

Berlin-Grunewald, 20 July 1906

Most esteemed Professor,

Before anything else, I have to ask your forgiveness for the delayed answer to your friendly letter of 31 May, and even now I would still write to you at greater length if the sad fate of my close colleague P. Drude did not also have a depressing influence on me, my mood, and my time. Nevertheless, I hope even so to be able to lay out for you the essence of my views.

Your objections to the electron theory, if I understand correctly, are not directed at the fact that this theory takes an atomistic approach to electricity, but rather at the fact that it seeks to trace the concept of kinetic energy completely back to the electromagnetic theory's concept. I myself consider these efforts quite hopeless for the time being, but I nevertheless cannot entirely take your side, and indeed for the following reasons:

You say that the equation

$$\frac{dE}{dt} + \int \mathcal{E}v\rho dt = 0$$

contradicts the principle of conservation of energy as long as the integral $\int \mathcal{E}v\rho dt$ is different from zero. In this, you are entirely correct. Except for the electromagnetic energy \mathbf{E} , there is no energy at all according to the electron theory.

But I say that the integral $\int \mathcal{E}v\rho dt$ is equal to zero for every individual electron according to the electron theory, in the case that, as is necessary, one understands under \mathcal{E} the entire electrical field strength originating from the electron and from the other electrons. At base, leaving aside the designation of the same condition, this is what M. Abraham expresses in his equations (IIIa) and (IIIb) (*Ann. Phys.* 10, p. 118, 1903) and calls a “dynamic fundamental equation.” Each electron is always in equilibrium under the influence of the resulting internal

and external forces.* This gives rise to exactly as many equations for each electron¹ as the electron has degrees of freedom of movement.

Now, it is precisely these equations that you miss when you say in your 2nd objection that the electron theoretician's system of equations is incomplete. Certainly, one must demand that the velocities of the electrons are not given in advance but instead must be just as calculable from the given initial state as all other characteristics of the electromagnetic fields. But this happens precisely, and indeed unequivocally, by means of the "dynamic fundamental equation."

Your following objections are all extremely closely connected to these two,

* just as in the usual mechanics every material point is always in equilibrium under the influence of (external) force and inertial resistance ("internal"

force: $-m \frac{d^2x}{dt^2}, -m \frac{d^2y}{dt^2}, -m \frac{d^2z}{dt^2}$)

¹ Translator's note: "For each electron" is added above the line.

so I believe that I may leave off here for the time being. However, I urge you to tell me if you consider my remarks insufficient or unclear, for I would very much like us to understand each other fully on this point, which is indeed a very important one as a matter of principle.

With the best of greetings,

Your devoted

M. Planck