Light-Quanta and Interference.

IN a very important and stimulating paper on the scattering of X-rays by light elements (*Phys. Review*, May 1923), Prof. A. H. Compton suggests that a study of the problem of scattering by atoms with tightly bound electrons and by groups of atoms may shed some light upon the difficult question of the relation between interference and the quantum theory.

In an investigation of this kind it may be useful to keep in mind an important difference between an electron and a light-quantum, which depends on the fact that generally most of the electron's energy is unavailable, while the whole energy $h\nu$ of a light-quantum seems to be available. This indicates, of course, that a light-quantum is a simpler form of matter than an electron or proton.

Roughly speaking, a light-quantum possesses a large amount of available energy and a small momentum, while a moving electron generally possesses a small amount of available energy and a comparatively large momentum. As a rule, then, we cannot expect a free or lightly bound electron to absorb the whole energy of a light-quantum. It is indeed possible, according to the theory of Compton and Debye, for an electron which encounters a light-quantum $h\nu$ to move away with a kinetic energy equal to $h\nu$ if the electron has an initial kinetic energy nearly equal to $h\nu$, but this case is not of much physical interest. When, however, an electron is tightly bound to an atom, so that some of the energy of an impinging quantum may be transformed into potential energy, there is a possibility that the whole energy of the quantum may be absorbed in a single impact.

If we admit that the energy of a quantum can be absorbed bit by bit, it does not follow that the type of absorption considered by Compton is the only one which can occur. Let us suppose that a quantum $h\nu$ after encountering an atom is transformed into a quantum $h(\nu - d\nu)$ travelling in the same direction as the original quantum. Assuming that the atom (of mass m) acquires the energy $hd\nu$ and momentum $hd\nu/c$ lost by the quantum, the centre of mass of the atom may be supposed to move forward with velocity $hd\nu/mc$ and a kinetic energy $h^2(d\nu)^2/2mc^2$, which is generally negligibly small in comparison with $hd\nu$. The acquired energy $hd\nu$ may therefore be energy of small oscillations about a state of steady motion. To ascertain the nature of these oscillations we represent the incident quantum by a field of type

$$E_x = H_x = 0, \quad E_y = H_z = \frac{\partial \Omega}{\partial y} f\left(t - \frac{x}{c}\right),$$

$$E_z = -H_y = \frac{\partial \Omega}{\partial z} f\left(t - \frac{x}{c}\right),$$

where
$$f(t) = \int_0^{2\pi\nu} \cos(pt + a) d\phi.$$

(See *NATURE*, April 28, p. 567.)

The emergent quantum may be represented by a field of the same type with $\nu - d\nu$ instead of ν , while the field which is really effective in producing the oscillations is the difference of these two, and is of the same type with

$$f(t) = \int_{2\pi(\nu-d\nu)}^{2\pi\nu} \cos(pt + a) d\phi.$$

When $d\nu$ is very small, this represents approximately a homogeneous train of waves of frequency ν . The small oscillations set up in the atom are thus specified approximately by a trigonometrical function of type $2\pi d\nu \cos(2\pi\nu t + a)$ and are practically undamped and of frequency ν . The phenomenon of interference may, then, be quite compatible with quantum theory, for it may depend really on an inter-

ference of small oscillations produced in the atoms by the quanta. If a number of quanta in phase strike the same atom, the small oscillation may become large and eventually result in a quantum jump, but the growth of an oscillation may depend, of course, on the phenomenon of resonance.

Since we have endowed a quantum with a field, a single quantum may produce small oscillations in a large number of atoms in accordance with Compton's idea, and so a second difficulty in the theory of interference may not be so great as it seems at first sight.

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A Mountain Mirage.

AS part of a magnificent view from Ben More of Mull on July 13, my sister and I saw a striking mirage on the Coolins of Skye. To begin with, Skye and all the Highlands to the eastward of it were covered by a level sheet of white cloud, with the highest peaks just showing clear and sharp above it. Then, starting from the sea, this cloud gradually melted away, and revealed a magnificent prospect extending far past the Coolins into the mountains of Ross. But as the cloud first melted it left the Coolins strangely transformed, each of their jagged crests drawn up into a fantastic spire. In the course of a very few minutes this effect died away and the Coolins took on their natural outline.

This was about 6.30 P.M., summer time. Presumably the mirage had some connexion with the cloud sheet; at one stage of its absorption the sheet must have been represented by a refracting layer, which would be very nearly at our eye-level. The air was remarkably clear, not only to the north but also to seaward. For some time a long line of the Outer Hebrides, from about South Uist to Barra Head, was visible, pale but perfectly clear-cut.

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July 18.

Probable Aeolian Origin of Greywether Sandstone.

ON reading Mr. C. Carus-Wilson's note (*NATURE*, March 3, p. 292) referring to the long tubular holes seen in sarsen stones, which he says suggest "the work of marine annelids, anterior to the consolidation of the rock," it struck me that some important light may be thrown on this subject by observations made on this side of the globe. First of all one might suggest that if these were annelid burrows they would have an average diameter, and there seems to be no evidence that the greywether sandstone, with its once softer siliceous matrix, was of marine origin. In Australia we have a great extent of country along the coast and inland, covered with dune formation, and these deposits enclose enormous quantities of vegetation. Plants that are growing on or near these dune areas, sometimes under swampy conditions, are covered over with sand, which is being blown about the stems of such grasses, reeds, and shrubs so as to completely enclose them. When the dune rock, some of which dates back to the early Pleistocene, has consolidated, a fracture reveals tubular holes which might suggest worms, but from their positions, at all angles, as well as vertical, and from their varied diameter and outline, are easily traced back to plant origin.

From many years' observations upon our Australian dunes, I cannot help thinking that here we have a similar process going on, which obtained during the arid interludes of the Eocene in the south of England.