been to help to restore them to their rightful place as the greatest scientific generalization we have seen. But there has been a decided tendency to neglect them of late, and I am convinced that this has been due to the complexity of the mathematical processes associated with Maxwell's equations, which has obscured their simple physical basis and conclusions. Dr. Wilcken is to be congratulated on being able to make them easily intelligible to students, but quite recently a professor of physics at a leading London college told me frankly that he had never been able to understand Maxwell's electromagnetic theory of light, and I have found that considerable confusion exists among all with whom I have discussed it. The simplified treatment has given me a much clearer realization of the physical processes involved and has convinced me that Maxwell's conclusions were entirely sound although his equations were not completely fundamental.

Dr. Wilcken commences by objecting to my "abrupt" substitution of $j\frac{\delta}{\delta x}$ for Maxwell's curl function, and suggests that it was introduced as a quasimathematical device to give colour to a preconceived bias in favour of the flux-cutting principle. I admit and am sorry for the abruptness, but my article was a highly condensed epitome of a long unpublished paper and was intended merely to give an outline of the theory in the shortest possible space. According to my recollection and notes, the inspiration for the modified (apparently I must not say "simplified") equations arose from wrestling with the array of differential equations in Drude's "Theory of Optics"; and becoming tired of the effort I decided on examining the problem of electromagnetic wave propagation from first principles. The most simple way of doing so was to consider a forced electromagnetic disturbance created by moving a magnet with wedge-shaped gap with velocity V in a direction transverse to its magnetic field B and in a plane containing the normals to its plane faces; and it was easy to see that in this case curl $E = \frac{\delta E}{\delta x}$ as regards magnitude and that $\dot{B}\left(=\frac{dB}{dt} = \frac{\delta B}{\delta t} + \frac{\delta B}{\delta x}\frac{dx}{dt} + \frac{\delta B}{\delta y}\frac{dy}{dt} + \frac{\delta B}{\delta z}\frac{dz}{dt}\right) = \frac{\delta B}{\delta x}\frac{dx}{dt} = V\frac{\delta B}{\delta x}$; so that Maxwell's third equation-curl $E = \dot{B}$, becomes $-\frac{\delta E}{\delta x} = V\frac{\delta B}{\delta x}$, or $E = -VB$, if $E = 0$ when $V = 0$. Similar treatment of Maxwell's fourth equation, curl $H = 4\pi\dot{D}$, of course gave $\frac{\delta H}{\delta x} = 4\pi V\frac{\delta D}{\delta x}$, or $H = 4\pi VD = VJ$ if $H = 0$ when $D = 0$, and $J = 4\pi D$. As x disappears in the integration, the equations $E = -VB$ and $H = VJ$ are independent of the direction of propagation.

Up to this point, I had not considered the flux-cutting principle, but the correspondence of the equation $E = -VB$ with the dynamo designer's or flux-cutting formula of course struck me, and as I had long ago come to the conclusion that Faraday's rotating disk experiment showed that the induced E.M.F. was due to the cutting of the magnetic flux, it was apparent immediately that the equation $E = -VB$ was not a mere transformation of Maxwell's third equation but an expression of an independent experimental fact. Similarly Rowland's demonstration that a magnetic field was induced by the rotation of two oppositely charged disks or the cutting of an electrostatic field afforded experimental verification of the formula $H = VJ$. The two equations $E = -VB$ and $H = VJ$ may therefore be regarded simply as direct expressions of the results of Faraday's and Rowland's rotating disk experiments, and my original derivation of them by transformation of the Maxwellian equations, which I quite admit was not general, is of no importance except as showing a connexion between them. The equations $E = -[VB]$ and $H = [VJ]$ are completely general, and I hope to show that they are more fundamental.

As Dr. Wilcken does not like my employment of the quadrantal versor $\mathbf{j} = \sqrt{-1}$ to indicate the directions of the induced forces, on the grounds that it leads to confusion with its use in alternating current theory and with vector analysis, there is no objection to writing the four equations for an isotropic dielectric as $J = \varepsilon E$, $B = \mu H$, $E = VB$, and $H = VJ$, and leaving the directions to be determined by the ordinary rules. I fail to see, however, why students who are familiar with the use of $\mathbf{j}$ for alternating current vectors should be confused by its application to any other vectors.

I dissent entirely from Dr. Wilcken's remarks concerning the flux-cutting principle, but to deal with them and his complete misapprehension of my method of explaining the generation and propagation of an electromagnetic wave would take too much space for a note; and I propose shortly to submit a further article, which I hope will make the flux-cutting principle and its application quite clear and indisputable.

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Why do we have Winter Heating?

The layman will answer: "To make the room warmer." The student of thermodynamics will perhaps so express it: "To import the lacking (inner, thermal) energy." If so, then the layman's answer is right, the scientist's wrong.

We suppose, to correspond to the actual state of affairs, that the pressure of the air in a room always equals that of the external air. In the usual notation, the (inner, thermal) energy is, per unit mass,

$$u = c_v T.$$

(An additive constant may be neglected.) Then the energy content is, per unit of volume,

$$u^1 = c_v \rho T,$$

or, taking into account the equation of state,

$$p/\rho = RT,$$

we have

$$u^1 = c_v p/R.$$

For air at atmospheric pressure,

$$u^1 = 0{\cdot}0604 \text{ cal. cm}^{-3} = 60{\cdot}4 \text{ Cal. m.}^3$$

The energy content of the room is thus independent of the temperature, solely determined by the state of the barometer. The whole of the energy imported by the heating escapes through the pores of the walls of the room to the outside air.

I fetch a bottle of claret from the cold cellar and put it to be tempered in the warm room. It becomes warmer, but the increased energy content is not borrowed from the air of the room but is brought in from outside.

Then why do we have heating? For the same reason that life on the earth needs the radiation of the sun. But this does not exist on the incident energy, for the latter apart from a negligible amount is re-radiated, just as a man, in spite of continual absorption of nourishment, maintains a constant body-weight. Our conditions of existence require a determinate degree of temperature, and for the maintenance of this there is needed not addition of energy but addition of entropy.

As a student, I read with advantage a small book by F. Wald entitled "The Mistress of the World and her Shadow". These meant energy and entropy. In the course of advancing knowledge the two seem to me to have exchanged places. In the huge manufactory of natural processes, the principle of entropy occupies the position of manager, for it dictates the manner and method of the whole business, whilst the principle of energy merely does the book-keeping, balancing credits and debits.

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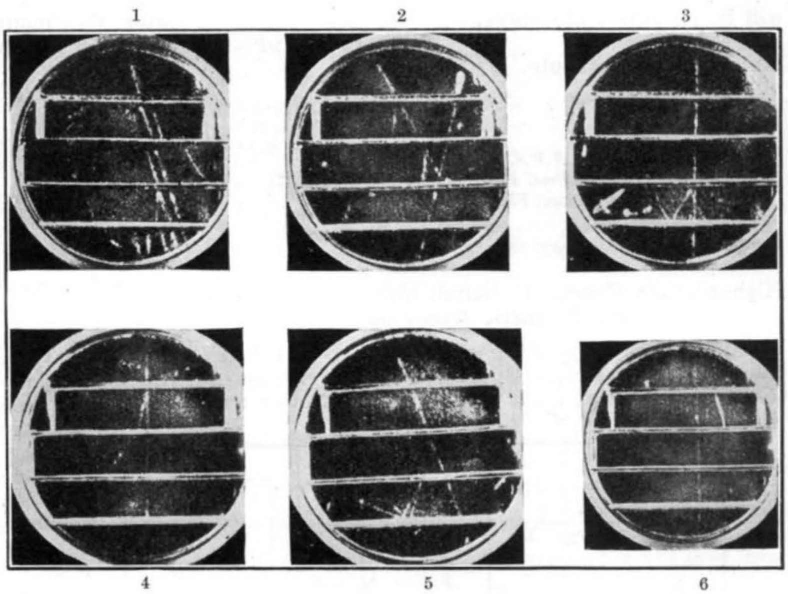
Secondary Effects of the Hard and Soft Components of Cosmic Rays

IT has been shown in a previous paper[1] that the major part of the electron showers produced in a lead plate are formed by a 'cascade process' in accordance with the shower theory proposed by Bhabha and Heitler[2] and Carlson and Oppenheimer[3]. Our experiments have been made with an automatic cloud chamber. Four lead plates of 3 cm. thickness are placed inside the chamber in a distance of 5 cm. A cloud chamber divided up in this way offers good opportunity of studying the way in which the showers are generally produced.

Fig. 1 shows a typical 'cascade process'. In later experiments two counters were used to detect the passage of the particles through the cloud chamber. One was placed above and the other below the chamber in such a position that any ray passing straight through both must also go through the chamber and the four lead plates. The intention was to study the production of secondaries when the primaries pass the lead plates and to make statistical investigations of their frequency in the various sections. Figs. 2 and 3 show some track photographs made in this way. Secondary, not ionizing, light quanta are here seen to have produced ionizing particles near the main ray.

A statistical examination of results, obtained without screening the chamber, gives the following result. Out of every 100 particles (hard plus soft radiation) passing the chamber, 30 were without visible secondary effect. 26 tracks were found in section I, 35 in II, 44 in III, and 45 in IV, the sections being numbered from above. The cloud chamber was then screened with an iron filter of 33 cm. in order to absorb the soft radiation. In this way it was possible to ascertain whether the hard radiation gave the same statistical results as the hard plus soft radiation. The following result was obtained: Out of every 100 particles of the hard radiation, 41 give no visible effect. 18 tracks were found in section I, 21 in II, 22 in III and 23 in IV. Thus the hard radiation gives considerably less secondaries than the hard



plus soft radiation. Assuming now that the 30 particles without visible secondary effect in the first experiment all belong to the hard component, we shall find, in agreement with experiments, that the soft component amounts to about 27 per cent of the total radiation at the earth's surface.

In order by these calculations to get a correct value of this distribution factor, we are furthermore forced to assume that the quantities of hard particles being transformed into soft particles in the filter are negligible. On this assumption, we can now calculate the statistical distribution of secondaries for soft rays alone. We will find that practically all the soft rays give visible secondary effects, and as distinct from the hard rays the number of secondaries increases rapidly from one section to the other in the downwards direction. The number of secondaries stated in this way seems to be in good agreement with the electron absorption theory of Bhabha and Heitler.

The theory has been proposed that the hard rays are electrons having an energy higher than some critical energy above which the quantum absorption theory is not valid. If this be correct, we shall have to assume that the iron filter will decrease the energy of some of the hard particles and in this way produce a new soft radiation component. Our experiments seem, however, to show that this cannot be the case, and consequently we shall have to conclude that the hard particles cannot be electrons.

As to the secondary effect of the hard rays, it might be mentioned that the secondaries most frequently form a branch of the main rays, as shown in Fig. 4. Secondaries—electron pairs and single rays—among which are found strongly ionizing nuclear particles, may, however, also appear at some distance from the main ray according to the effects shown in Figs. 5 and 6. Such cases show that the hard radiation also may be accompanied occasionally