CHAPTER IX

On the General Theory of Ether Waves

IN Chapters II and III I have gone over the early past history chiefly in order to recall to your attention the extraordinarily brilliant work of Clerk Maxwell. It was not of a kind to get into the newspapers or to be understanded of the people. But in the students of those days—I mean the students of mathematical physics—it aroused the utmost enthusiasm; and it is well that this mighty work in pure science should not be forgotten and overwhelmed in the mass of practical detail and exuberant invention which is a characteristic of the additional developments in our own day. "All can raise the flower now, for all have got the seed." But it is well occasionally to think of what we owe to the sowing of that seed, as sprinkled in algebraical symbols on the pages of Clerk Maxwell's papers, and incorporated, some of them, in his great book.

Since that time Sir Joseph Larmor has shown that Clerk Maxwell's equations contain the whole theory of radiation, due to the relation between electric charge and the ether of space. He has also shown that radiation is always

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excited to a known extent whenever an electron is accelerated, and that without electric acceleration there is no radiation. I must just give Larmor's expression for the radiation of energy, because it is very fundamental. It is :—

$$\dot{W} = \frac{2\mu}{3c}(e\dot{u})^2$$

This gives the energy radiated per second from an accelerated electron, where e is the charge of the electron ; c is the velocity of light ; $\dot{u}$ is the mechanical acceleration ; and μ the magnetic constant of the ether.

Why is that expression so important ? It is because it is exceedingly general and comprehensive. Radiation of so many kinds is known—X-rays, wireless telegraphy, light, radiant heat—all these obey that law—there is no radiation if an electron is not accelerated. There are three possible states : an electric charge stationary is one of them, an electric charge at steady speed is another, an electric charge with varying speed, or acceleration, is another. You have the three great departments of the science. Static, kinetic, oscillatory. In the first the charge is at rest, i.e. ordinary static electricity. In the second the charge is in motion—steady motion—that is, current electricity and magnetism. Directly

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a charge is put in motion you get magnetic lines surrounding the path of the charge. That is all that magnetism is: you don't get any magnetism unless there is a moving charge. In the third, the charge is accelerated, and that is light, because in any oscillation there must be acceleration. The connexions between these three groups are indicated in the table :—

Charge at Rest	Charge in Motion	Charge in Accelerated Motion
Static	Kinetic	Oscillatory
Electricity	Magnetism	Optics

Wherever you have acceleration, and therefore whenever you have oscillation, you must get radiation to an amount which depends upon the frequency in the way I have been explaining, and the amount of energy radiated depends upon the square of the acceleration—i.e. upon $\dot{u}^2$ ($\dot{u}$ being the first time-differential of the velocity u). If an electron is moving steadily it does not radiate at all, it does not lose any energy—a magnet loses no energy. When its velocity changes, it radiates energy depending on the square of the acceleration. It must, however, be admitted that the acceleration to be effective involves a change of speed: steady

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circular motion does not radiate. In that respect Larmor's theory has to be modified, in the light of later knowledge.

It has also to be supplemented. For early this century a step of revolutionary and surprising importance was made, in the detection by Prof. Planck, of Berlin, of the quantum. We all hear about the quantum: we do not hear so much about the quantum as we do of Einstein, but it is, nevertheless, a very important thing in physics. It is that curious and unexpected phenomenon which prevents free and easy radiation of energy, and causes it to be emitted in packets or bundles in a numerable manner—by which I mean that the packets can be counted—and that no fraction of a packet can be got. It is rather like buying postage stamps. You may buy any number but not half a stamp; or it is like coins of the lowest denomination, you can pay with any number of them but you cannot have fractions; so that it seemed as if energy was given to us in quantum units or packets, but no fractions—if you could not have a whole quantum you could not have anything. If an atom cannot emit a whole quantum of energy it does not lose any energy at all. But quanta are not of fixed size: their magnitude depends on radiation frequency. A long-

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wave quantum is quite small, and it is easy to emit such; but to emit a short-wave or really big quantum demands violence or high temperature.

The quantum thus brilliantly discovered in physics is a fundamental constant of Nature, and we now see that it must depend somehow on the properties of the atom. Although a great deal has been said in the other direction I contend there is no discontinuity in the ether or in energy or in time, but there is discontinuity in a group of electrons, and in the atoms which are built of electrons, and, accordingly, in atomic theory the quantum is of fundamental importance, and in the hands of Prof. Böhr, of Copenhagen, has begun to solve the secret of atomic constitution. Prof. Böhr's work is well known to those who know it, and too elaborate for anyone else. But it is the needed supplement to Larmor's theory, and the quantum may be said to be the first vital and fundamental discovery in the region of electromagnetism since Clerk Maxwell; for all the rest of the theory of electricity, magnificent and extensive as it is, may be regarded as a legitimate development of those astonishing equations which contain within themselves a great part of the secret of the ether, except in so far as it is modified and sophisticated by the presence of the discontinuities of matter.