



## XXXIV. On the principle of relativity

Edwin Bidwell Wilson Ph.D.

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perfect membranes, and this is due to two circumstances: for the first the value of  $\left(\frac{d\lambda'}{d\pi}\right)_{\pi'}$  will be greater for a better membrane, and for the second the reversion point will keep more constant.

From the measurements here done we have for the temperature coefficients between 0 and 11.5:

$$\text{For } C=161 \quad \left(\frac{d\pi_0}{dT}\right)_C > 0.00296,$$

$$,, \quad C=320 \quad \left(\frac{d\pi}{dT}\right)_C > 0.0017.$$

Thus the temperature effect upon  $\pi_0'$  is made up of two parts, (1) the temperature effect upon the permeability of the membrane, (2) the temperature effect upon osmotic pressure; and these two effects counteract each other.

I wish to thank Prof. O. E. Schiotz of Christiania for suggesting this work to me and for the interest he has taken in it. I should also like to thank Prof. J. J. Thomson for allowing me the privilege of continuing the work in the Cavendish Laboratory.

XXXIV. *On the Principle of Relativity.* By EDWIN BIDWELL WILSON, *Ph.D., Professor in Mathematics at the Massachusetts Institute of Technology* \*.

IN the present formative state of the theory of atomic electricity, when, in addition to the idealized mathematical electron which is the simple and frequently sufficient "point of beknottedness" in the æther, we have the Abraham electron spherical and rigid, the Lorentz-FitzGerald electron deformable under rectilinear motion into an oblate spheroid with constant equatorial diameter, and the Bucherer-Langevin electron deformable under rectilinear motion into an oblate spheroid of constant volume, it is necessary to pursue several methods of attacking the problems that arise in connexion with the theory; and of these methods the principle of relativity is among the most interesting and powerful, whether considered in its mathematical, physical, or philosophical import.

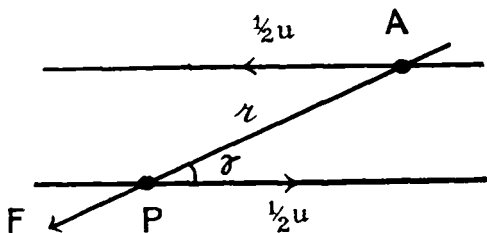
\* Communicated by the Author.

This principle has been discussed by Lorentz\*, by Poincaré† with reference to the theory of groups, by Einstein‡, and recently in this Magazine by Cunningham§, and by Bucherer||, who introduces a new principle of relativity. It is not my desire at this time to go into the mathematics of a question which has been discussed at such length, but merely to point out a few general observations suggested, especially with reference to Bucherer's formula (1), and then to show the application of those remarks to any such theory of relativity.

With a slightly modified notation, Bucherer's formula for the force  $\mathbf{F}$  exerted by one electron upon another is

$$\mathbf{F} = \frac{r_1 q^2 (v^2 - u^2)}{r^2 (1 - \beta^2 \sin^2 \gamma)^{\frac{3}{2}}}, \quad \dots \dots (1)$$

where  $q$  is the charge of the electron,  $v$  is the velocity of light,  $u$  is the total relative velocity of the two electrons,  $r$  is the distance between them,  $\beta$  is the ratio  $u/v$ , and  $\gamma$  is the angle between the direction of motion and the line joining the electrons. In the figure the velocity  $u$  is divided



into two equal parts, one-half being attributed to each of the electrons which are assumed to be moving (instantaneously) in parallel lines ¶. The electron at A is what Bucherer calls the active electron; that at P, the passive one. The role of P and A could be interchanged, and a force equal and opposite to  $\mathbf{F}$  would then act on A from P. In this theory, action and reaction are equal and opposite.

It will be taken for granted that Kaufmann and, for that matter, innumerable other experimenters have observed and

\* "Electromagnetic Phenomena in a system moving with any velocity smaller than that of Light," Proceedings of the Amsterdam Academy, 1904.

† "Sur la dynamique de l'électron," *Rendiconti del Circolo Matematico di Palermo*, vol. xxi.

‡ *Annalen der Physik*, vol. xvii.

§ October 1907.

|| April 1907.

¶ Of course, on any strict conception of relativity such an apportionment would be impossible; but relative to the floor and walls of the laboratory, it is not only possible but highly convenient.

measured swiftly-moving  $\beta$  rays—that is to say, electrons moving with velocities well up to within a few per cent. of the velocity of light, or at any rate much in excess of half that velocity. Suppose, now, that two sources of  $\beta$  rays were set functioning in such a manner as to discharge the rays directly towards each other along a right line. The distance between the sources is quite immaterial so long as the  $\beta$  particles may be considered as subject solely to their mutual action without disturbance from other influences. With this arrangement,  $\gamma=0$ . If, for simplicity, it be imagined that only one  $\beta$  particle leaves each source, the two particles will move toward each other along the line joining them, and the force becomes merely

$$\mathbf{F} = -\frac{q^2(v^2 - u^2)}{r^2}.$$

If the rays are not too swift, that is, if their velocity relative to the experimenter is under half that of light, the total relative velocity is less than  $v$  and the force  $\mathbf{F}$  is negative—a repulsion, as is usual with negative charges. If, however, each particle has the velocity  $\frac{1}{2}v$ , their relative velocity is equal to  $v$  and the force  $\mathbf{F}$  vanishes at all distances. Inasmuch as the electron, on any theory, is generally supposed to travel with a uniform velocity unless interfered with, it would appear that in this case a collision were imminent. If, on the other hand, the rays were distinctly swift, their relative velocity would considerably exceed that of light and, indeed, might approach  $2v$ . In this case the force would actually be attractive and an impact would appear even more sure.

If, then, the formula (1) has been correctly interpreted, one of two consequences would appear to follow. Either *two  $\beta$  particles cannot be discharged directly toward each other with an arbitrary initial distance between them and each with a velocity greater than half that of light; or two particles so discharged would attract instead of repel.*

In practice, it would be impossible to discharge merely two particles, and we should have to consider the action of pencils of  $\beta$  rays. It does not seem, however, as if the main conclusions could be qualitatively upset, especially if the force on an electron is to be evaluated by summation over the individual particles acting. In this case of pencils of rays, there would be another interesting inference from (1). Consider, for example, two particles moving in opposite directions along parallel lines. Let the initial velocity of each particle be greater than  $\frac{1}{2}v$ , and for convenience it may be assumed that  $\frac{1}{2}u=0.578v$ . Then the force  $\mathbf{F}$  in (1)

will again be attractive when the particles are at great distances relative to the perpendicular distance between their paths. But here the denominator of  $\mathbf{F}$  has the form

$$r^2[1 - (1.155 \sin \gamma)^2]^{\frac{3}{2}};$$

and hence, when the position of the particles is such that  $\gamma$  is nearly  $60^\circ$ , the attractive force becomes enormous. In fact, when  $\gamma = 60^\circ$  and  $\sin \gamma = 0.866$ , the force is infinite; and when  $\gamma > 60^\circ$ , the force is neither attractive nor repulsive, but imaginary.

Without going into the question of the inertia of the particles, it would be impossible to state what would be their final configuration if they were started in such a position that  $\gamma < 60^\circ$ ; however, unless the inertia became infinite, an impact at an angle of less than  $60^\circ$  appears highly probable. It is conceivable that the inertia of both of the particles would be infinite when their relative velocity  $u$  was greater than  $v$ ; in which case the impossibility of discharging the particles in the manner proposed would follow. Bucherer, however, directly asserts (p. 419) that the masses are the same as those derived from the Maxwellian theory. What, therefore, the result of an attempt to start the particles with a velocity  $\frac{1}{2}u > 0.578v$  might be in the region for which  $\gamma > 60^\circ$  and the force is imaginary, is difficult to conceive.

The foregoing observations are not intended specifically as an objection to Bucherer's theory. It is quite possible, and even probable, that I have outraged his formula and mistaken his point of view, as he asserts in the current (March) number of this Magazine was the case with Cunningham. I should not, however, merely on that account abandon my position; for it seems to me as though, now that very swift  $\beta$  rays are a common subject of experiment, the question of relativity has an aspect somewhat different from that which it had previously. Either we can or we cannot obtain, with the swift  $\beta$  rays, velocities which, measured relatively, are greater than that of light. If we cannot, then some principle of relativity, analogous to Bucherer's new principle by which electrodynamics is based wholly on the relative motion of the electric and magnetic masses and the forces between systems are evaluated by summation of formulas like (1) extended over the masses constituting the systems, may stand; but if we can, then it appears that, unless this extreme form of the principle of relativity is abandoned, at any rate relative to swift  $\beta$  rays, there must ensue a veritable tangle of results fully as discordant as those which the principle hopes to avoid.

16 Lee Street, Cambridge (Mass.).