pendently in 1482, just ten years before his discovery of America. The first known work for the use of seamen was written during the reign of Queen Elizabeth. It was entitled "A Discourse on the Variation of the Cumpas or Magneticall Needle," and is dedicated to "the travaillers, sea-men, and mariners of England." The dip was discovered accidentally in 1576 by Robert Norman, an English instrument-maker. He found the dip at London to be 71° 50′. Dr. Gilbert, the physician of Queen Elizabeth, published his great work, "De Magnete," about 1600. In this he announces his belief that the earth is a great magnet, controlling the direction of the needle. The variation in intensity of the earth's magnetic force has become known chiefly during the present century.

X.

ELECTRICITY.

"THAT power which, like a potent spirit, guides
The sea-wide wanderers over distant tides,
Inspiring confidence where'er they roam,
By indicating still the pathway home;—
Through Nature, quickened by the solar beam,
Invests each atom with a force supreme,
Directs the cavern'd crystal in its birth,
And frames the mightiest mountains of the earth,
Each leaf and flower by its strong law restrains,
And binds the monarch Man within its mystic chains."

HUNT

ANALYSIS OF ELECTRICITY.

ELECTRICITY.

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ELECTRICITY.

One's hair often crackles under a gutta-percha comb. Stroke a cat's back in a dark, dry room; the crackling will be heard and little sparks will be seen.* Touch together the two wires of a common battery-cell and then separate them; a minute snap will be heard and a spark seen. The same may be noticed when a small "dynamo" in motion is substituted for the battery. A magnetic needle quickly shows that the dynamo is in the midst of a field of magnetic force.

The effects observed are due to electricity. We know not with certainty what is its nature, but we recognize it by its effects. According to the mode of production and the nature of the effects, the discussion of it may be conveniently divided.

Frictional electricity is the name given to that obtained directly or indirectly by friction, as with the cat's back. Voltaic electricity is that produced from a battery. Electricity may be *transformed* into various other modes of energy.

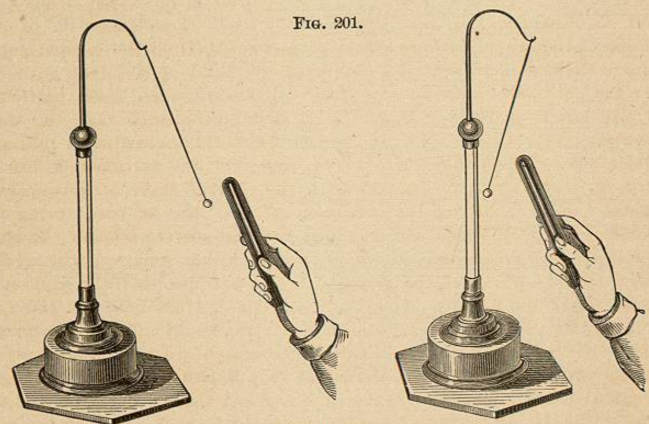
* In cold, frosty weather, a person, by shuffling about in his stocking-feet upon the carpet, can develop so much electricity in his body that he can ignite a jet of gas by simply applying his finger to it.—Blasts in mines intended to be fired by electricity have thus been prematurely discharged by the workmen touching the wires. To prevent this disastrous effect, at the Sutro Tunnel, Nevada City, the workmen who are handling exploders wet their boots, stand on an iron plate to conduct off the electricity of the body, and wear rubber gloves.

I. FRICTIONAL ELECTRICITY.

1. Electricity may be developed by friction. There are more delicate modes of detecting it than those just described. Any instrument adapted to this purpose is called an electroscope.

2. The Electroscope.—Bend a glass tube and suspend from it by silk threads an elder-pith ball, as shown in Fig. 201; or put an egg in a wine-glass,

Fig. 201.



Electroscopes.

and balance on the egg a dry lath. Each may serve as an electroscope. A very convenient one is a straw suspended by a silk thread at the middle so as to hang horizontally.

3. Electrical Attraction and Repulsion.—If a warm dry glass, such as a lamp-chimney, be rubbed with a silk handkerchief, a crackling sound will be heard.

If the tube be held near the face, a sensation like that of touching cobwebs will be felt. The tube will attract bits of paper, straw, feathers, etc.* Present

* The following simple experiments are instructive:—1. A rubber comb passed a few times through the hair will furnish enough electricity to turn the lath entirely around, and empty egg-shells, paper hoops, etc., will follow the comb over the table in the liveliest way.—2. Take a thin sheet of gutta-percha, about a foot square; lay it upon the table, and rub it briskly a few times with an old fur cuff; the gutta-percha will become powerfully electrified.—3. Lift the gutta-percha by one corner, and some force will be required to separate it from the table.—4. Hold the electrified gutta-percha in the left hand; bring the fingers of the right near the paper; it will be attracted to the hand, and sparks will pass to the fingers with a snapping sound.—5. Hold some feathers, suspended by a silk thread, near the excited gutta-percha, and the feathers will be attracted.—6. Hold the excited paper, or the excited sheet of gutta-percha, over the head of a person with dry hair; the hair will be attracted by the gutta-percha, and each particular hair will stand on end.—7. Hold the excited gutta-percha near the wall; the gutta-percha will fly to it, and remain some minutes without falling.—8. Place a sheet of gutta-percha on a tea-tray; rub the gutta-percha briskly with a fur cuff; place the tea-tray with the excited sheet of gutta-percha on a dry tumbler; lift off the gutta-percha from the tea-tray; bring the knuckle of your hand near the tray, and you will receive a spark. Replace the gutta-percha on the tray and apply your knuckle, and you will receive another spark. This may be repeated a dozen times.—9. Take a sheet of foolscap paper and a board about the same size. Heat both till they are thoroughly dry. While hot, lay the paper on the board and rub the former briskly with a piece of rubber. The paper and board will cling together. Tear the paper loose and try experiments 4, 5, 6, and 7. Return the paper and rub as before. Cut the paper so as to form a tassel. Then lift, and the strips of the tassel will repel one another.—10. Take a piece of common brown paper, about the size of an octavo book, hold it before the fire till quite dry and hot, then draw it briskly under the arm several times, so as to rub it on both sides at once by the coat. The paper will be found so powerfully electrical, that if placed against a wainscoted or papered wall of a room, it will remain there for some minutes without falling.—11. While the paper still clings to the wall hold against it a light, fleecy feather, and it will be attracted to the paper in the same way the paper is to the wall.—12. If the paper be warmed, drawn under the arm as before, and then hung up by a thread attached to one corner, it will sustain several feathers on each side; should these fall off from different sides at the same time, they will cling together very strongly; and if after a minute they are all shaken off, they will fly to one another in a singular manner.—13. Warm and excite the paper as before, and then lay on it a ball of elder-pith,

it to the pith ball of an electroscrope. This will be attracted till it touches, and then fly off. The end of the suspended straw will likewise be first attracted, but then repelled just after it is touched. Grasp the pith ball or straw for a moment. It will no longer be repelled. Rub a stick of sealing-wax with a woolen cloth or some fur. The behavior of the pith ball or straw toward it will be the same as toward the glass. But bring the rubbed sealing-wax near to the pith ball or straw that is repelled by the rubbed glass; there will be attraction instead of repulsion. If the excited glass be held on one side of a ball and the

about the size of a pea; the ball will immediately roll across the paper, and if a needle be pointed toward it, it will again roll to another part, and so on for a considerable time.—14. Support a pane of glass, well dried and warmed, upon two books, one at each end, and place some bran underneath; then rub the upper side of the glass with a silk handkerchief, or a piece of flannel, and the bran will dance up and down like the images in Fig. 208. —15. Place a common tea-tray on a dry, clean tumbler. Then take a sheet of foolscap writing-paper (as in No. 9) and dry it carefully until all its hygrometric moisture is expelled. Holding one end of the sheet on a table with the finger and thumb, rub the paper with a large piece of India rubber a dozen times vigorously from left to right, beginning at the top. Now take up the sheet by two of the corners and bring it over the tray, and it will fall like a stone. This, as well as the apparatus in No. 8, forms a simple *Electrophorus*, fit to perform many experiments ordinarily performed with that instrument. If the tip of a finger be held close to the bottom of the tray, a sensible shock will be felt. Next, lay a needle on the tray with its point projecting outward, remove the paper, and, in the dark, a star sign of the negative electricity will be seen; return the paper, and the positive brush will appear. Lay a dry, hot board, as in No. 9, on top of four tumblers. If a boy stand on the board he will be insulated, and on his holding the tray vertically, the paper will not fall. Sparks may then be drawn from his body, and his hair will be electrified.—16. Warm a lamp-chimney, rub it with a hot flannel, and then bring a downy feather near it. On the first moment of contact, the feather will adhere to the glass, but soon after will fly rapidly away, and you may drive it about the room by holding the glass between it and the surrounding objects; should it, however, come in contact with any thing not under the influence of electricity, it will instantly fly back to the glass.

excited wax on the other, it will fly between the two, touching each in succession alternately. From this we conclude that (1), there are *two kinds of manifestation of frictional electricity;* and (2), *like kinds are manifested by repulsion, and unlike by attraction.* The electricity from the glass is termed positive [+], and that from the wax, negative [—].*

4. Theory of Electricity.—It is thought that positive and negative electricity exist in every body, in a state of total or partial equilibrium. When this is disturbed, as by friction, electrical separation follows, and each kind becomes manifested, just as in the polarization of a magnet, if the proper conditions are observed. Electricity is not a fluid, as was long taught. It may be a condition of strain among the molecules of a body, capable of being communicated like a fluid. We know only its laws, and not its nature.

5. Electric Potential.—A body electrically excited by friction or otherwise is said to be *charged.* The charge may be either positive or negative, strong or weak. If two bodies equally and oppositely charged are put into contact, the charge of each is neutralized by that of the other. A body strongly charged positively is said to be at high potential; if nega-

* In the following list, each substance becomes positively electrified when rubbed with the body following it; but negatively, with the one preceding it.—Ganot.

1. Cat's fur.	5. Cotton.	9. Shellac.	13. Caoutchouc.
2. Flannel.	6. Silk.	10. Resin.	14. Gutta-percha.
3. Ivory.	7. The hand.	11. The metals.	15. Gun-cotton.
4. Glass.	8. Wood.	12. Sulphur.	

tively, at low potential; when discharged, at zero potential. The surface of the earth is electrically at zero.

6. Conductors and Insulators.—A body which allows electricity to pass through it freely is termed a *conductor;* one which does not, is called a *bad conductor*, or *insulator*. Copper is one of the best conductors, and hence it is used in many electrical experiments. Glass is one of the best insulators. A body is said to be insulated when it is supported by some bad conductor, which is generally glass or vulcanite. A body can be highly charged only when insulated. In damp air electricity is quickly dissipated. This is due to the deposit, on the glass insulators, of a thin film of moisture, which conducts away the electricity. For success in electrical experiments, therefore, it is important to keep the air dry and warm, since dry air is one of the best of insulators.*

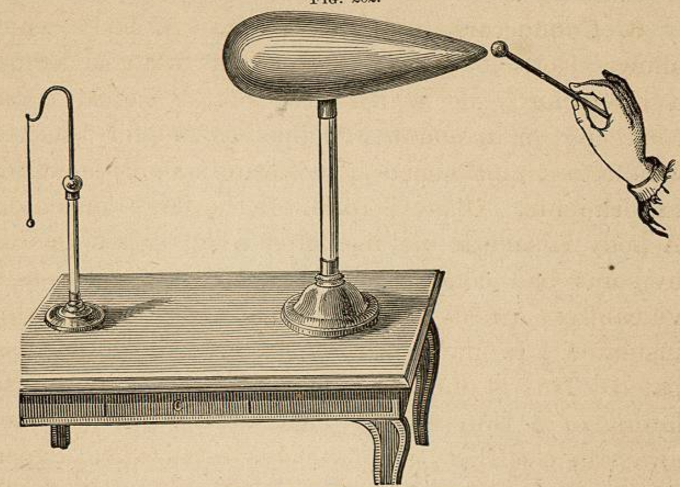
7. Distribution of Electricity on Bodies.—A charge communicated to one part of an insulator is not spread over its whole surface; but when a good conductor is charged at any point the spread is instantaneous. It spreads, however, *only* on the surface, and

* The following list contains some of the most common conductors and insulators:

Conductors.		*Insulators.*	
Metals.	Vegetables.	Dry Air.	Glass.
Charcoal.	Animals.	Shellac.	Silk.
Flame.	Linen.	Amber.	Dry Paper.
Minerals.	Cotton.	Sulphur.	Caoutchouc.
Acids.	Dry Wood.	Wax.	
Water.	Ice.		

not through the interior. A pith ball, if made to touch the outside of an electrified metal cup or hol-

Fig. 202.

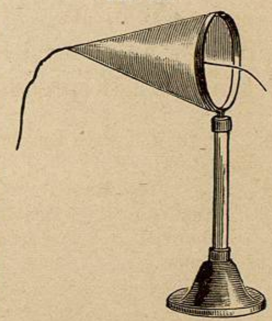


Variation in Electric Density.

low ball, is strongly repelled; but on the interior there is no such effect.* If the ball is spherical, the

* Faraday once made a hollow cube of wood, measuring 12 ft. each way and covered with tin-foil. Insulating this, he charged it with a powerful machine until sparks darted off from every corner on the outside. Going within this little room with his most delicate electroscopes, he could not detect the least effect upon them. He made a conical bag of linen, and fastened its open end to an insulated ring. Pulling it out with a silken cord, he electrified it. The charge was manifest on the outside, zero on the inside. Reversing the pull so as to turn it inside out, the new exterior was found to be charged. A half-minute previously it had been a neutral interior. The student should try this interesting experiment, using the most delicate electroscope that he can make.

Fig. 203.

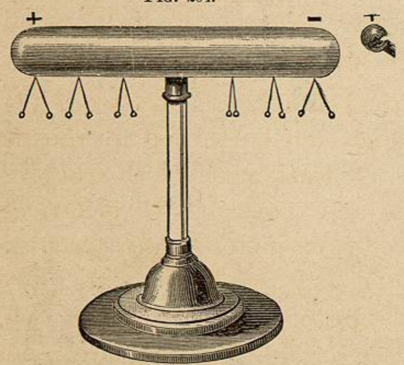


Faraday's Conical Bag.

amount of electricity at all points of its surface is the same; or, we may say that the *electric density* is uniform over its surface. On a cylinder the electric density is greatest at the ends. If one end is blunt and the other sharp, the density at the sharp end becomes so great that the neighboring air molecules are quickly electrified by contact and instantly repelled. Others in turn are successively repelled, and the body is soon discharged. Electricity thus escapes rapidly from jutting points.*

8. Electrical Induction.—Let an insulated conductor, Fig. 204, be brought near another conductor that has been strongly charged positively, and let a series of pairs of pith balls be suspended from the first. The motion of the balls shows that the ends of the insulated conductor are electrically excited, while the middle is neutral. The end nearest the charged conductor is excited negatively and the remote end positively. If the charged conductor be removed, all of the pith balls collapse. Place several insulated

FIG. 204.

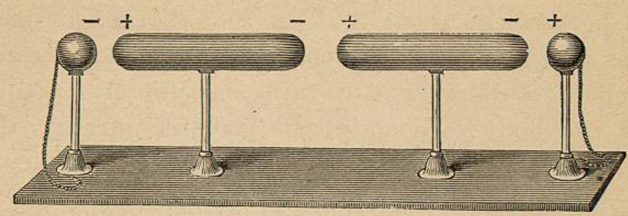


Electrical Induction.

* The *electric whirl*, mounted on the prime conductor of an electrical machine, illustrates this action. As each molecule of air is repelled from a point, it reacts with equal force against the point. This is sufficient to set the light wire-wheel in rapid rotation.

conductors, as shown in Fig. 205, the balls being strongly charged, that at the right positively, and that at the left negatively. Each intermediate conductor becomes excited, as indicated, and becomes

FIG. 205.



Electrical Induction.

neutral when the balls are discharged. It has been *polarized by induction*, like a magnetic body when brought into the field of a magnet pole.*

9. The Plate Electrical Machine consists of (1) a circular glass *plate* which can be turned by means of a crank; (2) a pair of leather or cloth *rubbers* pressed against the plate and covered with electrical amalgam or tin dioxide; † (3) a metallic *comb* or fork with sharp points which nearly touch the plate; (4) a *prime conductor*, consisting of a rounded brass cylinder, insulated by resting on a glass standard, and connected at one end with the comb. Frequently

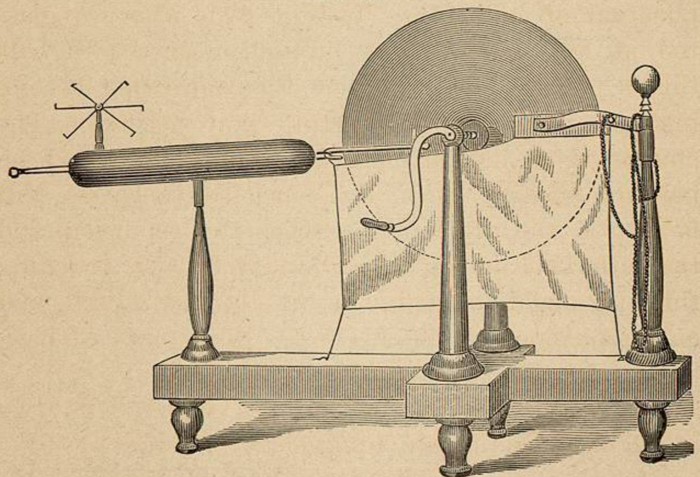
* The experiment in Fig. 204 can be nicely performed by means of an egg covered with tin-foil and placed flatwise on the top of a dry wine-glass and the glass tube represented in Fig. 201. Several eggs and glasses will show the principle of Fig. 205. See Tyndall's "Lessons on Electricity," p. 39.

† Electrical amalgam is a mixture of tin, zinc, and mercury. By experience it has been found that, when this is rubbed on glass, electrical separation is most easily effected. Tin dioxide is often called "mosaic gold," because of its metallic yellow color. It is used in bronzing.

the lower half of the plate is made to revolve between a pair of silken flaps (Fig. 206). A chain is usually attached to the knob in connection with the comb, and connects this with the ground through the medium of a gas-pipe or other conductor.

On turning the crank, the friction of the plate against the rubbers produces electrical separation;

FIG. 206.



The Plate Electrical Machine.

the rubbers becoming charged negatively, the plate positively. The negative charge is conducted off to the earth by the chain, which thus restores the rubbers to zero potential. The positive charge on the plate, when this is brought opposite the comb, polarizes the prime conductor and comb by induction. Positive electricity becomes manifested on the remote conductor, and negative electricity at the comb

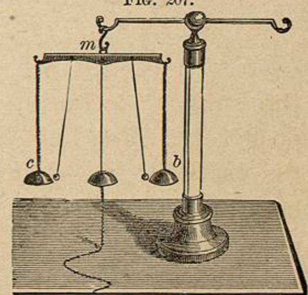
is communicated at once by the sharp points to the air, whose molecules are repelled into contact with the plate, thus neutralizing its positive charge. The prime conductor is hence left charged to high potential.

The action of the plate machine is thus an application of both friction and induction.

10. The Theory of Attraction is likewise an application of induction. In Fig. 201, where a glass rod at high potential is brought near a pith ball, this is polarized by induction, the nearer half becoming negative, and the remote half positive. The charge on the rod attracts the negative half and repels the positive half. But since the negative half is nearer, the attraction exceeds the repulsion, and the pith ball moves toward the rod. On touching this the negative charge is wholly neutralized, and only repulsion can be effective. Every case of electrical attraction is thus a case of induction.

The *electric chime* consists of three bells, two of which, *c* and *b*, are hung by brass chains, while the middle one is insulated above by a silk cord, and connected below with the earth by a chain. The balls between them are also insulated. The outer bells becoming charged with positive electricity from the prime conductor of an electrical machine, polarize the balls by induction

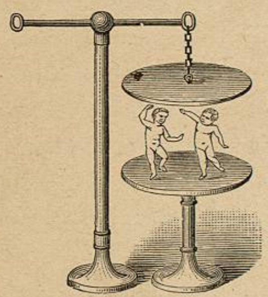
FIG. 207.



Electric Chimes.

through the intervening air. The balls being then attracted to the bells, are charged and immediately repelled. Swinging away, they strike against the middle bell, discharging their electricity, and are forthwith attracted again. Flying to and fro, they ring out a merry song.

Fig. 208.



Dancing Images.

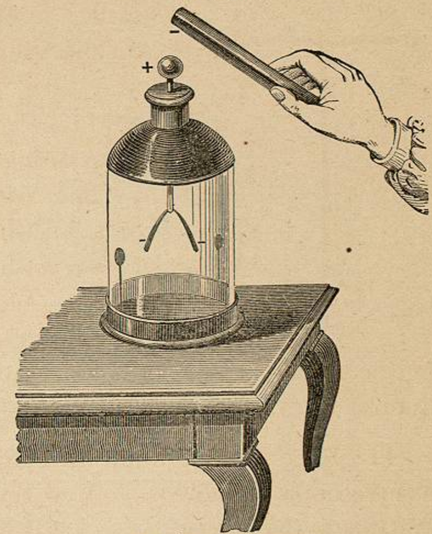
The *dancing image* consists of a pith-ball figure placed between two metallic plates, the upper one hanging from the prime conductor, and the lower one connected with the earth. The dance is conducted by alternate attraction and repulsion.*

11. Free and Bound Electricity.—The gold-leaf electroscope is more sensitive than one of pith balls. Within a dry glass jar a pair of strips of gold-leaf are suspended from a metal rod terminating at the top in a knob or plate. If a rod, excited for example negatively, be brought near the knob, then by induction this becomes charged positively while both leaves are charged negatively, and hence repel each other. By placing the finger on the knob and withdrawing it while the rod is still near, the leaves collapse. Their negative charge has been conducted off to the earth. But on withdrawing now the rod, they diverge again and remain apart. The positive charge

* A slow motion should be given to the electrical wheel, and a pin thrust into the heel of the image will add much to the stamp of the tiny feet.

on the knob was "*bound*" there by the presence of the negatively excited rod and could not be conducted away, like the negative charge on the leaves. On removing the rod after the finger has been taken away the positive charge becomes "*free*"; it is distributed over knob and leaves, and these now repel each other with a positive charge. So long as a charge is "bound," it fails to manifest itself; its energy is potential, and becomes kinetic only when freed by the removal of the inducing body.

Fig. 209.



Gold-leaf Electroscope.

12. Inductive Capacity.—A body through which induction occurs is called a *dielectric*. Air is a good dielectric, but when two oppositely charged bodies are brought near enough together in air, each charge binding the other strongly, the intervening molecules soon attain their limit of polarization, and a spark passes, announcing that the opposite charges have become neutralized through the dielectric. Glass is a far better dielectric than air.

13. Electrical Condensation.—By putting a good