*, powder might be placed in the pan of the lock, and it will not be exploded.

Exp. 70.—*Gunpowder in Vacuo.*—I mention this experiment, for which apparatus is provided in most English sets of apparatus, to *caution* lecturers with regard to it; although from the usual arrangement, there is little need, as the current of air produced by exhausting will sufficiently *cool* the red hot iron to prevent the *least danger*. Yet if they do succeed, the gunpowder not exploding, but melting, gives off a very explosive vapor, which, if great care is not taken to exhaust or expel it, *will be liable to explode with dangerous effect.* This experiment might be tried with *great care*, by placing 10 or 12 grains of powder upon the stages of the guinea and feather apparatus, and letting them fall on a hot iron beneath.

Fig. 37.

Exp. 71.—*Apparatus for Freezing of Water.*—This consists of a shallow bell-receiver, under which is placed a watch-glass resting upon a glass support over a shallow dish of *highly concentrated sulphu-*

ric acid, which absorbs the vapor of the water, and causes such an absorption of the latent heat of the water as to cause it to congeal. This experiment depends very much on the skill of the operator and the *strength* of the acid, and will not succeed unless the pump will exhaust at least 99-100ths of the air and retain it.

Fig. 38.

Exp. 72.—*Wollaston's Cryophorus.*—This consists of two glass balls connected by a glass tube, which is bent at right angles near the balls, to suffer them to be immersed in glass tumblers. A portion of water is left in one of the balls, and the air was expelled as much as possible, by boiling, before it was hermetically closed. One of the tumblers should contain a frigorific mixture of salt and snow, and the other empty, and covered with a *hood* of paper. This forms a convenient arrangement for supporting it; and the *air* round the ball in the empty glass being a good non-conductor, the water is frozen in about half the time that it would be otherwise.

Exp. 73.—*Fire in Air.*—This is a brass tube well fitted with a tight piston; in the bottom of the piston is a cavity to hold a small piece of *spunk* or German fungus—or even common dry tinder: the piston is drawn out—the tinder put into the cavity, and then suddenly forced to the bottom of the tube—the whole tube of air is thus compressed into so small a space that the *latent heat* is set free in the same manner that a piece of iron is made hot by hammering—and the tinder is lighted.

THE NEW TRANSFERRING APPARATUS.

The writer has recently added a very useful combined apparatus, which supersedes several expensive articles in the English catalogues. When complete, it consists of two ground plates connected by a stop cock—an open top

bell glass receiver—a small bell glass—a brass cigar tube —a brass cup for pieces of charcoal—a brass candlestick and taper—a brass smoke tube, and a wire to suspend the candle in the mephitic or carbonic air.

Fig. 39.

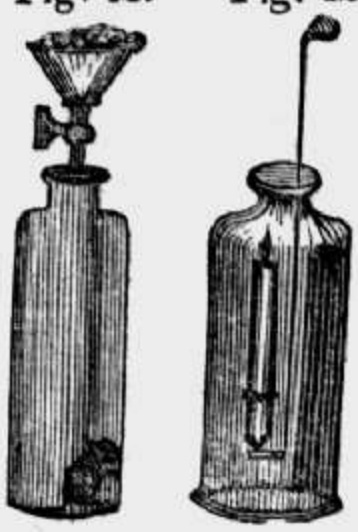
Exp. 74.—*The Double Transferrer.*—Place the open top receiver on the pump, on the top of which put the small plate with the cock *shut*—exhaust the air—put the small receiver on the upper plate—open the cock, and the air will rush into the exhausted receiver, and the small one will, by the transferring of its air, be firmly pressed to the plate; the cock may be shut, and the air let into the large receiver—and the plates with the small receiver attached may be removed.

A variety of pleasing experiments may be performed, such as almost instantly to expand air in a bladder, or soap bubbles—deprive beer of its flavor—extinguish a taper by opening the cock communicating with the exhausted receiver, after they have been placed under the small receiver.

Fig. 40.

Exp. 75.—*Smoke in Vacuo.*—One end of the stop cock attached to the plates, is screwed on the inside, which is adapted for the cigar tube and charcoal cup; arrange the receiver and plates as before; screw in the cigar tube, and with the cock *open*, move the lever of the pump gently, after applying a light to the end of the cigar; the receiver will act as the mouth of a person, and the cigar will be smoked till the receiver is full; the smoke tube should be previously screwed into the pump-plate, that the air may be exhausted from the *top* of the receiver); make *one* or *two* strokes of the pump, which will slightly rarify the air, and the smoke will begin to descend, in a very beautiful manner, until the receiver is not more than half filled—illustrating the cause of smoky chimneys in damp weather.

Fig. 41. Fig. 42.



EXP. 76.—*Carbonic Acid Gas.*—Remove the cigar and the smoke tubes, and put the brass cup in its place—exhaust the receiver, and then place a few live coals of wood in the cup—open the cock, and the air rushing through the fire will be deprived of its oxygen, and carbonic acid gas be produced, which will descend into the receiver. Its specific gravity being greater than the atmosphere, the plates may be removed—and if the taper be unscrewed from its foot, and attached to the wire, and let into the receiver from the top, as Fig. 42, it will be immediately extinguished; or a small animal or insect will be killed if put into it.

It cannot but be observed that the variety and forms of the experiments on the properties of the air, are of the most interesting character. It shows us that to a knowledge of its principles we are indebted for many of our comforts and conveniences. And in conclusion, I cannot forbear to suggest to the teacher, the importance of a frequent *application* of the *principles* of the experiments to their *uses* in common life—and let the illustrations be as simple and yet interesting as possible. From a neglect of this, and of showing how intimately connected are all the sciences, arises the too frequent and selfish question of what *use* are these things to me? It might, in some cases, be sufficient to say that it constituted a part of *knowledge*—that it was one step upward on the ladder which, "though based on earth, ends but in heaven;" and that *one step* is placing man so much farther from the brute creation and nearer his high and glorious destiny. But for others, familiar examples are required—they must

be shown that if principles had not been learned till a direct application to practice required it, we should still have remained in a chaos of mind. A person seeing a small fire balloon rise in the air, asked Dr. Franklin, what benefit the discovery, so trivial, could possibly be—" Stop a while," answered the philosopher, " it is as yet a child—it may become a man ; " and thus it is with simple facts—they may lead to the most important results. In nature and art, are constant examples of the application of the properties of the air. The infant draws its nourishment from the mother's breast—the horse, the ox and the elephant drink—the water is pumped from the well—and the skilful surgeon causes the thick blood to flow, which would otherwise remain in the body with fatal effect, by the application of the known pressure of the air.

And so with windmills and the sails of a ship,—it is the resistance of the air which is employed ; and the surfaces to be exposed, must be proportioned to the power desired to be obtained ; these proportions, a knowledge of the laws of the fluid furnish. We are shown also the great loss of power in machines from this cause, and of the necessity of having every part in quick motion, as smooth and round as possible. Recent experiments by Dr. Lardner, on the Liverpool and Manchester Railroad, have demonstrated, that the resistance of the air to the Locomotive, when moving with great velocity, is so great, that a speed of 40 miles an hour requires such an enormous increase of force, as to amount to a virtual impracticability. I might increase the number of applications almost without limit; but these, with the assistance of those connected with the experiments, will undoubtedly be sufficient for the teacher to apply his *own* illustrations, bearing in mind that to be *useful*, they *must* be *simple*.

APPENDIX.

The Sliding Rod and Plate, as used in Experiments 24, 37, 67 and 69, consists of a ground brass plate, fitting on the top of the open receivers. Through a collar of air tight leathers on top, a polished steel rod slides, on the bottom of which is a hook for suspending the experiment in the receiver. On the sliding rod above the plate is a small clamp, with a tightening screw, by which it can be fixed on any part of the rod, to prevent the weight of the suspended body from drawing the rod through. The use of the clamp is shown in Fig. 16. If the air leaks by the rod, it may be stopped by screwing down the cap confining the collar of leathers.

Brass Connectors.—The kind mentioned in Experiments 5 and 44, is drilled and screwed on the *inside*, for the purpose of connecting two similar screws of stop cocks together. This is the most common form, although there are a variety of forms used to connect different parts of apparatus.

Names of Glass Receivers for Air Pumps.

Knob Bell Receiver, ...	Fig. 11.
Knob Bulb Receiver, ...	Fig. 33.
Tall Knob Bell Receiver, ...	Fig. 23.
Open Top Bell Receiver, ...	Fig. 16.
Open Top Bulb Receiver, ...	Fig. 17.
Tall Open Top Bell Receiver, . .	Fig. 14.

Open top Receivers are always accompanied with a flat Glass Plate, of sufficient size to close the top, and prevent the necessity of having a variety of Receivers, with close and open tops, of the same size. *One* Plate is sufficient for all the Receivers.