Letters to the Editor.

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A Quantum Relation in Large Scale Electric Wave Phenomena.

It is well known that associated with a medium containing free electrons of mass m and charge e there is a definite critical frequency ν_o where $\nu_o^2 = \frac{Ne^2}{\pi m}$. This frequency is characterised by the fact that electric waves of frequency less than ν_o cannot travel through the medium.

The group and phase velocities of waves of greater frequency than ν_o are given by the relations :

$$V_{\text{phase}} = \frac{c}{\sqrt{1 - \frac{\nu_o^2}{\nu^2}}},$$

$$V_{\text{group}} = c\sqrt{1 - \frac{\nu_o^2}{\nu^2}},$$

so that they tend to ∞ and 0 respectively as : $\nu \longrightarrow \nu_o$.

This relation :

$$\nu = \nu_o \text{ or } \frac{Ne^2}{\pi m \nu^2} = 1,$$

which determines the critical frequency of the medium, can be expressed in a way which connects it up with the quantum theory. In a paper in the *Philosophical Magazine* (July 1926, vol. 2, p. 267) I showed how to calculate the ratio $\frac{4\pi h\nu}{\beta^2}$, which is the ratio of the total energy of a quantum (engaged in an encounter with an electron) to the energy per unit volume. This ratio must therefore be of the dimensions of a volume which, for want of a better expression, was called "The Volume Occupied by the Quantum."

The expression which represented this quantity was found to be :

$$\frac{e^2}{\pi \nu^2 m_o} = V \text{ say},$$

so that the relation giving the critical frequency can be expressed in the simple form $NV = 1$. Since $1/N$ is the average volume occupied by each electron, we may say that the critical frequency occurs when this is such that the 'volume occupied by the quantum' is equal to the average volume occupied by each electron. In order to conform with the ideas of statistical mechanics, of which long wave propagation appears to be an example, I prefer to consider that $NV = \nu_o^2/\nu^2$ represents the probability of a direct hit of the quantum and electron, or more precisely the fraction of quanta per unit volume which are in collision at any instant with the electrons in that volume. In the case of the critical frequency this probability is unity, and the relations of quantum mechanics gives a justification for the use of this description. For the analysis of the 'Compton scattering' shows that when a direct hit occurs the momentum given to the electron $M = \frac{h\nu}{c}(1 - \cos\theta)$, where θ is angle of scattering ; the average of which may be considered to be : $h\nu/c$ the momentum in the wave.

It follows that when the probability of a direct hit is unity all the wave momentum will on the average be given up to the electrons and the wave can travel no farther, this state of affairs resulting in the zero group velocity which occurs at the critical frequency.

In one respect this analysis seems to shatter the picture of a quantum as an objective particle of radiation, for such a picture would inevitably imply that the probability of a direct hit should be jointly proportional to the radiation energy density or density of quanta and the electron density, whereas the foregoing analysis shows this probability to be independent of the density of quanta.

This aspect of the quantum theory has already been pointed out by Eddington in his discussion of Einstein's derivation of Planck's law of radiation ("The Internal Constitution of the Stars," p. 56).

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Non-Magnetic Films of Iron, Nickel, and Cobalt.

A year and a half ago one of us (Ingersoll and De Vinney, *Phys. Rev.*, 26, 86, 1925) reported the results of some experiments on films of nickel cathodically sputtered in hydrogen at a pressure of 1 mm. or less. These films as produced were entirely non-magnetic, showing no tractive effects in a strong magnetic field. Upon heating to about 350° C. for a few minutes, however, they become strongly magnetic.

We have since continued this work on nickel and extended it to iron and cobalt, and find that, while it does not seem possible to produce non-magnetic films of these latter metals in hydrogen, they can be made in helium. Argon has also been used as a residual gas with nickel. In all cases heating for a few minutes to 350° or more in a vacuum—or, for that matter, passage through a bunsen flame in air—makes films of these three metals strongly ferro-magnetic.

The crystal structure of these films has been investigated by the X-ray method (iron and tungsten anticathodes). In the original work on nickel the evidence was to the effect that, while the film after heating showed the normal lattice for nickel, as originally produced it was amorphous, giving no clear evidence of crystal structure. In our recent work, however, we find—using an improved technique, whereby the crystal structure is determined without removing the film from the glass—that the film as produced (*i.e.* non-magnetic state) has in general the same crystal structure as after heating but *with a larger lattice spacing*. The distension or swelling may be so much as 20 per cent. In most cases the lattice shown by the film after it has been heated and rendered magnetic is the normal one for the metal : the exceptions may be explained on reasonable grounds.

The basis on which we are seeking to explain these facts is the occlusion by the metal of large amounts of the residual gas, *i.e.* hydrogen, helium, or argon, during the process of sputtering. Palladium, as is well known, absorbs in favourable circumstances hundreds of volumes of hydrogen, and, as has been shown (McKeehan, *Phys. Rev.*, 21, p. 334, 1923), this results in a lattice distension of some 2 or 3 per cent. It is true that it is a long step from this to the 6 to 20 per cent. distension we have found in many cases—and this too in metals such as iron, nickel, and cobalt, which are by no means so notable in their gas-occluding properties as palladium; nevertheless, it is the only explanation we can offer at this time.

If the presence of such large volumes of gas in these non-magnetic films be granted, although the direct experimental proof of its existence seems difficult