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An Experiment for the Measurement of the Weight to Mass Ratio of Elementary Particles

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Summary

Although for macroscopic bodies the weight to mass ratio is independent of the type of body, this may not be true for elementary particles, the ratio for the large bodies being only an average of the value for particles. A proposal is made for an experiment using atomic beam techniques which would detect variations in the weight to mass ratio of a particle. The experiment is discussed in detail for the proton in the hydrogen atom.

This essay is on a proposed experiment for measuring the weight to mass ratio of individual particles and hence may not be strictly within thesubject prescribed for this essay. But we believe the possibility of increasing the knowledge of gravitational phenomenon is compatible with the idea behind the prescribed subject, so that this essay is respectfully submitted.

A superficial survey of the gravitational phenomenon involved in masses and distances of earth size or smaller may lead to the conclusion that a sure description of those phenomenon can be given. A basic part of this description is the statement that for any body in a uniform gravitational field, the ratio~~n~~ of the weight to the mass is independent of the type of body.That is, in a uniform gravitational field the force on a body is equal to the product of the mass of the body and a constant which depends only on the field. Of course this is true for bodies of macroscopic size, or more precisely for bodies whose masses are sufficiently large to permit weighing. But the question may be raised as to whether the statement holds for particles of atomic or sub-atomic size.

In this paper we are specifically concerned not with whether the weight-mass ration may differ between different elementary particles, but if there is any variation in that ratio in a group of the same kind of particles. One might suppose that the weight-mass ratio for an elementary particle varies according to some distribution law and further that some very small fraction of the particles actually have ratios of opposite sign from the majority.These would then be repelled by a gravitational field.This idea is no more strange then the occurence of positrons which could be characterized as electrons with a charge to mass ratio of opposite sign, that are found relatively infrequently. Let us see what conclusions can be drawn from known phenomenon as to the possibility of variation of the weight-mass ration of a particle. For the smaller particles such as electrons and mesons nothing can be deduced except that the order of magnitude of the weight-mass ratio is that of macroscopic bodies. Any smaller variations in the ratio are masked by the hevier particles when these light particles are in matter and by electromagnetic and high energy effects when these light particles are in a free state. From the constant weight-mass ratio of macroscopic bodies we know that the ratio for the heavier particles, protons and neutrons, if not constant, must have a distribution function sharply peaked about the value for the macroscopic ratio. But the statement that protons or neutrons have a constant weight-mass ratio is certainly not justified by the known facts.

To measure the weight-mass ratio of individual particles we propose an experiment analagous to that carried out in atomic beams investigations on magnetic moments*. In the experiment a collimated beam of particles would be deflected by the action of a gravitational field on the particle mass, ratherthen by a magnetic field on the particle's magnetic moment. The extent of the gravitational deflection measures the weight-mass ration. In particular a beam would issue from a source and be collimated using standard atomic beam techniques. The beam would then travel horizontally through the earth's gravitational field and fall on a detector. Any variation of the weight-mass ration would be revealed by a vertical spreading of the beam as measured by the detector. Of course the entire apparatus must be well evacuated. We do not have the space here to discuss details of sources, collimation or detection. but these techniques are well developed in atomic beams*. It is to be noted that no absolute measurement of the deflection is necessary in this experiment.

Next we consider what particles could be used in this experiment. Unfortunately the collimation of slowly moving charged particles is very difficult due to collection of surface charges and stray fields. It is hardly necessary to point out that good collimation and small beam width is necessary for production of a small beam trace at the detector. The smaller the beam trace in area at the detector the smaller the detectable variation in beam deflection. Thus protons and electrons would be very difficult to use. However neutrons, neutral hydrogen atoms, or neutral hevier atoms could be used. It would not be wise to use too heavy an atom since the large number of protons and neutrons in the nucleus would already have an average weight-mass ratio close to the ratio for macroscopic bodies. The most promising material is the hydrogen atom and the experiment will be discussed further using this for the beam.

Now the gravitational deflection should be as large as possible. This means the time the particles spend between collimator and detector should be long. This can be accomplished by a large distance between detector and collimator and a low beam velocity. However as the particles travel away from the collimator they spread out so that the beam area increases proportional to the square of the distance from some point on the beam axis. This limits the distance at which the detector may be placed and we take 2 meters as the maximum practical distance. The average beam velocity is related to the temperature of the source from which the beam issues by the equation $v = \sqrt{2KT/m}$ where m is the particle mass. Though difficult it appears possible to have the source at near liquid hydrogen temperatures, say 30 deg. K.. This gives an average beam velocity of

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*R. G. J. Fraser, Molecular Beams (1938)

7×10^4 cm./sec and for the two meter distance a vertical deflection of .05 mm. We may hope to get a beam width at the detector of .03mm. Thus the total gravitational deflection will be almost twice the beam width. We can then detect a 10% variation in the weight-mass ration of the proton and certainly detect if any protons have a ration with the opposite sign. It should be noted that scattering of the beam due to collision with residual gas in the apparatus may interfereconsiderably with interpretation of the results. The long beam length and low beam velocity make the rate of collision higher then that usually encountered in atomic beam work.

The experiment described above is admittedly very difficult. Some increase in deflection due to lower beam velocities might be gained using helium instead of hydrogen. H ere variation in the weight-mass ratio of protons or neutrons would not be averaged out in a single atom. However the basic difficulty in the experiment remains. This difficulty is that on the basis of present theory we expect negative results and completely unambiguous data will be needed to contradict this present theory. The experiment may nevertheless be worth further consideration for the discovery of a variation in the weight-mass ratio of an elementary particle would certainly have farreaching consequences. Finally we may point out that one could regard a variation in the weight-mass ratio~~n~~ of an elementary particle as meaning that the type of particle being considered is actually a family of similar particles which are distinguished by being acted on differently by the same gravitational field.

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