ferro- and para- Curie point. The Lorentz factor L is 3 ± 0.2.

(b) Near the Curie point the susceptibility κ is a function of the applied field. The observed values of $\kappa(E)$ agree with the theory.

(c) Above 35° the Kerr effect approaches a quadratic dependence upon the applied field and gives a Kerr constant of the same order of magnitude as that of most liquids.

(d) Near the Curie point the Kerr effect is proportional to the 2/3 power of the applied field. This agrees with the assumption that the Kerr effect is proportional to the square of the inner field $F=E+LP$.

(e) The Kerr effect is different in the b and c axis of the crystal. There exists a longitudinal Kerr effect.

(f) The theory explains the observed size and shape of the hysteresis loops.

(g) Small crystals act as a single elementary Weiss region. They show a real pyroelectric effect. The pyroelectric moment is identical with the permanent moment calculated from the theory. It vanishes above the upper and below the lower Curie point.

(h) Large crystals consist of a limited number of Weiss regions. The Weiss regions in Rochelle salt have a cross section of about 2 cm². They can be made visible with electrified powder (analogy to Bitter's experiment).

(i) Large crystals have a very pronounced Barkhausen effect. This effect exists only on the steep part of the hysteresis loop. It disappears above the Curie point.

(j) Points (g) and (h) explain the asymmetries observed in small crystals.

(k) The Kerr effect below the Curie point shows a quadratic hysteresis loop and follows the theory even for large fields. For large fields the effect is nearly proportional to the absolute value of the applied field.

(l) The temperature variation of the natural birefringence shows a sharp discontinuity at both Curie points. This change of double refraction agrees quantitatively with the assumption that it is due to the Kerr effect of the permanent Weiss field. The Weiss field can be measured. It has a maximum value of 200 kv per cm at 0°.

(m) Measurements of the reversible susceptibility as a function of the applied field gives a curve which is the derivative of a hysteresis loop.

(n) The susceptibility for $E=0$ follows a Weiss law below the upper Curie point $1/\kappa_0=C(T_c-T)$.

(o) A similar Weiss law holds below and above the lower Curie point. All these results refer to fields in the a direction.

(p) The dielectric constants in the b and c direction increase with temperature. This is a consequence of the liberation of the dipoles at higher temperatures.

A complete account of the experiments and of the theory will appear soon.

HANS MÜLLER

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October 26, 1933.

Azimuthal Asymmetry of the Cosmic Radiation in Colorado

An investigation of the azimuthal asymmetry of the cosmic radiation near Fulford, Colorado, geomagnetic latitude 48°N, elevation 9500 feet, shows a difference between the west and east intensities of about two percent for angles of 30° and 40° from the vertical. The measurements were made with the same apparatus and in the same manner as at Swarthmore.[1] The results are summarized in Table I and are in accord with those found at Swarthmore.[1]

TABLE I.

Angle from vertical	Total time T (min.)	Total counts C	Counting rate C/T	Number of data n	Probable error from residuals R	Probable error from total counts R'	West-East difference (Counts/min.)
0°	1432	16,552	11.56	20	0.064	0.061	0
30° east	3951	30,463	7.71	25	0.031	0.026	0.17±0.045
west	4169	32,843	7.88	28	0.032	0.029	
45° east	4186	19,867	4.74	26	0.026	0.023	0.11±0.034
west	4801	23,295	4.85	25	0.022	0.022	

Also there is agreement with Korff[2] who set an upper limit of 3 percent for the west-east difference with an indication of a slightly greater west intensity. The dispersion of the points on the curves of Stearns and Bennett[3] indicates that their probable errors were too great to detect such a small asymmetry as exists at these latitudes.

This investigation was made possible by the invitation of Dr. A. J. Allen to spend a few weeks at his cabin in the mountains and use the facilities of his hydroelectric plant.

E. C. STEVENSON

Bartol Research Foundation
of The Franklin Institute,
October 23, 1933.

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[1] Thomas H. Johnson and E. C. Stevenson, Phys. Rev. **44**, 125 (1933).

[2] S. A. Korff, Phys. Rev. **44**, 515 (1933). Phys. Rev. **44**, 130 (1933).

[3] J. C. Stearns and R. D. Bennett, Phys. Rev. **43**, 1039 (1933).

Scattering Processes Produced by Electrons in Negative Energy States

Recent calculations[1] of the changes in the absorption-coefficient of hard gamma-rays due to the formation of electron-positron pairs have lent strong support to Dirac's picture of holes of negative energy. Still, the almost insurmountable difficulties which the infinite charge-density without field offers to our physical understanding make it desirable to seek further tests of the theory. Here purely

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[1] J. R. Oppenheimer and M. S. Plesset, Phys. Rev. **44**, 53 (1933).

radiation phenomena are of particular interest inasmuch as they might serve in an attempt to formulate observed effects as consequences of hitherto unknown properties of corrected electromagnetic equations. We are seeking, then, scattering properties of the "vacuum."

Two possible types of phenomena must be considered separately in connection with the foregoing: (1) All incident quanta have the same direction of propagation; (2) The incident quanta have different directions of propagation. Since we are only interested in purely radiation phenomena the frequencies in the second case should lie below mc^2/h so that no permanent formation of electron-positron pairs can occur.

When all incident quanta have the same direction of propagation, the principle of conservation of momentum excludes all scattering processes other than those in the direction of the incident radiation. These scattering processes would be observable if accompanied by a change in frequency. In the language of Dirac's theory of radiation such splitting of the incident quantum occurs in processes of the following type: An electron in a negative energy state passes by absorption of the incident quantum into a state of positive energy; the electron then returns in several steps under emission of $h\nu$ in toto to its original state. At each step total momentum should be conserved. A scattering process of this type can only *reduce* the frequency; the reduction, if small, would on the average be proportional to the distance travelled by the quantum through "vacuum." In this connection the hypothesis may be mentioned that Hubble's constant might be reducible to atomic constants without utilizing gravitational theories.

When the directions of propagation of the incident quanta do not coincide the additional case of simultaneous action of two quanta, of different frequencies in general, must be considered. This case can always be reduced by a Lorentz-transformation to the action of two equal and oppositely propagated quanta. In this "Pauli frame of reference" the scattering process would simply consist of a rotation of the line indicating the direction of propagation through a certain angle. In the original frame of reference we would of course encounter changes of both frequency and direction.

The writer will supply shortly the necessary quantitative considerations lacking at present.

O. HALPERN

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October 26, 1933.

On the Calculation of the Coefficient *C* in Frank's Formula for Change of Resistance

In Dr. Frank's formula,[1] $\Delta\rho/\rho = BH^2/(1+CH^2)$, for the relative increase in resistivity in a transverse magnetic field, the symbol ρ denotes the resistivity in the *presence* of the field.

On examining the tables in which $\rho(C)^{\frac{1}{2}}$ (calculated from Kapitza's measurements) is compared with accepted values of the Hall coefficients, I was struck by the fact that, for Sb and Bi, $\rho(C)^{\frac{1}{2}}$ is recorded as *less* than the Hall coefficient. For the other six metals the ratio is greater than 1. Mr. Norman A. Hedenberg and the writer therefore undertook to measure the resistivity and the Hall coefficient for two bismuth plates, at room temperature, in fields up to 13,000 gauss. The coefficient C turns out to have the same value, 13×10^{-9} gauss^{-2}, for each plate and $\rho(C)^{\frac{1}{2}}$ is more than twice as large as the Hall coefficient, even if one substitutes for ρ the value of the resistivity when H is zero.

In the writer's opinion, an error in calculating C from Kapitza's experimental results has made the recorded values of $\rho(C)^{\frac{1}{2}}$ too small for all the metals. The error is very large in the cases of Sb and Bi. The recorded values, it is true, agree very closely with those obtained by assuming that $\Delta\rho/\rho$ is equal to Kapitza's $\Delta R/R$. But in the latter's paper,[2] R denotes the resistance *before* the field is applied (otherwise $\Delta R/R$ could never be greater than 1 as it actually is for Sb, Bi and certain other metals). Accordingly, if Kapitza's $\Delta R/R$ be denoted by k, it follows that Frank's $\Delta\rho/\rho$ should be, not k, but $k/(k+1)$.

Using Kapitza's results and taking account of the discrepancy just mentioned, one finds that, for all the metals listed by Dr. Frank, the value of $\rho(C)^{\frac{1}{2}}$ is considerably increased. For Sb, the new values are 440×10^{-3} e.m.u. at 290°K, 390×10^{-3} at 193°K, and 370×10^{-3} at 90°K. Calculations have not yet been made for all the metals investigated by Kapitza, but so far the writer has found no exception to the rule that $\rho(C)^{\frac{1}{2}}$ is larger than the Hall coefficient at the same temperature.

I am very much indebted to Mr. Hedenberg for assistance in the calculations. We hope to publish soon the results of our experiments on bismuth.

K. K. SMITH

Northwestern University,
Evanston, Illinois,
October 29, 1933.

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[1] Frank, Zeits. f. Physik **64**, 652 (1930). Sommerfeld and Frank, Rev. Mod. Phys. **3**, 18 (1931).

[2] Kapitza, Proc. Roy. Soc. (London) **A123**, 300 (1929).

Preliminary Report of the Results of Angular Distribution Measurements of the Cosmic Radiation in Equatorial Latitudes

A preliminary survey of the angular distribution of the cosmic radiation in equatorial latitudes has now been completed and measurements have been made in Mexico,[1, 2] geomagnetic latitude 29°, at elevations 10,000 ft., 7500 ft., and sea level; in Panama, geomagnetic latitude 20° at sea level; and in Peru, geomagnetic latitude 0°, at eleva-

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[1] T. H. Johnson, Phys. Rev. **43**, 834 (1933).

[2] Confirmatory measurements were also made in Mexico by L. Alvarez and A. H. Compton, Phys. Rev. **43**, 835 (1933).