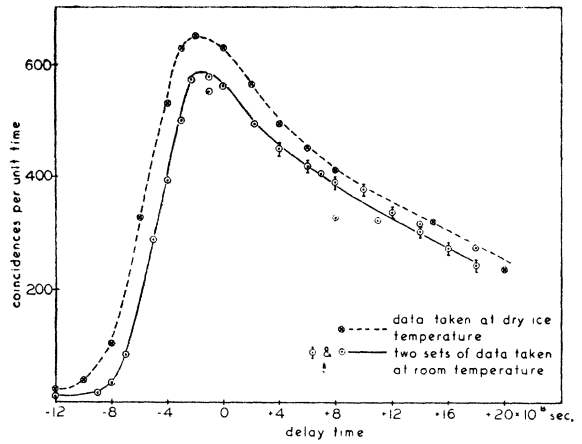

FIG. 2. Comparison of coincidence rate *versus* delay curve for calcium fluoride scintillations taken at room temperature and at dry ice temperature. Note similar decay rates within the accuracy range of the equipment.

magnitude to be detected by this equipment. Plotting of this decay section of the curve shows the half-life to be still in the range of $14\text{–}16\times10^{-8}$ second.

The apparent temperature independence together with the magnitude of the decay time indicate several possibilities: (a) the process of emission may be a straight radiative transition of a slightly forbidden state; (b) if the process is one of electron migration the barrier would be small, say of the order of a few hundredths of an electron volt with the tunnel effect being large in relation to overcoming the barrier; (c) the process may be twofold, with fast electron migration preceding radiative transition.

The writer wishes to express his thanks to Professor E. C. Pollard for valuable discussions throughout, to Professor H. L. Schultz for discussion of coincidence counting techniques and circuits involved, and to Dr. R. B. Setlow for suggestions on interpretation. Thanks are also due Mr. J. A. Rich for loan of the naphthalene and calcium fluoride crystals.

* Assisted by the joint program of the ONR and the AEC.

[1] Conference on Scintillation Counters and Crystal Counters, University of Rochester, Rochester, New York, July 1948.

[2] H. L. Schultz, *High Speed Counters and Short Pulse Techniques* (Brookhaven Conference Report, August 1947), p. 35.

[3] F. W. Van Name, Phys. Rev. **75**, 102 (1949).

Anomalous Behavior of the Dielectric Constant of a Ferromagnetic Ferrite at the Magnetic Curie Point

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March 14, 1949

IN the discussion following our papers "Magnetic Properties of a Ferromagnetic Ferrite," presented at the 1948 Annual Meeting of the American Physical Society, we showed the lantern slide reproduced here. This represents the effective dielectric constant, as a function of temperature, measured at 10,000 c.p.s. on a block of a commercial ferromagnetic ferrite (Ferroxcube III) provided with evaporated gold electrodes. Direct current measurements of the resistivity of the block were made at the same time and show, in the same temperature interval, only the variation with temperature expected of semiconductors.

At that time we thought that the almost discontinuous course of the dielectric constant *versus* temperature curve at the magnetic Curie point might be some indication of the

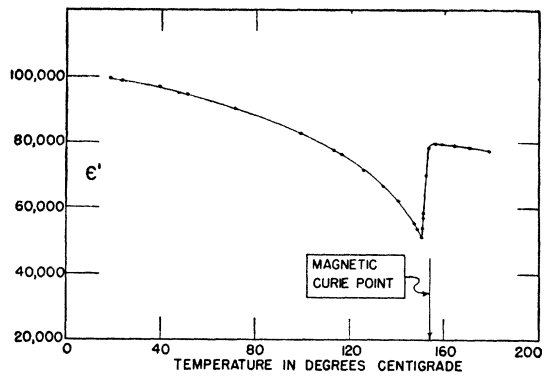

FIG. 1. Real part of dielectric constant *vs.* temperature.

fundamental character of the dielectric behavior, perhaps related to a coupling of the electric and magnetic dipoles.

We have found, however, that the behavior of the dielectric constant at the magnetic Curie point can be described on the basis of straightforward electromagnetic theory. The decrease in the measured dielectric constant between room temperature and the Curie point is due principally to the increasing ohmic conductivity in this region. The sudden rise at the Curie point follows from the collapse of the permeability. Differences between the experimental and calculated curves indicate that the actual dielectric constant decreases slowly with increasing temperature throughout the entire region.

A paper covering in more detail our work on the dielectric and magnetic properties of a ferromagnetic ferrite is in preparation for submission to the Physical Review.

Divergences in Field Theory

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March 17, 1949

THE considerable advances which have recently been achieved in quantum electrodynamics have been based on the twin concepts of charge and mass renormalization. Thus it has been found that the divergences that occur as a result of the interaction between electron and electromagnetic fields are due to terms which, if finite, would be interpreted as changing the mechanical mass and charge of the electron to the empirically observed values. On separating out the additional mass and charge terms, it has been found that the present form of electrodynamics gives finite and unambiguous predictions with at least reasonably close agreement with experiment.

The question immediately arises as to whether the use of these concepts is sufficient to remove the divergences of other current or proposed forms of quantum field theories, or if their success is an accident peculiar to electrodynamics. Offhand, one would say that the latter is obviously the answer. The divergences encountered with a Dirac electron interacting with the electromagnetic field are particularly weak. While it would seem not unreasonable that the removal of two infinite quantities would render electrodynamics convergent, the success of this procedure in theories with much stronger divergences is *a priori* rather unlikely. Surprisingly, it has been found that the utilization of the renormalization ideas does give convergent results for the scalar and pseudoscalar meson theories (even with dipole coupling) and for the scalar electron interacting with the electromagnetic field. This might tend to support the view that all the divergences of the

customary field theories have been isolated and put into an innocuous form.

A more critical test of this hypothesis is the vector meson theory with tensor coupling between mesons and nucleons. Here the divergences are most acute. We have made calculations with this theory using the new covariant methods.[1] Particular care was taken to consider all effects of renormalization of charge and of both the nucleon and meson mass. It was found that there are additional divergences beyond those in mass and charge. Thus, the anomalous neutron and proton moments were found to be logarithmically infinite. Similar results were found for the velocity independent neutron-electron interaction and the corrections to the interaction of a proton with a fixed external field. In addition, vacuum polarization phenomena gave rise to an infinite dipole density distribution with zero total dipole moment. It is interesting that the analog of the latter term in electrodynamics gives rise to the usual charge renormalization. In the present theory this term, if finite, would not renormalize the electric charge and so would not give different proton and electron charges.

Two conclusions follow: The first is that new methods must be developed before the vector meson theory with tensor coupling can be used for calculations. The second follows from the fact that the above divergences were not a consequence of the finite meson mass. The same lack of convergence is contained in a phenomenological description of the anomalous neutron, proton, or electron moments by means of a Pauli type magnetic moment term.

From this work we can state that mass and charge renormalization do not completely encompass the divergences of field theory. New developments would be required to enable us to use vector mesons as a supplement to the pseudoscalar theory. Recent calculations with the latter have given rather unsatisfactory results. In fact, if the recently proposed experiment of Wentzel should show the π-meson to have spin one, we could be sure of our inability to treat the nuclear force problem by present methods.

It is a pleasure to acknowledge a very helpful discussion with Professor J. R. Oppenheimer and Dr. A. Pais.

This work was supported by a grant-in-aid from the AEC to the Institute for Advanced Study.

[1] In a footnote, Luttinger states that Villars has previously found that tensor coupling yields infinite magnetic moments. Since the method of this calculation was not indicated, it was thought advisable to repeat the calculation explicitly, using the renormalizations and the covariant formalism. J. M. Luttinger, Helv. Phys. Acta **XXI**, 483 (1948).

On Meteor Speed Measurements by the Radio Doppler Method at Low Frequencies*

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February 14, 1949

IT has been shown[1] that meteor speeds can be determined with good accuracy at 30 megacycles from a recording of the Doppler whistle produced when continuous-wave radio energy reflected from the nose of a meteoric ion trail is combined with a portion of the transmitted signal. The question has been raised as to whether the same accuracy can be obtained by this method at lower frequencies in view of Pierce's suggestion[2] that the echo from an ion column at these frequencies might be more indicative of the rate of growth of the column than of the velocity of the meteoric particle.

During the Geminid shower of December 11, 1948, simultaneous radio Doppler speed measurements were made at 30.66 and 12.8625 megacycles between 0400 and 0700 P.S.T. The velocities of twenty meteors were obtained at both frequencies. Figure 1 shows a plot of the velocity of each meteor

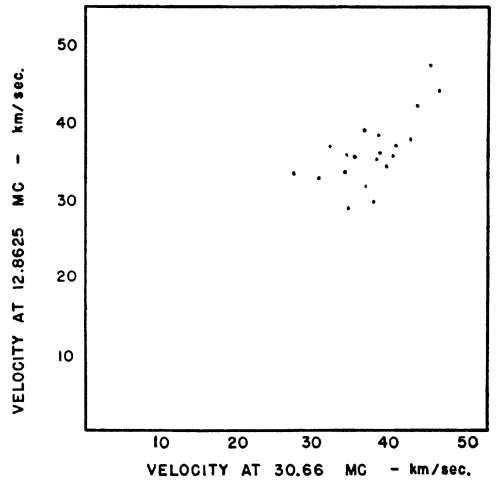

FIG. 1. Correlation of velocities measured at 12.8625 Mc and 30.66 Mc.

as measured at 12.8625 megacycles, *versus* the velocity as measured at 30.66 megacycles.

When a line through the origin was fitted to the points by the method of least squares, the slope was found to be 1.015. The correlation coefficient of the points was 0.97. It, accordingly, appears that radiofrequency is not a factor in the Doppler velocity measurement.

A simplified technique was used to obtain the slope of the whistle-pitch *versus* time-curve from which velocity is calculated. In the earlier experiments[1] the meteor whistles had been recorded on a magnetic tape and then transcribed by a moving-film oscillograph; in this test the intermediate step was eliminated. A Brush "penmotor" direct-inking magnetic oscillograph—which operates very satisfactorily with inexpensive adding machine paper as the recording medium—was connected to the output of the radio receivers. Since the frequency response of this instrument extends up to 120 c.p.s., it is possible to record four or five cycles of the whistle of a 35-km/sec. meteor at a radiofrequency of 30 megacycles—or an 85-km/sec. meteor at 12 megacycles—before the pitch falls to zero. This number of points has been found to be sufficient to establish the slope of the whistle-pitch curve. While the accuracy of this recording technique is somewhat less than the other, its simplicity is very attractive. Meteor velocity measurements may thus be made with a minimum of equipment.

Figure 2 is a plot of the velocities of all the meteors whose speed was recorded during the test.

As in reference 1, an effort was made to establish which of the recorded meteors belonged to the shower. The relationship between their direction and range was compared with the approximate relationship which must be satisfied by shower meteors having a given radiant and producing reflections within a relatively narrow range of altitudes centered about 100 km. In this test the azimuth of the reflections was obtained by means of an instantaneous radio direction-finder.

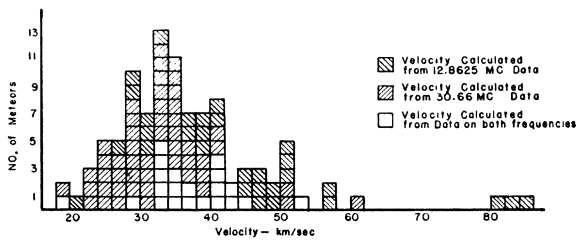

FIG. 2. Velocities of all meteors whose speed was recorded during the test.