CHAPTER XXII

Comparison of the Absolute Magnitudes of Capacity and Inductance

I PROPOSE to prelude some calculated and practical considerations by a little theoretical point of some interest. For wireless workers and amateurs surely like to think occasionally of the ether whose properties they are utilizing.

In electro-magnetic waves the electric energy and the magnetic energy are equal; or, in more general terms, in every wave, or system of waves, the kinetic and the potential energies are equal. This is obvious, because (at any given spot) the energy alternates from one form to the other. At one instant it is static; at the next it is kinetic. Hence the two energies must be equal.

So it is, also, with the discharge of a Leyden jar, or any other capacity area. At one instant it is charged electrically, and at the next (that is, after a quarter swing) it is momentarily discharged, and all the energy is contained in the rushing current. Then, once more, the energy piles itself up statically in the opposite direction, and then swings back again. So it

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is even in a swinging pendulum: the potential energy at the end of the swing is equal to the kinetic energy in the middle. So it is, also, in a vibrating spring.

Consider, then, a spring with a load on it which you can set vibrating. At the extremity of the swing the energy can be called elastic energy, or the energy of recoil. It is static. It depends on the elasticity of the spring; it does not depend on the inertia of the load. It does not depend on inertia at all; it would be the same if the spring were bent an equal amount and not loaded.

But now let the spring go, and consider what happens as the load is rushing past the middle position. The whole energy is now the energy of movement. It depends wholly on inertia—that is, on the massiveness of the load—it does not depend on the elasticity of the spring at all. It would be just the same for the same moving load if the spring were instantaneously abolished.

This energy may be called inertia energy, or the energy of current or movement. The elastic and the inertia energies must be equal. The spring adapts itself to them. Its rate of vibration is thereby determined. If it is a very stiff spring with a small load, it will vibrate with extreme rapidity. It must, in order that the motion energy can equal the elastic energy. If, on the other hand, it is a weak spring heavily loaded, it will vibrate very slowly; because, since the energy is small, the motion of a massive body must be slow.

All this is very elementary and simple mechanics; but now apply it to the electrical analogy. Are we to regard a Hertz vibrator or a wireless sending station as represented by a stiff spring and a light load, or a feeble spring and a heavy load? Or, again, should we not rather try to arrange it so that the spring is moderately stiff and the load moderately massive, the one being adapted to the requirements of the other, and neither being over-balanced by the other?

Now, in the electrical case, the oscillating thing is a group of electrons. They are very highly charged, but they are certainly not massive. They possess a kind of inertia due to the magnetic field which surrounds them when they are in motion. But the magnetic field due to a moving charge is but feeble, unless the charge is great and the motion exceedingly fast.

Now, the electrons, though not massive, are highly charged, and they are presumably moving very quickly. Hence their current or magnetic energy is by no means negligible. But to bring it up to the required amount we must magnify it by coiling up the path of the electrons into a close spiral, so that all the magnetic fields reinforce each other and give a large, combined result. In that way, by the use of a sufficient coil, we may make the inertia what we please, and obtain the required amount of kinetic energy.

Now, what about the static energy? Here we must regard the ether as strained, probably sheared, so as to call out what is analogous to rigidity. And the ether's rigidity is excessively high. We know that, because of the rate at which light travels. Its elasticity, compared with its density, is accurately determined as equal to the square of the velocity of light; that is to say, the ratio of the two is excessively great.

A very small amount of distortion will account for a great amount of energy. But, to make room for all the electrons which are to take part in the discharge, an extensive area is required. If we use only a small area, we can hardly get any charge in it. It is like trying to bend a very stiff spring.

A tuning-fork, for instance, can be excited by a blow, or by a succession of timed impulses in synchronism with its natural period, which

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is practically what a violin bow does. Such a bow grips and releases a string or a spring in a synchronous, and therefore effective, manner. But a tuning-fork hardly yields to a steady pull. The amount a small force can thus bend the prong of a stiff fork is insignificant. To be able to bend it sufficiently the spring must be long, and the greater the rigidity of the material the longer it must be. That means that, to get an effective capacity area, it must be of large extent.

The aerial must be the most visible and conspicuous item in a telegraph station. On the other hand, the coil responsible for the magnetic energy may be quite small; we might even say the smaller the better, within certain limits. The capacity area should be quite big; we might almost say the bigger the better, again within certain limits.

There is no doubt a best relation between the size of the capacity area and the size of the inductance coil, and this relation is determined by the fact that the electric and magnetic energies must be equal. A great margin of variation is permissible, just as is the case in musical instruments, which may vary from the stiffness of a tuning-fork to the laxness of the column of air in a flute, with all manner of strings and reeds as intermediaries.

So it is with a telegraph station. One person may be working with a small capacity and a big self-induction, while another one may be working with a great capacity and a small self-induction; and yet both may have the same period of vibration. Indeed they will have the same period if the product of capacity and inductance is the same for both. But there is sure to be a best relation between the two things which, however over-ridden in practice, it may be instructive to consider.

And it is specially instructive to realize that the great size of the aerial, as compared with the small size of the coil which is in circuit with it, is an immediate consequence of the relation which exists between the two properties of the ether, its elasticity and its density. One is incomparably bigger than the other. The ratio, in c.g.s. measure, is 10^{21}. Hence we may think that the ratio between the size of an aerial—which depends on the ether's elasticity—and the size of the little coil—which depends on the ether's density—is also of something like the order 10^{21}.

No; it can hardly be as big as that, even with the best possible arrangement. But it is legitimate to regard that as a sort of ideal, and to emphasize the importance of a big as well as of a high aerial, and of a small, compact coil.

The size of the aerial has to be fixed by practical and often financial considerations. The size of the coil is at our disposal, and must be determined by the rapidity of vibration—that is, the wave-length that we want. And it must be adjusted so as to give this wave-length when worked in combination with the given aerial.

That, then, is the problem before us. Given an aerial of definite capacity, and required a certain wave-length, whether for receiving or for emitting—but especially we will consider receiving,—what sized coil shall we use, and what wire shall we wind it with?