An introduction to modern Influence

Vocabulary issues

The name "Influence" and the corresponding adjective "influence" were widely used in the past to describe the effects of an electric charge on a distant material body (conducting or not). These terms were mainly associated to electrostatic machines[1]. These machines were used in the eighteenth century to produce high-voltages mainly for amusement. A few of these, like the Wimshurst machine and the Van de Graff generator, are still present in modern laboratories. In a typical university curriculum in the USA, these old machines are barely studied and distant effects of electric charges are often designated by the confusing term "electric induction". In parallel, magnetic effects are also improperly called "electromagnetic induction". For complete accuracy, since "electric induction" designates the effect of electric charges or, more generally of an electric field on a distant electrical circuit this effect should be called "electro-electric induction". Its magnetic counterpart, the effect of a magnetic field on a distant electric circuit should be called "magneto-electric induction" as coined originally by Faraday. (Ref: Science In The Making: Scientific Development As Chronicled Historic Papers, edited by E. A. Davis)

For clarity and simplicity we will call "**Influence**" the non-contact effect of electric fields on electric circuits and "**Induction**" the non-contact effect of magnetic fields on electric circuits. Note that by non-contact we designate distances that may range from a fraction of the size of the device (a few mm for instance) to several times the size of the device (such distances can be as large as light-years for some galactic processes).

[1] See for instance John Gray "electric influence machines" or for modern reconstitutions see the wonderful job Dr. Antônio Carlos M. de Queiroz .

From static to dynamic

It is quite common to find expressions like electrostatic motor or electrostatic sprayer. Surprising isn't it? How can a motor or the acceleration of droplets of paint or ink be static?

One may argue that while the mechanical aspect is dynamic, the electric one is static. This is also incorrect as some electric current must be flowing to provide the mechanical output. Here again the vocabulary in use is a serious obstacle for a clear understanding.

What many scientists mean when they use the term quasi-static in electromagnetism (and in EM only) is that no EM waves are generated at some distance[2]. However it is like saying that the compression and later sudden expansion of gas driving the motor engine in your car is quasi-static whereas the song of a nearby bird belongs to dynamics.

Here again the use of "Influence" and "Induction" to describe dynamic systems that do not radiate energy far away seems a much more appropriate choice.

How energy & power can be transferred at some distance by Influence

What is fascinating with Influence and Induction is the possibility to transfer energy at a distance without involving waves. Let's explain simply how this is possible for Influence.

The starting point is the astonishing electrical action at a distance quantitatively studied by Coulomb but known centuries before. Consider the configuration of figure 1 where two charged pendulums are at equilibrium position under the influence of the electrostatic force and gravity.

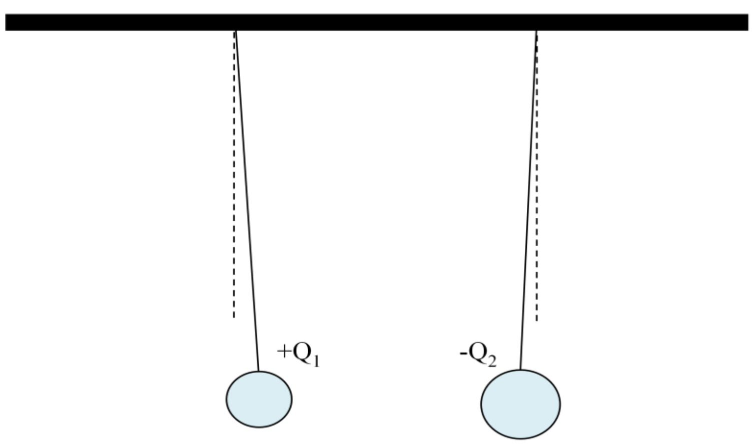

Fig. 1- Attraction between two distant charges

[2] To be more accurate it is possible to show that a part of the equations, those enabling the computation of the external electric field remains quasi-static.

Two electric charged bodies with same polarity repel whereas oppositely charged bodies attract. The particularly surprising thing with this force is that it prevails even through vacuum and to arbitrarily large distances[3]. In practice the force gets rapidly so weak that it is no more possible to measure it. However the electric force increases with the magnitude of the charge. For instance, if it was possible to remove all the electrons in the plasma of a star, the electrostatic field would have been measurable over several light-years. Electric forces are of much larger magnitude than gravity forces between any known pair of elementary charged particles.

In practice, however, it is not possible to consider very large charge densities due to dielectric breakdown effects in surrounding matter that bring the system closer to electrical neutrality. This is particularly true under standard air atmospheric conditions where the maximum obtainable electric forces between charged body is very small compared to the force experienced between two low cost magnets at comparable separation. However, we will explain below why this is no more a problem for today’s technologies.

The next step in our understanding of wireless power transfer is to consider what happens when you set one charge into oscillation, taking care not to touch it with the finger if you don’t want to remove the charge it carries. You may for instance use some air blower or act on the thread suspending the charge. You will observe that the other charge will progressively start to oscillate. Simultaneously the amplitude of the first one will decrease (fig. 2).

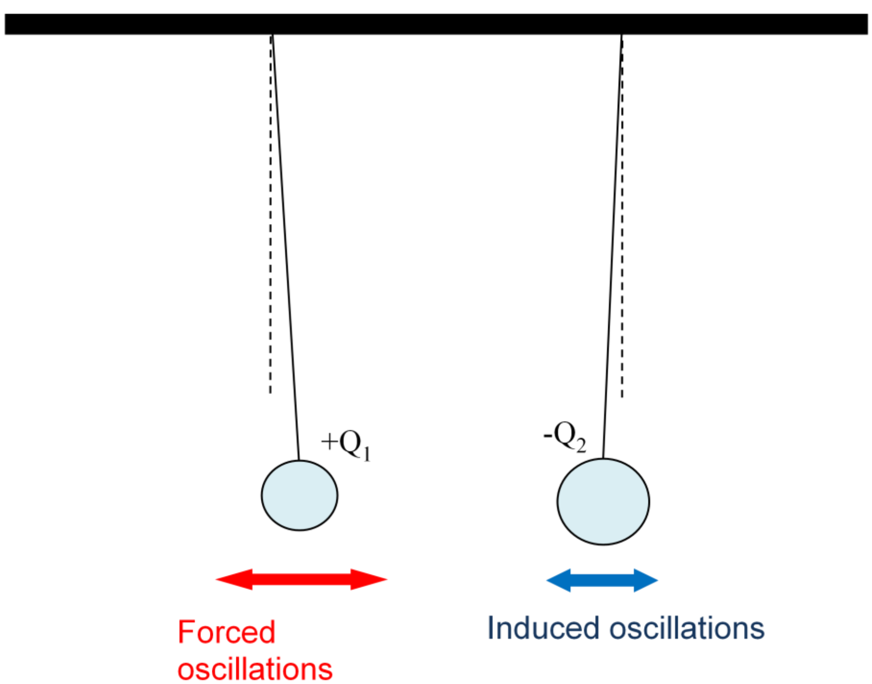

Fig. 2- Mechanical energy is transferred at a distance

[3] Provides involved frequencies are small enough.

This experiment shows that energy is transferred from the first pendulum to the second one. Besides, if the pendulums have large quality factors (if the isolated pendulum completes a large number of cycles before damping reduces its amplitude appreciably), it is possible to see that after a moment the first pendulum will stop to oscillate whereas the second one will oscillate with roughly the same amplitude the first one had when set into motion. At this particular moment all the energy will be transferred to the second oscillator. In following moments, energy will flow back to the first oscillator, showing that apart from viscous effects no energy was lost in the process.

Another very interesting observation is possible: If the distance between the two pendulums is increased, all the energy can still be transferred but will take a longer time. In the end, the range is only limited by viscous losses (the quality factors) and the time available for the transfer of the whole energy (that eventually becomes a power level limitation).

To summarize, the previous pendulum arrangement shows that **energy (and power) could be transferred at some distance by an electrical force in a longitudinal manner (along the axis of the oscillating device) and to a distance only limited by viscous losses and power level considerations**.

Now what about power level figures? We have explained previously that electric forces are very small, with the result that the amount of energy transferred for an alternation is also very small. But if you imagine a system that is not oscillating slowly like pendulums but **at megahertz rates, you can achieve power transfers millions of times larger, allowing a shift from the milliwatt to the kilowatt range**. However, before arriving at this result, we must find a way to switch from mobile systems to solid states ones.

The third step in our understanding is to replace the second pendulum by an elongated conducting material mechanically immobilized to a fixed support[4]. Let's assume that this body is originally uncharged. Now imagine the charged first body (not necessarily a conducting one) is brought close to it. Experiments made in the eighteen century with electrometers have reported that some charge where now present on the conductor, positive on one side and negative in the other side (fig. 3). This effect gave birth to the concept of "Influence" and to associated machines.

[4] Not able to oscillate mechanically but still insulated from ground.

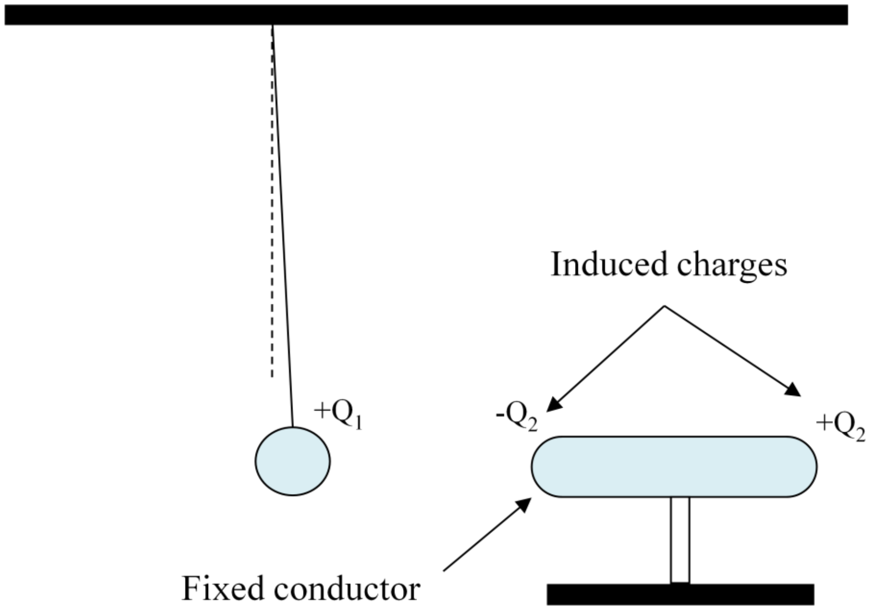

Fig. 3- A charge influences charge distribution on a distant conductor

In other words; **the mobile charge has induced some charge displacement on the fixed distant conductor**.

Let's now consider mechanical oscillations of the mobile charge; it will obviously lead also to charge oscillations in the distant fixed conductor (Fig. 4).

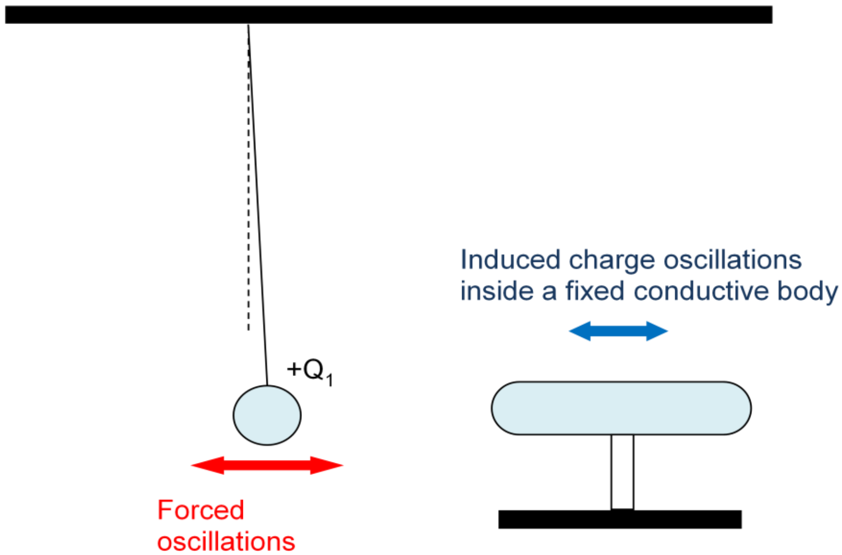

Fig. 4- A mechanical oscillations of a charge induces alternating current in a fixed conductor.

But charge oscillations also mean electric current and then some dissipation in the distant body. Let's summarize: **an oscillating electric force or equivalently an oscillating electric field alone can transfer energy wirelessly in a longitudinal manner into a distant immobile load**.

The fourth step is obvious; charge oscillation to the left (the generator side) and hence electric field oscillation can also be produced through electrical means by applying, for instance, an alternative voltage source between an electrode pair. Similarly the second conductor can be replaced by a resistance placed between tow electrodes. **It corresponds to a situation where electric energy is transferred longitudinally between two oscillating solid state dipoles arranged longitudinally along the same axis** (see Fig. 5).

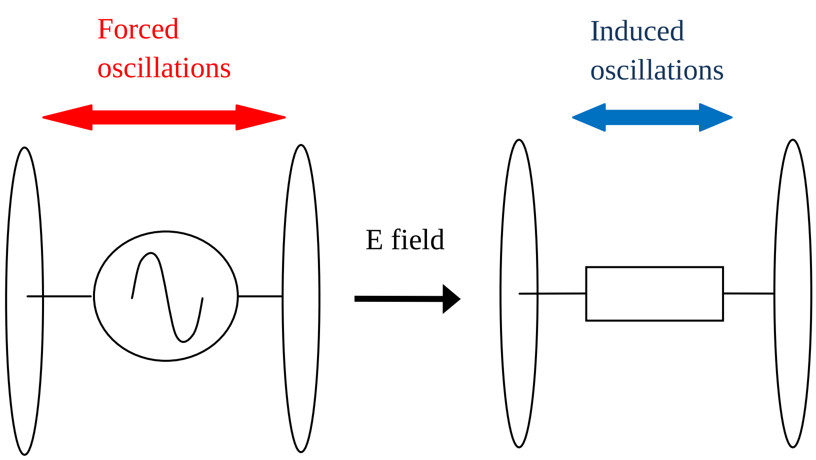

Fig. 5- A solid state illustration of longitudinal coupling

In the preceding we have insisted on the longitudinal aspect of the transfer of energy. This was for a good reason: An oscillating electric dipole alone radiates energy mainly in the transverse direction ant not at all longitudinally, showing conclusively that the transfer does not involve waves. On top of that, at low frequencies the amount of energy that could be radiated through waves is extremely small.

Conversely the mechanical interpretation given above is perfectly clear. As a result: **The fundamental differences arising between longitudinal energy transfer, well described by a classical mechanical approach, and the wave paradigm that is the only workable at very large frequencies, suggest a profound transition between the two domains.**

Besides for practical applications, the power abilities rise from mW for electrostatic pendulums up to kW for solid state devices working in the MHz range.

For more on this topic:

A didactic introduction to modern Influence (short pptx presentation)

Influence as a challenger to induction for near-field wireless power transfer (pdf)