understanding and solution of the milk problem."

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SPECIAL ARTICLES

GRAVITATIONAL REPULSION[1]

IN a paper entitled "Gravitation and Electrical Action" published by The Academy of Science of St. Louis, on July 28, 1916,[2] the following passage may be found:

> These results seem to indicate clearly that gravitational attraction between masses of matter depends upon their electrical potential due to electrical charges upon them.

Every working day of the present college year has been devoted to testing the validity of the above statement. All of the experimental results confirm this conclusion. No discordant results have been obtained. Not only was gravitational attraction diminished by charges of electricity upon the attracting bodies, when direct electrical action was wholly cut off by a metal shield, but gravitational attraction was converted into a repulsion which was greater than the normal attraction. On two days, when the influence machine, driven by a single-phase motor, was most highly efficient, the value of the gravitation constant was reduced by 250 and 300 per cent. of its maximum value. The maximum value of the gravitational attraction was evidently exerted when the potential of the attracting masses was zero absolute. The suspended masses were two spheres of lead, having a diameter of one inch, and distant from each other 91.5 cm. They were suspended on two untwisted threads of silk fibers, about 3.4 millimeters apart, and having a length of 179 cm. These silk threads were tied together at the top and hung around a pulley one inch in diameter. Below were two movable pulleys by means of which the distance between the silk threads could be adjusted to a parallel position. The large masses were spheres of lead having a diameter of 10 inches. They were mounted on blocks of wood having caster-wheels provided with roller bearings, which rested upon heavy sheets of hard rubber. The screen around the suspended masses was in part composed of wood, forming the top, bottom, and ends. The sides which faced the large masses each consisted of two sheets of heavy cardboard, outside of which was a sheet of metal. They were securely clamped to the top, bottom and ends of the enclosing shield by means of bars of wood and the joints were sealed by means of bees-wax, which was melted and run into the joints by means of a hot iron. The entire screen was then surrounded by another shield of metal. A layer of air about 1.5 cm. in thickness was thus formed between the two metal sheets on either side. A sheet of glass was also placed between each of the large masses and the metal sides of the shield. A box of metal filled with loose cotton-batting was placed in contact with the metal shield, alternating in position with the large masses. This was done in order to prevent as far as possible radiation from the northern sky from producing unbalanced convection currents in the air within the screen.

The large masses, the metal boxes containthe cotton, and the metal screen were all in metallic connection with each other. All heat from the heating system of the building was cut off. The change in the position of the suspended masses was determined by means of a mirror, telescope and scale, observation being made through a narrow slit in the screen which was covered by a plate of photographic glass, sealed to the inner sheet of metal.

Three feet distant from the ends of the screen and the side opposite to the observing telescope was a line of insulated metal rods upon which was hung metal strips armed with 800 pins. At one end of this line of rods was a metal disc armed with 150 pins. Facing this disc was a duplicate disc attached to a line of rods hung upon silk cords, and leading to the influence machine in an adjoining room. There was no gap in the line of rods excepting between the two discs having 150 pins soldered to them. The rods carrying the 800 pins were

[1] Abstract of a paper to be published by the Academy of Science of St. Louis.

[2] *Trans. Acad. of Sc. of St. Louis,* XXIII., 4, p. 173.

directly connected with the shield and the large masses if a rapid change was desired.

When either the positive or the negative terminal of the machine was applied, the attraction of the large masses for the suspended masses was diminished. It sometimes happened that a slight increase was shown at first, until a condition of zero potential was reached. This was only observed when direct contact of the masses with the 800 pins was not made. It then required several hours for the decrease in gravitational attraction to reach a limit. Then when the other terminal was applied the masses slowly returned to the original position. If this deflection were due to heat effects causing convection currents of air within the shield, this return motion due to change in terminals would not occur.

On the occasion when the most marked effects were obtained, the decreasing effect took place very slowly, requiring five hours. There was no direct contact between the large masses and the 800 pins. The positive terminal had been applied. Negative electrons were being drained from the air surroundiing the large masses and from the outer surface of these masses. Gravitational attraction had been reduced to zero. The negative terminal was then applied, and the masses were directly connected with the pin conductors by means of a metal rod. In five minutes (the time of a semi-vibration) the suspended masses had swayed back about half the angle over which they had slowly moved in the previous five hours. They then swayed back and oscillated to and fro, the mean of the extreme readings representing a decrease of 250 per cent. in the normal value of gravitational attraction between the masses. The arc of vibration during the next forty minutes was about equal to that due to normal attraction between the masses.

On the next morning the suspended masses were at rest, in a position which indicated that the large masses still repelled the suspended masses with a force about 2.5 times that of gravitational attraction. This position remained constant for two hours. The positive terminal was then applied and direct contact was made between the masses and the 800 pin conductors. During the next eighteen minutes the suspended masses swayed over an arc very nearly equal to that due to normal attraction. The attraction between the masses was increased. During the next twelve minutes they swayed backward over an arc about twice as great. The condition of zero potential had been passed. The force steadily decreased during the following ninety minutes. The gravitational attraction had then decreased to more than 300 per cent. of its maximum value. The negative terminal was then applied, and in two hours the reading was that at the beginning of the work of the previous day.

It is not necessary to continue an experiment of this kind throughout an entire day. Either terminal may be applied when the suspended masses are at rest, until an appreciable decrease in the gravitational attraction has become evident. A reversal of contacts of the machine may then be made and the masses will slowly sway back to their original position. This operation requires less than one hour. The evidence is as convincing as that produced by a feeble current of electricity upon a magnet suspended above it.

No attempt has been made in this work to obtain precise results. The aim has been to determine whether it would be proper to construct the much more expensive apparatus which will be needed, and which will permit the independent electrification of the suspended masses. Some results which have been obtained have aroused the suspicion that the "charges" on these masses varies from day to day, and that when their potential due to these charges is zero absolute, the electrification of the large masses will have no effect upon gravitational attraction. A modification of the apparatus used by Boys will be required.

The work here described has been done in a private laboratory in the second story of Ead's Hall, now occupied by the physics department of Washington University.

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