LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

An Alternative Interpretation of Jauncey's "Heavy Electron" Spectra

In the February first number of *The Physical Review*,[1] Jauncey has shown two photographs of magnetic spectra of electrons, in both of which the main deflected image is taken as evidence of a heavy electron of rest-mass about 3 times normal. Following the suggestion of C. T. Zahn[2] that this image may be caused by scattered electrons, I have calculated that in both of Jauncey's photographs the image in question corresponds with that to be expected from electrons once scattered by the lower plate of his velocity selector.

Jauncey has shown that his velocity selector, with parallel plates 5 cm long and 0.105 cm apart, and with the magnetic and electric fields used in his experiments, will not transmit β-particles coming directly from Ra E, except in the chosen low range of velocities. When these β-rays are however bent by the magnetic field to strike the lower plate, this part of the plate becomes the source of secondaries of only slightly reduced energy. The rays moving forward may then pass through the selector if they do not again strike the plate. Thus for β-rays once scattered, the resolving power is no greater than for a velocity selector of half the length if primary particles only were considered. From the dimensions of Jauncey's apparatus it can thus be shown that while for primary particles the minimum transmissable radius of curvature is 30 cm, the corresponding minimum for particles once scattered is 7.5 cm.

Numerical calculation shows that with the magnetic and electric fields used in Jauncey's experiments any electron with curvature low enough to reach the film will have a radius of curvature of more than 7.5 cm between the plates. That is, the apparatus is not effective in selecting velocities of electrons that have been once scattered. That it does, however, act as an effective velocity selector for the direct β-rays is shown by the sharpness of Jauncey's line *C*, due to electrons with velocities close to the chosen value of $\beta = 0.33$.

Calculations of the position of the images to be expected from such once-scattered rays are also in satisfactory agreement with the observed positions of the diffuse images in Jauncey's photographs.

It would thus appear that the heavy electron interpretation of Jauncey's photographs is not required. His new lines may alternatively be ascribed to a kind of "second-order" magnetic spectrum caused by once-scattered particles. Higher order scattering might also, as suggested by Zahn, be supposed to produce detectable effects. The present calculation indicates, however, that only single and not multiple scattering processes need be considered to account for Jauncey's results.

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February 16, 1938.

[1] G. E. M. Jauncey, Phys. Rev. **53**, 265 (1938).
[2] Made in discussion of Jauncey's results at the meeting of the American Physical Society, Indianapolis, Dec. 30, 1937, and soon to appear in the *Physical Review*.

Heavy Beta-Particles?

During the past year preliminary cloud-chamber experiments by H. R. Crane, J. J. Turin, D. S. Bayley, and E. R. Gaerttner, on primary beta-particles and Compton recoil electrons, suggested the possibility that beta-particles may be heavier than normal. It was proposed in the above group[1] that the beta-ray paradox might be explained in this way, rather than by the neutrino hypothesis.

Preliminary direct experiments to test this hypothesis were carried out in collaboration with A. H. Spees, and the results[2] were negative. In parallel with this investigation, the continued experiments by Crane's group also finally indicated negative results. Further experiments were performed with a considerably improved apparatus; and the final results, a detailed account of which appears in this issue of the *Physical Review*, indicate agreement with the relativity theory to within the limits of experimental error.

In the course of a mathematical analysis of the instrument it became apparent that the usually accepted simple interpretation of the Bucherer-Neumann experiments might be subject to serious limitations. A similar analysis (to be published in the near future) was then carried out for the *unmodified* Bucherer-Neumann experiment—and it was discovered that the *supposed* velocity filter in Neumann's experiments, even for the case of negligible scattering, must have been completely broken down on the high velocity side, for $\beta > 0.7$; and that, even for the lower velocities, the resolution width was approximately as great as that equivalent to the whole relativistic mass effect! Since it is not clear whether Neumann's electron beam was composed largely of scattered radiation, or of direct radiation—and since the effective resolving power decreases very rapidly after scattering—it is obvious that the ordinary simple interpretation of experiments of the Bucherer type is not justifiable.

In the meantime (at an unofficial meeting in Indianapolis, December, 1937, and also in a recent Letter to the Editor) this same possibility for dispensing with the neutrino hypothesis was again proposed—by G. E. M. Jauncey, who also described experimental evidence for heavy beta-particles, based on measurements of the Bucherer-Neumann type. The conflicting results obtained here at the University of Michigan were again pointed out by the author at this meeting, and a description was given of the unpublished results of our analysis showing that the Bucherer method is unreliable as regards its simple interpretation.

We believe it quite possible, if not probable, that the radiation photographed by Jauncey was largely scattered radiation, for the following reasons: Jauncey's experiments were performed at a low velocity where the distribution function is small, so that the radium E spectrum was composed almost exclusively of velocities larger than that "observed." When electrons are scattered, their average momentum is reduced, and at the same time the effective resolution width is increased. If the ratio of the condenser separation to the square of the length is near the critical value at which the filter breaks down, then, under the above conditions, the probability for the *leakage* of high velocity scattered radiation becomes relatively large, and one might expect the apparatus to behave rather as a momentum spectrograph for the scattered radiation. Hence one might obtain a spurious peak due to the scattered electrons, and even miss the weak theoretical line altogether.

An examination of the values of Jauncey's geometrical constants in the light of our theory shows that his theoretical resolving power was very near the critical value. We therefore believe it quite possible that his observations correspond to the conditions just outlined. In any case, our results for radium E electrons of $H\rho$ 2000, or $\beta = 0.75$, are definitely not consistent with the particular hypothesis discussed here. It is conceivable that *another* type of heavy beta-particle exists, such that the anomaly is inappreciable for $\beta = 0.75$ and large for $\beta \sim 0.4$; but this does not seem probable in view of the above-mentioned uncertainties.

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February 4, 1938.

[1] See G. Breit, Rev. Sci. Inst. **8**, 141 (1938).
[2] Zahn and Spees, Phys. Rev. **53**, 524 (1937).

Ferromagnetic Impurities

An experimental method has been developed whereby very minute ferromagnetic impurities may be detected in various materials and the magnetic properties of these impurities studied.

The specimen to be tested may have any shape but a short rod of about 0.3 cc volume is most convenient. It is first placed in a field of several thousand oersteds supplied by an electromagnet. This serves to magnetize all ferromagnetic impurities in one direction; the field is then removed and it is assumed that any ferromagnetic impurities present will then be left with a certain remnant magnetization in this direction. This is detected and measured by hanging the specimen from a quartz fiber in the center of a pair of Helmholtz coils, the remnant magnetization being at right angles to the axis of the coils. A field of 40 oersteds or less is applied and the resulting rotation noted by a mirror and scale. The fact that reversing the field reverses the rotation, shows that the effect is a ferromagnetic one. With a strong quartz fiber, whose torsion constant was 0.028 dyne-cm per radian, a magnetic moment per cc, I, of 2×10^{-7} could be detected. A comparison of this with a remnant magnetization of over 500 for pure iron shows the sensitivity attainable.

The values of I found for various materials are given in Table I.

TABLE I.

Brass, commercial	7.5×10^{-2}
Copper, No. 12 D.C.C. wire, insulation removed	1.7×10^{-4}
Bismuth, extruded rod	3.4×10^{-4}
Bismuth, crystallized C.P. analyzed, 0.00% Fe	1.0×10^{-5}
Cadmium, Baker analyzed, 0.003% Fe	6.2×10^{-5}
Tin, Baker analyzed, 0.002% Fe	8.5×10^{-6}
Bakelite	1.0×10^{-4}
Pyrex rod	3×10^{-7}

The surfaces were carefully cleaned and handled only with forceps. Tests failed to show the effect a surface one, unless perhaps for the Pyrex.

Calculations showed that dia- or paramagnetism of a specimen could cause rotation only through (1) different demagnetizing factors in different directions when the specimen is not spherical, or (2) different susceptibilities, K_1 and K_2, in different directions. As (1) depends on K^2H^2 it was too small to be noticeable in the weak fields used, but (2) depends on $(K_1 - K_2)H^2$ and so is of a considerably larger order of magnitude. The crystallized Bi sample, which appeared to be a single crystal, gave just such an effect, dependent on H^2 and of just the right magnitude, in addition to the ferromagnetic effect which varies in magnitude and direction with H. We have then also a sensitive method of detecting magnetic anisotropy.

The ferromagnetic impurities could be magnetized in any direction desired or demagnetized by reversals. They would not likely be magnetic in such minute amounts unless they exist as inclusions of aggregates of atoms rather than in a state of diffusion throughout the metal, although the latter may explain the almost null result for Pyrex glass.

The foregoing was prompted by a discussion with F. Bitter at the Cornell Symposium in July, 1937.

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February 4, 1938.