except for the gravitational field of the grain of sand. If v is any subvolume of V large enough to contain G, then the *a priori* chance of finding the grain of sand at any instant in v is

$$P = v/V.$$

Now suppose that V is made so large that P is less than one chance quantum. According to the postulate of quantized probability, the grain of sand cannot exist in v. But v was *any* subvolume of V, hence the grain of sand cannot exist anywhere in V. An attempt to remove the contradiction by assuming that geometrical space is quantized in such a way that the smallest allowable volume is greater than v fails, since v was initially taken to be larger than G, the volume of the grain of sand.

[1] Alfred N. Goldsmith, Phys. Rev. 64, 377 (1943).

Comments on "On the Quantization of Probability" by Henry F. Dunlap

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March 12, 1944

WHILE the writer would prefer to leave the analysis of such thoughtful comments relative to the consequences of the probability-quantization theory as are given in the foregoing commentary to active specialists in the field of probability theory, he desires nevertheless to offer the following brief suggestions.

In the commentary a conclusion is reached that, under the stated conditions and in accord with probability quantization, the hypothetical "grain of sand cannot exist" any longer. At first sight, this seems a common-sense conclusion derivable from the premises.

But if probability is indeed quantized, "common sense" in its everyday meaning will not serve in such an analysis, any more than "common-sense" particularly and reliably assists us in the realm of quantum physics. It is possible to examine the problem from a different viewpoint and to draw a different conclusion. Let us for example first substitute for "grain of sand" the probably more appropriate term "smallest elementary particle." Such a particle might be of electronic dimensions or even less. Let us also substitute for "cannot exist" the phrase "cannot be located" or "cannot be discerned." This substitute language seems more in accord with the necessary treatment of the problem. We can then paraphrase the above commentary by stating that quantized probability appears to require that a sufficiently small particle enclosed in an adequately large volume becomes unlocatable by any physical means. This conclusion is not found troublesome or self-contradictory by this writer.

It may seem a radical or strange conclusion to state that when an extremely small particle is enclosed in a sufficiently large space it is, in a physical sense, altogether lost according to our chance-quantum theory. This would be tantamount to saying that it has become literally unfindable by any means available to the would-be observer. Yet this conclusion seems no more radical than others freely accepted by modern physicists. Our "lost particle" would be no more unfindable than is an amount of energy less than one quantum or an amount of matter less than the smallest elementary particle, both according to present-day theory. Our "lost particle" has no presence in our physical world in any meaningful sense, and no experiment, no matter how intellectually ingenious, will serve to locate it. The physical quest for such a particle thus becomes as meaningless as the search for an absolute frame of reference for motion. Such at least might be the inevitable consequence of probability quantization as the writer sees it, and he finds nothing intellectually repugnant in such a conclusion.

It should, however, be stressed, as it was in the original letter describing probability quantization, that no assertion is made as to the correctness and validity of the theory of quantized chance. It was there urged that this theory continue to be thoroughly explored, keeping in mind, however, that the final conclusion will doubtless be reached by experimentation.

The above commentary is appreciated by the writer and is believed by him to be a stimulus to further study of the subject. It is hoped that such study will deal with methods for the experimental proof or disproof of probability quantization as well as with attempted applications of such a theory to certain small-scale or infrequent electrical phenomena. In these last-mentioned realms the new theory might display special utility or significance.

Magnetic Ions

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March 27, 1944

EHRENHAFT[1] has described experiments which he claims establish the existence of "magnetic ions." His method involves a measurement of the velocity of small particles (radii approximately 10^{-5} cm) of various elements (Ni, Fe, Mn, Cr, Sb) which are acted on by the earth's gravitational field and a uniform vertical magnetic field produced by an electromagnet. The particles are illuminated at right angles to the direction of the field and are observed in a direction normal to both the field and the direction of illumination.

An attempt has been made to verify his conclusions by slightly modifying the apparatus used by T. H. Laby and the author[2] in the determination of the electronic charge, a horizontal magnetic field being substituted for the electric field used in that determination. The magnetic field was produced by a small *permanent* Alnico magnet which has a strong field strength of about 1000 oersteds at the midpoint between the poles. Fine particles of nickel (radii of the order of 10^{-5} cm) were drawn by an air current between the poles of the magnet and then allowed to settle under the action of the vertical gravitational and the horizontal magnetic fields, and their path was observed by means of a microscope. Thousands of particles have been observed, many being in the field of view at the one time, but no particle has been detected moving in such a manner as to verify the "magnetic ion" hypothesis. In the center of the magnetic field all particles fell vertically, and on either side of the central line particles either remained undeflected or deflected towards the nearer pole. No particles crossed the center of the field. This result agrees with existing theories of magnetic induction for the non-uniform but symmetrical field between the poles of the magnet. The experiment has been repeated with iron and rouge particles with the same results. Increase in illumination also made no difference except that vertical convection currents were produced when excessive heat entered the chamber.

A possible explanation of Ehrenhaft's results is that the particles he observed were electrically charged and were acted on by some stray electric field such as that produced between the coils of the electromagnet. A typical particle observed by Ehrenhaft has a radius of approximately 10^{-5} cm and maximum velocity due to the electromagnet of 10^{-2} cm/sec. Assuming that this velocity is due to an electric field and that the particle possesses a charge of ne where n is the number of electrons each of charge $e(\approx 4.8\times 10^{-10}$ e.s.u.) and applying the corrected form of Stokes's law, one finds that the field required to produce this velocity is of the order of $0.3/n$ e.s.u. or $90/n$ volt/cm.

Thus for sufficiently highly charged particles a velocity of the above magnitude would be observed for very small electric fields (of say <1 volt/cm) and these small fields may be produced by the potential differences between the two halves of the electromagnet or electrostatic leakage effects from the generator.

[1] Felix Ehrenhaft, Phys. Rev. **57**, 659 (1940); Ann. d. Physik **11e**, Sec. 13, 151 (1939–40); Science **96**, 228 (1942); J. Frank. Inst. **253**, 225 (1942).
[2] V. D. Hopper and T. H. Laby, Proc. Roy. Soc. **A178**, 242 (1941).

Test for Change of Pole Strength of Permanent Magnet

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May 22, 1944

At the Pittsburgh meeting of the American Physical Society, F. Ehrenhaft[1] reported an approximately 10 percent loss of strength of a permanent magnet in an experiment in which acidulated water is placed between the poles of the magnet in contact with the pole faces and allowed to remain so for a period of time. The energy loss of the magnet is claimed by Ehrenhaft to have gone into the "magnetolysis" of the water. In view of the unusual character of these results, it was decided to repeat Ehrenhaft's experiment as described in the *Bulletin of the American Physical Society.*

In our experiment, a stabilized Alnico permanent magnet was used, the strength of which was measured on five successive days before the commencement of the experiment in the same laboratory where the entire experiment was conducted. Measurements were made by means of a ballistic galvanometer and search coil, the ballistic galvanometer having been calibrated by a standard of mutual inductance prior to each measurement. The accuracy of the apparatus is better than 1 percent. A special attachment was constructed to assure that in each measurement the search coil would start and come to rest at precisely the identical position. Pole pieces for the Alnico magnet were made of Armco iron, the end of each terminating in a truncated cone the face of which was 6 mm in diameter. The geometrical arrangement is shown in Fig. 1. Measurements of the field before and after the experiment were carried out both with and without the pole pieces. The height of each pole piece was carefully measured under a microscope by comparison with a standard height gauge. The accuracy of this measurement was ± 0.004 mm. The purpose of this last phase of the investigation was to follow any possible change in gap length that might accompany the action of the acid on the soft iron pole faces.

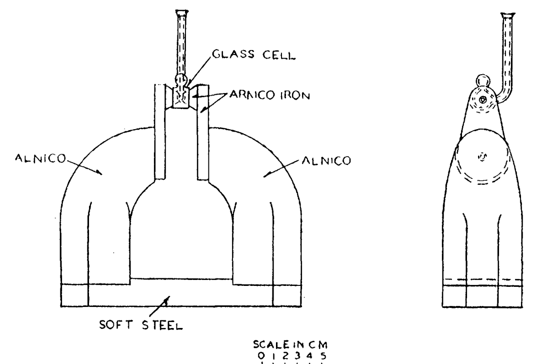

Fig. 1. Arrangement of permanent magnet pole pieces and glass cell containing acidulated water.

Two experiments were carried out to test directly Ehrenhaft's results. In one, 4 percent H_2SO_4 was placed in the glass cell, and the iron pole faces were exposed to the acid. As expected, there was a violent display of bubbles due to the liberation of hydrogen by the iron. At the end of 18 hours, the field of the magnet was measured and found to be identical with the value obtained at the beginning of the experiment within the measure of experimental error.

In the second experiment, the conditions were the same except that a 12 percent sulfuric acid solution was used in place of the weaker one used previously. This concentration was estimated to be of approximately maximum electrolytic activity. The entire pole structure with all but the pole face covered with paraffin was immersed in the solution and allowed to remain so for a similar period of time. No measurable decrease in field was observed as a result of this experiment. It is estimated that from the commencement of the investigation until its completion, the magnet poles were exposed to the "magnetolytic" action of the acid for approximately 60 hours during all of which time the magnet was not removed from its original surroundings, i.e., from the same laboratory where the measurements were made. The total magnetic flux at the pole face of the original Alnico magnet was $11{,}700\pm 50$ maxwells. This value was the same at the end of the experiment as at the beginning. It may be added parenthetically that when the experiment was carried out with the pole faces covered with paraffin and the acid previously boiled to drive off dissolved gases, no bubbles at all were observed when the acid was placed in the cell whereas they are observable if the acid is not previously boiled.

[1] F. Ehrenhaft, Phys. Rev. **65**, 349 (1944).