Letters to the Editor

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The Theory of Diffraction

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THE use of Kirchhoff's surface integral in the theory of diffraction has often been felt to be unsatisfactory, and many attempts at improvement have been made. The present state of the theory is described with references to Stratton.[1] These attempts, at the best, repair the deficiencies of the integral when the screen is perfectly absorbing or perfectly reflecting, and do not, I think, touch on the problem of a screen of any composition. Consideration of currents in sheets has led me to a more drastic process, valid when the wave-length is small.

Suppose that a wave falls obliquely on a sheet of small thickness d, and of dielectric constant ϵ and conductivity γ. If the wave-length is small, we can first solve the problem for an infinite sheet of thickness d and a plane wave, and then take the electric moments in the sheet as if they were finite and let them radiate like Hertzian oscillators. If γ is very great, the moments are all in a thin layer on the surface. In that case, a primary wave $A \cos (\omega t - kr_0)/r_0$ from P_0 (of any polarization) gives rise to a secondary wave $A \cos \varphi \sin (\omega t - kr - kr_0) dS/\lambda r r_0$ at Q, where dS is an element of the diffracting screen at P, φ the angle of incidence, $r_0 = P_0P$, and $r = PQ$. This is Kirchhoff's formula in the most important case of direct vision, the only case in which it is confirmed. Consideration of space compels me to forego details, which will be found in a book on *Currents in Aerials and High Frequency Networks* to be published shortly by the Clarendon Press, Oxford. If we have a small hole instead of a screen, and a plane wave, the current per meter in the perforated sheet is the same as in the hole. The electrical effect of the two is nearly that of a complete sheet, which below the sheet is equal and opposite to that of the incident light. This is Babinet's principle, a natural consequence of the smallness of the wave-length. I have investigated the diffraction of a sheet of dielectric constant ϵ and conductivity γ at any angle, but the results are complicated. In treating the problem this way we are treating the physical phenomenon as it is, and determining the electrical state of a diffracting screen at all points of it. Such a spoint of view must, I think, ultimately replace the delicate and restricted methods based on Kirchhoff's integral.

[1] Stratton, *Electromagnetic Theory* (McGraw-Hill Book Company, Inc., New York, 1941) pp. 460–70.

Hρ-Distribution of Fission Fragments

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AS was reported earlier,[1] the total charge of fission fragments has been determined by deflecting the fragments from a thin layer of uranium in the magnetic field of the Copenhagen cyclotron. The uranium was placed inside the cyclotron about 6 mm behind an internal target of beryllium which was bombarded by 6 Mev deuterons, thus being a strong source of neutrons. The dimensions of the uranium layer were: width 1.0 mm, length 20 mm, thickness 0.35 mg/cm²; it was placed parallel to the lines of the magnetic force and the fragments used were emitted nearly normally from the surface. They passed through a slit S_1 of variable width placed 10 cm from the uranium layer and through a second slit S_2 10 cm further away; the latter had a fixed width of 3.0 mm and was covered by a foil of thickness 0.79 mg/cm² of mica and 0.25 mg/cm² of aluminium through which the particles entered into an ionization chamber filled with pure argon. The collecting electrode of the chamber was connected to a linear amplifier and this in turn to a cathode-ray oscillograph, which was photographed on a moving film. The slit S_1 could be moved in a direction normal to the plane determined by the uranium layer and the window S_2; the various positions of this slit then allowed particles with various values of Hρ to pass from the uranium layer to the ionization chamber. For all positions of the slit was seen a background consisting of a great number of pulses due to recoiling argon atoms in the ionization chamber; but only when the slit S_1 was displaced between 7 and 14 mm from the plane through the layer and the mica window S_2 pulses of much higher energy corresponding to fission fragments occurred.

As more fully reported,[1] the Hρ-distribution curve for

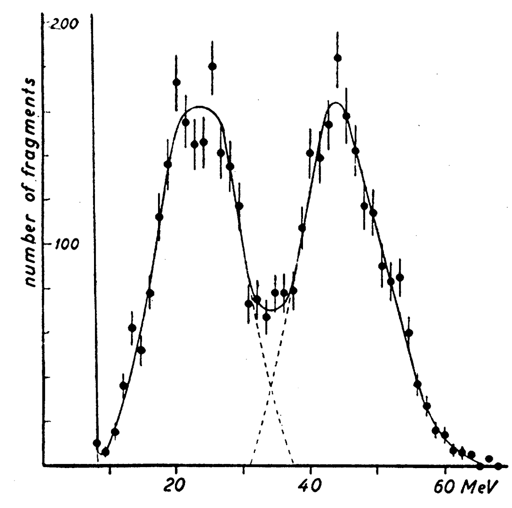

FIG. 1. Energy distribution of fission fragments having traversed 0.79 mg/cm² of mica.

the fission fragments was determined in this way. Later on, small improvements of the apparatus have made it possible to measure the Hρ-distribution for each of the two groups of fission fragments separately.

Figure 1 shows the energy distribution as obtained when

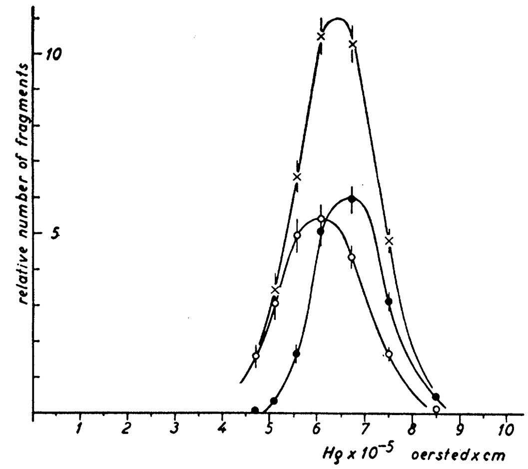

FIG. 2. Hρ-distribution of fission fragments. Full circles: light group. Open circles: heavy group. Crosses: Both groups.

the slit S_1 was made so wide (7 mm) that the fission fragments entering through S_2 could have all possible values of Hρ. The figure clearly shows that, apart from a very few exceptions, the pulses of energies higher than 34 Mev are caused by fragments of the light, most energetic group, while the fragments of the heavy group correspond to pulses between 9 and 34 Mev; pulses of energies lower than 10 Mev are caused by coincidences between recoiling argon atoms. In the Hρ-measurements the slit S_1 had a width of 1.0 mm and it was moved in steps of 1.0 mm; for the different positions of S_1 the number of fragments were counted, of course for equal neutron doses, and by means of the photographic record divided into two groups corresponding to the sizes of the pulses. In this way we get the number of fragments of each group as a function of the displacement of S_1 and we then calculate by means of the known magnetic field (which is not homogeneous) the Hρ-distribution curves shown on Fig. 2.

As seen, the two groups have nearly the same values of Hρ, but the light group has evidently slightly higher Hρ-values than the heavy one. Putting the most frequent value of mE to 8.5×10^3 mass units$\times$Mev[1] we get for the total charge of the light and the heavy group 20ϵ and 22ϵ, respectively, when ϵ denotes the electronic charge. This is in agreement with calculations by Professor Bohr[2] which predict an effective charge of fission fragments of about 20ϵ; yet the agreement is not perfect, as the theory involves a higher effective charge of the light group than of the heavy one in contradiction to the present experiments. Nevertheless, it is no real disagreement; as pointed out by Professor Bohr in the paper, the total fragment charge need not be identical with the charge effective in electronic interactions.

The author wishes to express his heartiest thanks to the Director of the Institute of Theoretical Physics, Professor Niels Bohr, and to Professor J. C. Jacobsen for their interest in the work and their great encouragement.

[1] N. O. Lassen, Kgl. Danske Vid. Sels. Math.-Fys. Medd. **22**, No. 2 (1945). In press.
[2] Niels Bohr, Phys. Rev. **59**, 270 (1941).

The Synchrotron—A Proposed High Energy Particle Accelerator

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ONE of the most successful methods for accelerating charged particles to very high energies involves the repeated application of an oscillating electric field, as in the cyclotron. If a very large number of individual accelerations is required, there may be difficulty in keeping the particles in step with the electric field. In the case of the cyclotron this difficulty appears when the relativistic mass change causes an appreciable variation in the angular velocity of the particles.

The device proposed here makes use of a "phase stability" possessed by certain orbits in a cyclotron. Consider, for example, a particle whose energy is such that its angular velocity is just right to match the frequency of the electric field. This will be called the equilibrium energy. Suppose further that the particle crosses the accelerating gaps just as the electric field passes through zero, changing in such a sense that an earlier arrival of the particle would result in an acceleration. This orbit is obviously stationary. To show that it is stable, suppose that a displacement in phase is made such that the particle arrives at the gaps too early. It is then accelerated; the increase in energy causes a decrease in angular velocity, which makes the time of arrival tend to become later. A similar argument shows that a change of energy from the equilibrium value tends to correct itself. These displaced orbits will continue to oscillate, with both phase and energy varying about their equilibrium values.

In order to accelerate the particles it is now necessary to change the value of the equilibrium energy, which can be done by varying either the magnetic field or the frequency. While the equilibrium energy is changing, the phase of the motion will shift ahead just enough to provide the necessary accelerating force; the similarity of this behavior to that of a synchronous motor suggested the name of the device.

The equations describing the phase and energy variations have been derived by taking into account time variation of both magnetic field and frequency, acceleration by the "betatron effect" (rate of change of flux), variation of the latter with orbit radius during the oscillations, and energy losses by ionization or radiation. It was assumed that the period of the phase oscillations is long compared to the period of orbital motion. The charge was taken to be one electronic charge. Equation (1) defines the equilib-