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1491 Hoboken N. J.
June 24th 1878

The following letter was written in answer to one which I addressed to Prof. Henry asking him to give me an account of his researches while connected with the College of New Jersey, for my use in preparing an article on Princeton & Science, & it is now placed by me in the College Library at Princeton

S. B. Dod

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My dear Sir:

In compliance with your request that I would give an account of my scientific researches during my connection with the College of New Jersey, I furnish the following brief statement of my labors within the period mentioned.

I Previous to my call from the Albany Academy to a Professorship in the College of New Jersey I had made a series of researches on electro-magnetism in which I developed the principles of the electro magnet and the means of accumulating the magnetic power to a great extent. And had also applied this power in the invention of the first electro magnetic machine, that is, a mechanical contrivance by which electro-magnetism was applied as a motive power. I saw, however, that the application of this power was but an indirect method of

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employing the energy derived from the combustion of coal, and therefore could never compete on the score of expense with that agent as a means of propelling machinery, but that it might be used in some cases in which expense of power was not a consideration to be weighed against the value of certain objects to be attained. A great amount of labor has since been devoted to this invention, especially at the expense of the Government of the United States by the late Dr. Page, but it still remains in nearly the same condition it was left in by myself in 1831.

I also applied while in Albany the results of my experiments to the invention of the first electro-magnetic telegraph, in which signals were transmitted by exciting an electro-magnet at a distance, by which means dots might be made on paper and bells

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were struck in succession, indicating letters of the alphabet.

In the midst of these investigations I was called to Princeton through the nomination of Dr. Jacob Green, then of Philadelphia, and Dr. John Torrey of New York. I arrived in Princeton in November 1832 and as soon as I became fully settled in the chair which I occupied, I recommenced my investigations, constructed a still more powerful electro-magnet than I had made before, one which would sustain over 3000 lbs. and with it illustrated to my class the manner in which a large amount of power might by means of a relay magnet be called into operation at the distance of many miles. I also made several modifications in the electro-magnetic machine before mentioned, and just previous to my leaving for England in 1837, again turned my attention to the telegraph.

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I think the first actual line of telegraph using the earth as a conductor was made in the beginning of 1836. A wire was extended across the front campus of the College grounde from the upper story of the library building to the Philosophical Hall on the opposite side, the ends terminating in two wells. Through this wire signals were sent from time to time from my house to my laboratory.

The electro-magnetic telegraph was first invented by me in Albany in 1830. Prof. Morse according to his statements conceived the idea of an electro magnetic telegraph in his voyage across the ocean in 1832 but did not until several years afterwards 1837 attempt to carry his ideas into practice, and when he did so he found himself so little acquainted with the subject of electricity that he could not make his simple machine operate through the distance of a few yards. In

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this dilemma he called in the aid of Dr. Gale who was well acquainted with what I had done in Albany and Princeton having visited me at the latter place. He informed Prof. Morse that he had not the right kind of a battery nor the right kind of magnets whereupon the Professor turned the matter over to him and with the knowledge he had obtained from my researches he was enabled to make the instrument work through a distance of several miles.

For this service Prof. Morse gave him a share of his patent, which he afterwards purchased from him for $5500.

At the time of making my original experiments on electro-magnetism in Albany I was urged by a friend to take out a patent both for its application to machinery and to the telegraph but this I declined on the ground that I did not then consider it compatible

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with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual. In this perhaps I was too fastidious.

In briefly stating my claims to the invention of the electro-magnetic telegraph I may say I was the first to bring the electro-magnet into the condition necessary to its use in telegraphy and also to point out its application to the telegraph and to illustrate this by constructing a working telegraph and had I taken out a patent for my labors at that time Mr. Morse could have had no ground on which to found his claims for a patent for his invention. To Mr Morse however great credit is due for his alphabet and for his perseverance in bringing the telegraph into practical use.

My next investigation after being

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settled at Princeton was in relation to electro-dynamic induction. Mr. Faraday had discovered that when a current of Galvanic electricity was passed through a wire from a battery a current in an opposite direction was induced in a wire arranged parallel to this conductor. I discovered that an induction of a similar kind took place in the primary conducting wire itself, so that a current which in its passage through a short wire conductor would neither produce sparks nor shocks, would, if the wire were sufficiently long, produce both these phenomena. The effect was most strikingly exhibited when the conductor was a flat ribbon covered with silk rolled into the form of a helix. With this brilliant deflagrations and other electrical effects of high intensity were produced by means of a current from a battery of low intensity such as that of a

single element.

III A series of investigations was afterwards made which resulted in producing inductive currents of different orders, having different directions, made up of waves alternately in opposite directions. It was also discovered that a plate of metal of any kind introduced between two conductors neutralized this induction, and this effect was afterwards found to result from a current in the plate itself. It was afterwards shown that a current of quantity was capable of producing a current of intensity, and vice versa, a current of intensity would produce one of quantity.

IV Another series of investigations of a parallel character was made in regard to ordinary or frictional electricity. In the course of these it was shown that electro-dynamic inductive action of ordinary electricity was of a peculiar

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character and that effects could be produced by it at a remarkable distance. For example, if a shock were sent through a wire on the outside of of a building, electrical effects could be exhibited in a parallel wire within the building. As another illustration of the it may be mentioned that when a discharge of a battery of several Leyden jars was sent through the wire before mentioned, stretched across the campus in front of Nassau Hall, an inductive effect was produced in a parallel wire the ends of which terminated in the plate of metal in the ground in the back campus at a distance of several hundred feet from the primary current, the building of Nassau Hall intervening. The effect produced consisted in the Magnetization of steel needles.

In this series of investigations the fact was discovered that the induced

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current as indicated by the needles appeared to change its direction with the distance of the two wires, and other conditions of the experiment - the cause of which for a long time baffled inquiry but was finally satisfactorily explained by the discovery that the discharge of electricity from a Leyden Jar is of an oscillatory character, a principal discharge taking place in one direction and immediately afterwards a rebound in the opposite and so on forward and backward until the equilibrium is obtained.

V. The next series of investigations related to atmospheric induction. The first of these consisted of experiments with two large kites, the lower end of the string of one being attached to the upper surface of a second kite, the string of each consisting of a fine wire the terminal end of the whole being coiled around an insulated drum. I was assisted in these experiments by Mr Brown of Philadelphia who furnished the kites. When they were elevated at a time when the sky was perfectly

clear, sparks were drawn of surprising intensity and pungency, the electricity being supplied from the air and the intensity being attributed to the induction of the long wire on itself.

VI. The next series of experiments pertaining to the same class was on the induction from thunder clouds. For this purpose the tin covering of the roof of the house in which I resided was used as an inductive plate. A wire was soldered to the edge of the roof near the gutter, was passed into my study and out again through holes in the window-sash and terminated in connection with a plate of metal in a deep well immediately in front of the house. By breaking the continuity of that part of the wire which was in the study, and introducing into the opening a magnetising spiral, needles placed in this could be magnetised by a flash of lightning so distant that the thunder could scarcely be heard. The electrical disturbance produced in this

case was also found to be of an oscillatory character, a discharge first passing through the wire from the roof to the well, then another in the opposite direction, and so on until equilibrium was restored. This result was arrived at in this case as well as in that of the Leyden Jar before mentioned by placing the same or a similar needle in succession in spirals of greater and greater numbers of turns; for example, in a spiral of a single turn, the needle would be magnetised plus or in the direction due to the first and more powerful wave. By increasing the number of coils the action of the second wave became dominant so that it would more than neutralize the magnetism produced by the first wave and leave the needle minus. By farther increasing the number of turns the third wave would be so exalted as to neutralize the effects of the preceding two, and so on. In the case of induction by lightning the same result was obtained by placing a num

ber of magnetizing spirals of different magnetizing intensities in the opening of the primary conductor, the result of which was to produce the magnetization of an equal number of needles plus and minus indicating alternate currents in opposite directions.

VII On connection with this class of investigations a series of experiments was made in regard to lightning rods. It was found that when a quantity of electricity was thrown upon a rod the lower end of which was connected with a plate of metal sunk in the water of a deep well, that the electricity did not descend silently into water, but that sparks could be drawn from every part of the rod sufficiently intense to explode an electrical pistol and to set fire to delicate inflammable substances. The spark thus given off was found to be of a peculiar character, for while it

produced combustion, it gave a slight shock, and fired the electrical pistol it scarcely, at all, affected a gold leaf electroscope. Indeed it consisted of two sparks, one from the conductor and the other to it, in such quick succession that the rupture of the air by the first, served for the path of the second. The conclusion arrived at was that during the passage of the electricity down the rod, each point in succession received a charge analogous to the statical charge of a prime conductor, and that this charge in its passage down the rod was immediately preceded by a negative charge the two in their passage past the point at which the spark was drawn giving rise to its duplex character.

It was also shown by a series of experiments in transmitting a powerful discharge through a portion of air, that the latter, along the path of discharge

was endowed for a moment with an intense repulsive energy. So great is this that in one instance when an electrical discharge from the clouds passed between two chimneys through the cockloft of a house the whole roof was lifted from the walls. It is to this repulsive energy or tendency in air to expand at right angles to the path of a stroke of lightning that the mechanical effects which accompany the latter are generally to be attributed.

In connection with this series of investigations an experiment was devised for exhibiting the screening effect within a space enclosed with a metallic envelope of an external discharge of electricity. It consisted in coating the outside of a hollow glass globe with tin foil and afterwards inserting through a small hole in the side a delicate gold leaf electrometer. The latter being observed through a small

opening in the tinfoil was found to be unaffected by a discharge of electricity passed over the outside coating.

VIII Another series of investigations was on the phosphorogenic emanation from the sun. It had long been known that when the diamond is exposed to the direct rays of the sun, and then removed to a dark place, it emits a pale blue light which has received the name of phosphorescence. This effect is not peculiar to the diamond but is possessed by a number of substances, of which the sulphuret of lime is the most prominent. It is also well known that phosphorescence is produced by exposing the substance to the electric discharge. Another fact was discovered by Becquerel of the French Institute that the agent exciting phosphorescence traversed with difficulty a plate of glass or mica while it is transmitted apparently with

out impediment through plates of black quartz impervious to light.

My experiments consisted in the first place in the reproduction of these results and afterwards in the extension of the list of substances which possess the capability of exhibiting phosphorescence, as well as the effects of different interposed media.

It was found that among a large number of transparent solids some were permeable to the phosphorescing agent and others impermeable, or imperfectly permeable. Among the former were ice, quartz, common salt, alum. Among the latter glass, mica, tourmaline, camphor &c. Among liquid permeable substances were water, solutions of alum, ammonia, while among the impermeable liquids were most of the acids, sulphate of zinc, sulphate of lead, alcohol &c.

It was found that the emanation took place from every point of the line

of the electric discharge, but with more intensity from the two extremities, and also that the emanation producing phosphorescence whatever be its nature, when reflected from a mirror obeys the laws of the reflection of light; but no reflection was obtained from a surface of polished glass. It is likewise refracted by a prism of rock salt in accordance with the laws of the refraction of light. By transmitting the rays from an electric spark through a series of very thin plates of mica it was shown that the emanation was capable of polarization and consequently of double refraction.

X The next series of investigations was on a method of determining the velocity of projectiles. The plan proposed for this purpose consisted in the application of the instantaneous transmission of the electrical action to determine the time of the passage of the ball between two screens

placed at a short distance from each other in the path of the projectile. For this purpose, the observer is provided with a revolving cylinder moving by clockwork at a uniform rate, and of which the convex surface is divided into equal parts indicating a fractional part of a second. The passage of the ball through the screen breaks a galvanic circuit the time of which is indicated on the revolving cylinder by the terminal spark produced in a wire surrounding a bundle of iron wires. Since the publication of this invention various other plans ~~founded~~ on the same principle have been introduced into practice.

X Another series of experiments was in regard to the relative heat of different parts of the sun's disc and especially to that of the spots on the surface. These were made in connection with Prof. S. Alexander and consisted in throwing an image of

the sun on a screen in a dark room by drawing out the eye piece of a telescope. Through a hole in the screen the end of a sensitive thermopile was projected, the wires of which were connected with a galvanometer. By slightly moving the smaller end of the telescope different parts of the image of the sun could be thrown on the end of the thermopile and by the deviation of the needle of the galvanometer the variation of the heat was indicated. In this way it was proved that the spots radiated less heat than the adjacent parts and that all parts of the sun's surface did not give off an equal amount of heat.

XI. Another series of experiments was made with what was called a thermal telescope. This instrument consisted of a long hollow cone of pasteboard lined with silver leaf and painted outside with lamp black. The angle at the apex of the cone was such as to cause all the parallel rays from a distant object entering the larger end of the cone to be reflected on to the end of a thermo-pile the poles of which were connected with a delicate galvanometer. When the axis of this conical reflector was directed toward a distant object of greater or less temperature than the surrounding bodies, the difference was immediately indicated by the deviation of the needle of the galvanometer. For

example, when the object was a horse in a distant field the radiant heat from the animal was distinctly perceptible at a distance of at least ~~an eighth~~ several hundred yards ~~of a mile~~. When this instrument was turned towards the celestial vault the radiant heat was observed to increase from the zenith downwards, when directed however to different clouds it was found to indicate in some cases a greater, and in others a less degree of radiation than the surrounding space.

When the same instrument was directed to the moon a slight increase of temperature was observed over that of the adjacent sky but this increase of heat

was attributed to the reflection of the heat of the sun from the surface of the moon and not to the heat of the moon itself To show that this hypothesis is not inconsistent with the theory that the moon has cooled down to the temperature of celestial space, a concave mirror was made of ice and a thermo-pile placed in the more distant focus, when a flame of hydrogen rendered luminous by a spiral platinum wire was placed in the other focus, the needle of the galvanometer attached to the pile indicated a reflection of heat; care being taken to shade the pile by a screen with a small opening in it introduced, between it

and the flame.

XII. Another series of experiments connected with the preceding may be mentioned here. It is well known that the light from a flame of hydrogen is of very feeble intensity, the same is the case with that of the compound blowpipe while the temperature of the latter is exceedingly high, sufficiently so to melt fine platinum wire. It is also well known that by introducing lime or other solid substance into this flame its radiant light is very much increased. I found that the radiant heat was increased in a similar ratio or in other words, that in such cases the radiant heat was commensurate