Letters to the Editor.

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Collisions between Light-quanta.

THE equations which have been applied so successfully by A. H. Compton[1] and P. Debye[2] to encounters between electrons and light-quanta may be applied in a slightly modified form to an encounter between two light-quanta. It seems better, however, to consider first the result of supposing that the encounter results primarily in the production of a localisation of energy which can be represented by a moving particle of stationary mass m.

Assuming that quanta (of energies $h\nu$ and $h\nu_0$) moving initially along lines the directions of which may be specified by two unit vectors s and s_0, coalesce into a particle of mass m moving with velocity v, we have the equations

$$c(\nu s+\nu_0 s_0)=(\nu+\nu_0)v,$$
$$\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}=h(\nu+\nu_0), \quad . \quad . \quad . \quad (1)$$

where h is Planck's constant.

Drawing lines OA,OB of equal length c in the directions of motion of the quanta and a line OP of length v in the direction of motion of the particle, we notice that the points A,B,P are collinear and that $\nu\mathrm{PA}=\nu_0\mathrm{PB}$. The same construction applies also to the case in which a moving particle of mass m breaks up into two quanta travelling in the directions OA and OB.

It is a significant fact that the above construction is identical with one used previously by the author[3] in the study of certain electromagnetic fields in which electric poles or dipoles, travelling with the velocity of light, are projected from a moving point. This is, indeed, a slight indication that there may be some connexion between light-quanta and projected dipoles.

The construction is related also to Pauli's idea of normal co-ordinates.[4] By making a suitable Lorentzian transformation, it is possible to study two impinging entities relative to a system of normal co-ordinates in which their momenta are equal and opposite. This means that in our case the resulting particle will be stationary. The velocity v of the Lorentzian transformation is found to be identical with the velocity v defined by equations (1). The direction of the velocity may be determined by the following construction, which is sometimes useful. Let SQ,QS′ represent the momenta of the quanta in magnitude and direction, then SS′ represents the momentum of the resulting particle and $c(\mathrm{SQ}+\mathrm{QS}')$ its total energy. If the particle now explodes, producing two new quanta, the momenta of these quanta may be represented by SR,RS′ respectively, where Q and R lie on a prolate spheroid with S and S′ as foci.

A similar construction may be applied to two particles with stationary masses m and m_0 respectively. The total energies of the particles before the encounter are represented by $c\sqrt{m^2c^2+\mathrm{SQ}^2}$ and $c\sqrt{m_0{}^2c^2+\mathrm{S'Q}^2}$ respectively and, if the total energy and momentum of the resulting particle are given, the locus of Q is a spheroid, but this spheroid no longer has S and S′ as foci.

The first of the equations (1) arises also in the investigations relating to the lines of force of a moving electric pole,[5] and it may be that there is some way of applying the correspondence principle to the impact of pairs of quanta, using the electromagnetic field as a guide.[6]

If we suppose that a localisation of energy is produced temporarily by impinging quanta, the particle of localised energy may be built up from a number of collisions before an explosion occurs, which results in the emission of pairs of quanta. If the particle also contains localised energy in the form of electrons, an explosion may result in the emission of an electron and a quantum as in the Compton effect. Compton's equivalent velocity is, in fact, that of a particle which can absorb the electron and light-quantum without any change in its own momentum and emit them again without losing momentum. It is this particle which is the moving primary singularity when we wish to build up an electromagnetic field from scattered radiation and use the correspondence principle as Compton has done.

Since an electron is accelerated in an electromagnetic field, it seems likely that it absorbs quanta (or electric dipoles) one by one and normally emits them in pairs or in some manner which on the average amounts to this. In producing an electromagnetic field an electron may, in fact, emit an enormous number of dipoles in all directions in a very short time without losing momentum, and the simplest way of picturing this emission is to think of it as taking place in pairs so that the continuity of the motion of the electron is preserved. But this may be only a convenient mathematical device, and the electron in reality may be moving along a zigzag path while it emits dipoles one at a time. If this be the case, the emission of a single quantum in one direction differs only from the other emissions in degree, the quantum jump being simply a large step in the zigzag path. The question whether the quantum is to be pictured as a single dipole or a chain of such dipoles must be left open. Attempts have been made to form a theory in which groups or chains are built up of unit dipoles,[7] but the idea has also been found useful that two unit dipoles may combine to form a dipole of larger moment.[8]

The word dipole is used here as a convenient term for the elementary type of entity which produces electric force. It consists of two particles of electricity, if we adopt primarily as our definition of a particle of electricity, the simple one that it is an entity which theoretically can be recognised and specified mathematically by three parameters which remain constant during its motion.[9] H. BATEMAN.

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Pasadena, California, May 29.

[1] *Phys. Review*, vol. 21, pp. 207 and 483 (1923), vol. 23, p. 439 (1924).
[2] *Phys. Zeitschr.*, April 15 (1923).
[3] *Mess. of Math.*, May (1915), March (1918); Proc. London Math. Soc. (2), vol. 18 (1919), p. 95.
[4] *Zeitschr. f. Phys.*, Bd. 18, p. 272 (1923).
[5] *Amer. Journ. of Math.*, April (1917); F. D. Murnaghan; H. Bateman, *l.c.*
[6] The principle of Huygens suggests that collisions between the entities producing a radiation field may actually occur.
[7] *Phys. Review*, vol. 17, p. 64 (1921); Bull. Amer. Math. Soc., vol. 27, p. 217 (1921).
[8] Publications of the Astronomical Society of the Pacific, vol. 34, p. 94 (1922).
[9] Bull. National Research Council, vol. 4, Dec. (1922).

An Experimental Effect of Light on the Sponge, Oscarella.

THE spicule-less sponge, *Oscarella lobularis*, is an interesting form found on our shores and elsewhere, and presents a wide range of colour variation. Topsent (*Arch. de Zool. Exp. et Gén.* 3, iii., 1895) has recorded that Oscarella when found exposed fully to light is deep red, as when growing on the stem of the weed