The results are interesting since they give the dependence on the shape of the body of the frequency at which the total magnetic moment of the ellipsoids shows resonance. In the calculations the dimensions of the ellipsoids are supposed to be small in comparison with the wave-lengths of the wave-lengths of the electromagnetic waves inside the material. A further application is the calculation of the index of refraction of an electromagnetic wave propagating through a (infinitely large) specimen of non-conducting magnetized ferromagnetic material. We have found that for every direction of propagation and for every frequency there exist two different, elliptically polarized waves with different indices of refraction. The refractive index of one of these two waves shows a resonance phenomenon at a frequency given by

$$\omega^2=\gamma^2 H_i(H_i+4\pi M_0 \sin^2\vartheta).$$

ϑ is the angle between the direction of propagation and the z axis. The other wave does not show resonance. In the special case $\vartheta=0$ there are two circularly polarized waves, and in the case $\vartheta=\frac{1}{2}\pi$ there are two linearly polarized waves. The extension of the theory to conducting materials is simply performed by the introduction of a complex dielectric constant in Maxwell's equations. A fuller account of our calculations will be given shortly.

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A Low Voltage Discharge between Very Close Electrodes

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When a condenser, charged to a potential between 15 and 60 volts, is discharged by two electrodes, a pit is formed on the positive having a volume approximately equal to the volume of metal which could be vaporized by the energy in the condenser (Fig. 1); the negative electrode shows on its surface the presence of metal spattered over from the positive. The pit can be reduced in size, or eliminated, by the addition of resistance or inductance to the circuit or by operating the contacts in vacuum. For voltages below 15 the pit is much smaller or non-existent; for voltages above 60 the discharge, which produces the pit, may be oscillatory and the difference in appearance between the two electrodes then tends to be lost. This vaporization of anode metal is one of the major factors in the erosion of telephone relay contacts.

The pit formed on the anode is the result of the melting and boiling of the metal caused by electron bombardment before the electrodes touch. Field emission from the cathode can supply the first electrons, but pure field emission would dissipate the energy over a time too long to result in marked local heating. To account for this heating, and for oscilloscopic records which have been obtained, it is necessary to assume an "avalanche" effect by which the emission is multiplied and the condenser is discharged in an enormously reduced time. For energies with which we

FIG. 1. Photomicrograph of a pit in platinum produced by a discharge of 11 ergs. Pit diameter about 5×10^{-4} cm.

have experimented, the total time of discharge must be less than 10^{-7} sec. Careful measurements of the separation at which the discharge occurs have shown it to be variable, from 500 to 20,000A for 50 bolts, apparently depending chiefly upon the roughness of the surface. In most of our experiments the discharge occurs at a separation less than the diameter of the anode pit which it forms, and the evaporated metal often welds the electrodes together.

When a positive ion, formed in the air or upon the anode surface by an electron which was drawn out by the field, approaches the cathode the field is appreciably increased by its presence. Since the field was already almost strong enough to draw out electrons, this further increase at once elicits a second electron. The new electron is, in general, drawn straight across to the anode, and will not in most cases combine with the ion as it would in the absence of the applied field. While the electron is between the ion and the surface, they produce together a net field opposing further emission, but as soon as the electron passes the ion the field is again directed in the sense to draw out an electron. Thus one electron at a time escapes from the cathode until the ion is neutralized or until it reaches the cathode. The fact that the energy is dissipated almost entirely upon the anode is proof that the current is carried chiefly by electrons and that therefore each positive ion must give rise to several electrons at the cathode.*

If each of these electrons were to produce one ion, the current would increase with enormous rapidity. Now residual inductance in the circuit, even though it be as low as 10^{-8}h, limits the possible rate of rise of current and holds the voltage across the gap steady at a value which gives to an electron a probability of ionization considerably less than unity and an over-all electron multiplication factor, by the double process of production of an ion for each few electrons and of several electrons for each ion, extremely close to unity. This corresponds to a gap potential probably very near to the ionization potential of oxygen; with this fixed potential across the gap for the duration of the discharge, the circuit is quite simple and its behavior is readily understood.

* Instability of "field emission" in the presence of residual gas is well known. An explanation approximately like that given here was suggested by W. H. Bennett, Phys. Rev. 40, 416 (1932). There seems to us little doubt that that suggestion was correct.

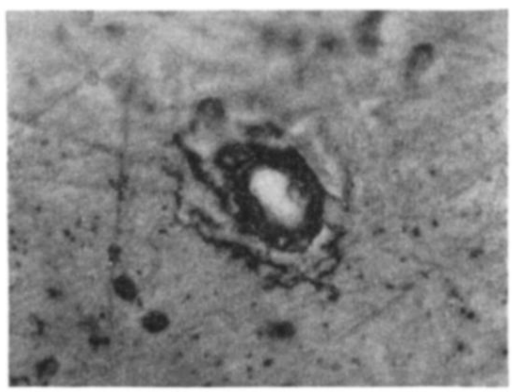

FIG. 1. Photomicrograph of a pit in platinum produced by a discharge of 11 ergs. Pit diameter about 5×10^{-4} cm.