Capacitance, Inductance and Resistance

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We have already mentioned how the capacitor and the inductor behave when they are "plunged" into a gravitational field [1]. What we intend to do now, is a further discussion about this subject, in order to be able to understand in a better way the (really tight!) link existing between *Gravity* and *Electromagnetism*.

The points on which this new explanation is based, are indicated below:

1. The new way of reading the behaviour of an interferometer, *in terms of variable speed of light*, has allowed us to state that [2]:

   - The variation of the physical (linear) dimensions of bodies, l, are directly proportional to the speed of light, c:

   $$l = l_\infty \frac{c}{c_\infty} \tag{1}$$

   - the speed of light is inversely proportional to the cubic root of the density δ of space [3]:

   $$c = c_\infty \left(\frac{\delta_\infty}{\delta} \right)^{1/3} \tag{2}$$

2. According to (1) it results that, *the time of a clock, when "plunged" into a gravitational field, does not vary.*

3. In searching an explanation to the detector "puzzle", we have conjectured the following:

   - the electric charge (of electrons and protons), e, varies in a way which is directly proportional to the speed of light:

   $$e = e_\infty \frac{c}{c_\infty} \tag{3}$$

[1] See **Gravity:** *The fundamental role of the speed of light.*

[2] Subscript "$_\infty$" indicates the space at "rest".

[3] It has to be remarked that the density, δ_∞, of space at "rest" is also corresponding, to the density measured by an observer "plunged" into the gravitational field, as his measuring instruments undergo same variations as well (that is to say, that they "adapt" to the speed of light)!

- energy, U, varies in a way which is directly proportional to the square of the speed of light:

$$U = U_\infty \, \frac{c^2}{{c_\infty}^2} \tag{4}$$

1 Capacitance

Let us imagine to "plunge " a charged and insulated plane capacitor into a gravitational field which space density, δ_0, is 1,000 times higher than the space one at "rest" (see **Figure 1**).

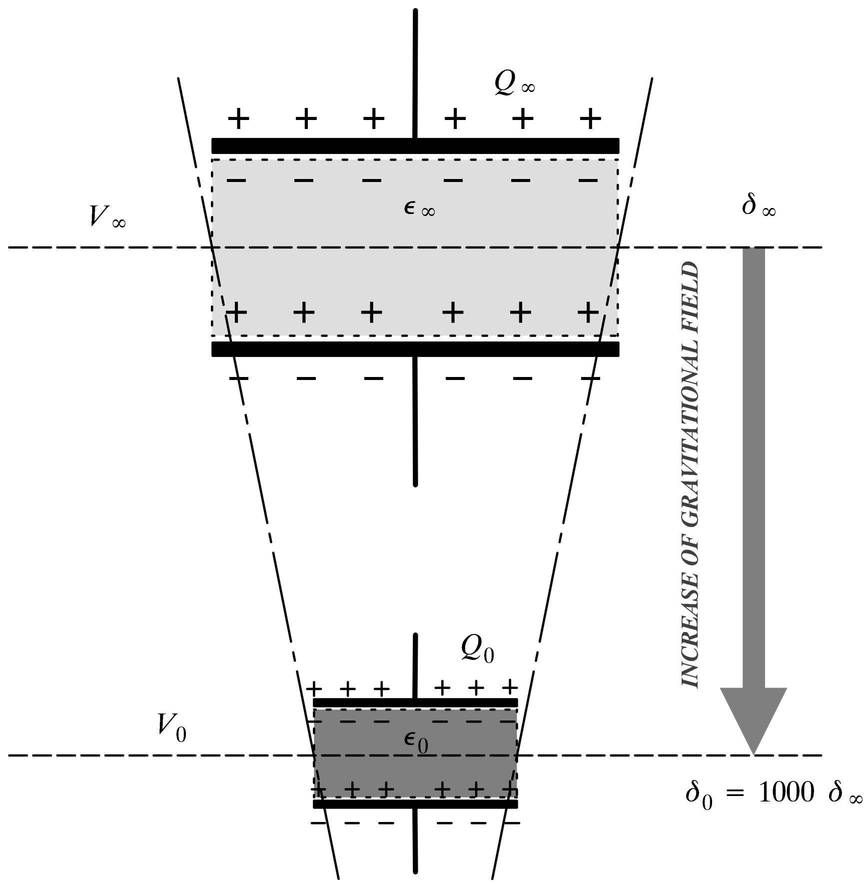

Figure 1: A capacitor "plunged" into a gravitational field

Whether the space density has become 1,000 times higher, it results from (2) that the speed of light results 10 times lower:

$$c_0 = c_\infty \left(\frac{\delta_\infty}{\delta_0}\right)^{1/3} = c_\infty \left(\frac{1}{1,000}\right)^{1/3} = c_\infty \, \frac{1}{10} \tag{5}$$

therefore, distance d and surface S of the capacitor have, respectively, decreased by 10 and 100 times:

$$d_0 = d_\infty \, \frac{c_0}{c_\infty} = d_\infty \, \frac{1}{10} \tag{6}$$

$$S_0 = S_\infty \, \frac{{c_0}^2}{{c_\infty}^2} = S_\infty \, \frac{1}{100} \tag{7}$$

But, what has happened to charge Q and to the voltage difference V?

According to *Electrostatics* we know the behaviour of a condenser may be represented in using the well known equation:

$$Q = C \; V \tag{8}$$

where C is the corresponding capacitance.

According to *Coulomb's Law* we know that *the voltage difference V is directly proportional to the electric charge Q*, therefore, in a gravitational field we can expect the following:

$$C = \frac{Q_0}{V_0} = \frac{Q_\infty}{V_\infty} \equiv constant \tag{9}$$

and, namely, that *the capacitance of a capacitor has not to undergo variations.* For a plane capacitor, C is given by the following equation:

$$C = \epsilon_0 \, \frac{S_0}{d_0} \tag{10}$$

where, ϵ_0 is the dielectric constant. If we replace (6) and (7) into (10) we will obtain:

$$C = \epsilon_0 \, \frac{S_\infty}{d_\infty} \, \frac{c_0}{c_\infty} \tag{11}$$

therefore, in order to have constant C, ϵ_0 *must vary in a way which is inversely proportional to the speed of light*:

$$\epsilon_0 = \epsilon_\infty \, \frac{c_\infty}{c_0} \tag{12}$$

This means that, according to (2), an important result, indicating that the *dielectric constant must vary in a way which is directly proportional to the cubic root of space density*, is obtained:

$$\epsilon_0 = \epsilon_\infty \left(\frac{\delta_0}{\delta_\infty} \right)^{1/3} \tag{13}$$

The electrostatic energy, U, of the capacitor, which *is stored in the dielectric*, is given by the well known equation:

$$U = \frac{1}{2} \, \frac{Q^2}{C} \equiv \frac{1}{2} \; C \; V^2 \tag{14}$$

that can also be written in a "local" form, where the electric field E is highlighted, in the following way:

$$U = \frac{1}{2}\ \epsilon_0\ E^2\ \mathcal{V}_\epsilon \tag{15}$$

where, $\mathcal{V}_\epsilon$ indicates the volume of the dielectric.

How is it possible to conciliate (14) and (15)? It is easy to check this is possibile if the electric tharge Q, there is on the plates, *undegoes variations which are inversely proportional to the dielectric constant*. That is to say [4]:

$$Q_0 = Q_\infty\ \frac{\epsilon_\infty}{\epsilon_0} \equiv Q_\infty\ \frac{c_0}{c_\infty} \tag{16}$$

therefore, also:

$$V_0 = V_\infty\ \frac{\epsilon_\infty}{\epsilon_0} \equiv V_\infty\ \frac{c_0}{c_\infty} \tag{17}$$

An important fact deriving from this, involves the electric field. If we use (6) and (17) we find that *the electric field inside the dielectric undergoes no variation.* Namely:

$$E_0 = \frac{V_0}{d_0} = \frac{V_\infty}{d_\infty}\ \frac{\epsilon_\infty}{\epsilon_0}\ \frac{c_\infty}{c_0} \equiv E_\infty \tag{18}$$

Now, if we place (16) (or (17)) into (14):

$$U_0 = \frac{1}{2}\ \frac{Q_0^2}{C} = U_\infty\ \frac{c^2}{{c_\infty}^2} \equiv \frac{1}{100}\ U_\infty \tag{19}$$

while, if we put (18) into (15), the result is:

$$U_0 = \frac{1}{2}\ \epsilon_0\ E^2\ \mathcal{V}_\epsilon = \epsilon_\infty\ \frac{c_\infty}{c_0}\ E^2\ \mathcal{V}_\infty\ \frac{{c_0}^3}{{c_\infty}^3} = U_\infty\ \frac{c^2}{{c_\infty}^2} \equiv \frac{1}{100}\ U_\infty \tag{20}$$

Therefore, when "plunged" into the gravitational field, the capacitor undergoes a given variation (decrease) in the electrostatic energy which is proportional to:

$$\Delta U \equiv U_0 - U_\infty \propto {c_0}^2 - {c_\infty}^2 \tag{21}$$

The electric "displacement" (or, also, electric induction), D, is given by the following equation:

$$D = \epsilon_0\ E \tag{22}$$

therefore, in using (12) we obtain that:

$$D_0 = D_\infty\ \frac{c_\infty}{c_0} \tag{23}$$

that is to say, *the variations of the electric induction are inversely proportional to the speed of light.*

[4]This result is quite different from what is given, today, by *Electrostatics*!

2 Inductance

In the same way as we have done for the condenser, we can analyse the behaviour of an inductor when "plunged" into a gravitational field.

To make things easier, we can consider a very long rectilinear inductor (or a toroidal one) and we can imagine to "plunge" it into a gravitational field, having a density 1,000 times higher than the one of space at "rest" (see **Figure 2**).

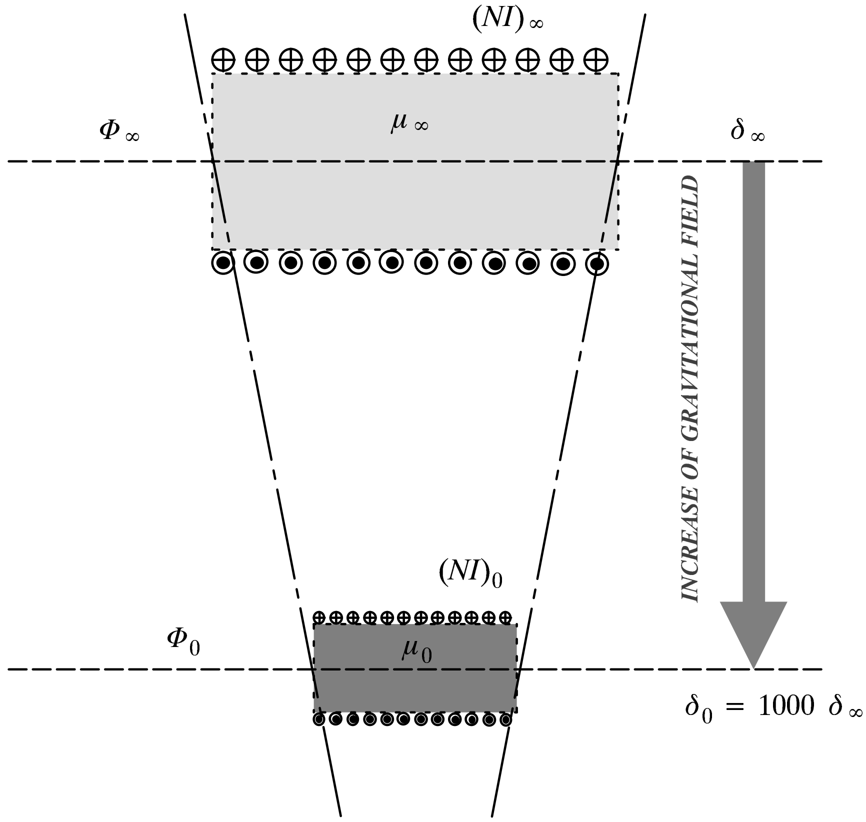

Figure 2: An indictor "plunged" into a gravitational field

Here too, length l and section S of the magnetic nucleus have respectively become 10 and 100 times lower:

$$l_0 = l_\infty \ \frac{c_0}{c_\infty} = l_\infty \ \frac{1}{10} \tag{24}$$

$$S_0 = S_\infty \ \frac{{c_0}^2}{{c_\infty}^2} = S_\infty \ \frac{1}{100} \tag{25}$$

It is well known that the behaviour of the inductor is represented by the following equation (*Hopkinson's Law*):

$$N\ I = \mathcal{R}\ \Phi \tag{26}$$

where, $N\ I$ are the ampere-turns, Φ is the total magnetic flux and $\mathcal{R}$ the reluctance of the magnetic circuit that can be calculated in using the following equation:

$$\mathcal{R} = \frac{l}{\mu_0\ S} \tag{27}$$

where, μ_0 is the magnetic permeability.

Inductance L is defined as the ratio between flux Φ and current I and is related to $\mathcal{R}$ by the following relationship:

$$L = \frac{\Phi}{I} = \frac{N^2}{\mathcal{R}} \equiv N^2\ \frac{\mu_0\ S}{l} \tag{28}$$

But, what did it happen to current I and flux Φ? As we know that *time does not change when a clock is "plunged" into a gravitational field, the current varies, as well as the electric charge, in a way that is directly proportional to the speed of light*:

$$I_0 = I_\infty\ \frac{c_0}{c_\infty} \tag{29}$$

Magnetic energy, U, *that is stored in the magnetic nucleus*, is calculated in using the well known relation:

$$U = \frac{1}{2}\ L\ I^2 \tag{30}$$

or,

$$U = \frac{1}{2}\ \mu_0\ H^2\ \mathcal{V}_\mu \tag{31}$$

where, $\mathcal{V}_\mu$ is the volume of the magnetic nucleus.

It is easy to verify that (30) and (31) match *if the variation of the current is inversely proportional to the magnetic permeability* [5]:

$$I_0 = I_\infty\ \frac{\mu_\infty}{\mu_0} \tag{32}$$

If we compare (29) with, (32), the important result obtained is that *magnetic permeability must vary in a way which is inversely proportional to the speed of light*:

$$\mu_0 = \mu_\infty\ \frac{c_\infty}{c_0} \tag{33}$$

[5] In this case too, the result is quite different from the one given, today, by *Magnetism*!

that is to say, *in a directly proportional way to the cubic root of space density*:

$$\mu_0 = \mu_\infty \left(\frac{\delta_0}{\delta_\infty}\right)^{1/3} \tag{34}$$

If we use (24), (25) and (33) in (28), we can easily verify that *inductance, L, of an inductor does not change when same is "plunged" into a gravitational field* [6].

Also the magnetic flux, Φ, varies in a directly proportional way to the speed of light:

$$\Phi_0 = \Phi_\infty \, \frac{c_0}{c_\infty} \tag{35}$$

It is now easy to verify that, when "plunging" the inductor into the gravitational field, there is a variation (decreasing) of magnetic energy which is proportional to:

$$\Delta U \equiv U_0 - U_\infty \propto {c_0}^2 - {c_\infty}^2 \tag{36}$$

An important implication involves the magnetic field. We know that the magnetic field, H, is given by the following equation:

$$H = \frac{N\ I}{l} \tag{37}$$

If we use (24) and (29) in (37) we still obtain:

$$H_0 = \frac{N\ I_0}{l_0} = \frac{N\ I_\infty}{l_\infty} \, \frac{\mu_\infty}{\mu_0} \, \frac{c_\infty}{c_0} \equiv H_\infty \tag{38}$$

namely, *in a gravitational field, the magnetic field does not undergo any variation.*

Finally, magnetic induction, B, is given by:

$$B = \mu_0 \ H \tag{39}$$

therefore, if we use (33) we will obtain:

$$B_0 = B_\infty \, \frac{c_\infty}{c_0} \tag{40}$$

namely, *magnetic induction, too, will result as inversely proportional to the speed of light.*

[6] And, as N, the number of turns, does not change, the reluctance of the magnetic field keeps constant too.

3 Resistance

What does a resistor undergo, when "plunged" into a gravitational field?

We know resistance, R, is defined as the ratio between the voltage difference V at its terminals, and the electric current I passing through it (*Ohm's Law*):

$$R = \frac{V}{I} \tag{41}$$

As previously remarked, both voltage and current are directly proportional to the speed of light, therefore, it results that, in a gravitational field, *resistance R too undergoes no variation.* Furthermore, we know that:

$$R = \rho \, \frac{l}{S} \tag{42}$$

where, l is the length of the conductor, S its section and ρ is the resistivity of material.

It is therefore *necessary* that resistsivity has to result as follows:

$$\rho_0 = \rho_\infty \, \frac{c_0}{c_\infty} \equiv \rho_\infty \left(\frac{\delta_\infty}{\delta_0}\right)^{1/3} \tag{43}$$

namely, *resistivity must have a variation which is inversely proportional to the cubic root of space density..*

Energy that has been "dissipated" by resistance per unit of time (power) is the result of (*Joule's Law*) [7]:

$$\dot{U}_0 = V_0 \; I_0 \equiv R \; {I_0}^2 = \frac{{V_0}^2}{R} \tag{44}$$

therefore, if we use (17) and (29) in (44), we obtain:

$$\dot{U}_0 = V_0 \; I_0 = V_\infty \; I_\infty \, \frac{{c_0}^2}{{c_\infty}^2} = \dot{U}_\infty \, \frac{{c_0}^2}{{c_\infty}^2} \tag{45}$$

namely, this energy (power) too, results as directly proportional to the square of the speed of light.

4 Remarks

Further than what discussed in the previous parts, the following has to be added.

1. Support to what stated in the previous paragraphs is given by what hereunder considered.

   In case we build an LC (inductance-capacitance) or RC (resistance-capacity) oscillator (clock), same *will not change its oscillation frequency when "plunged" into a gravitational field.* These results are, therefore, perfectly matching the new interpretation of the interferometer behaviour given by (1)!

[7] A dot on top of the symbol, indicates the variation respect to time (derivative)

2. *Electromagnetism* has taught us that the speed of light is linked to dielectric constant and magnetic permeability of the following (fundamental) equation:

$$c_0{}^2 \; \epsilon_0 \; \mu_0 = 1 \tag{46}$$

It is easy to check that (46) *still shows its validity also in a gravitational fied.* If we use (12) and (33), we will obtain in fact:

$$c_\infty{}^2 \; \frac{c_0{}^2}{c_\infty{}^2} \; \epsilon_\infty \; \frac{c_\infty}{c_0} \; \mu_\infty \; \frac{c_\infty}{c_0} = c_\infty{}^2 \; \epsilon_\infty \; \mu_\infty = 1 \tag{47}$$

3. It is also possibile to write (46) as follows:

$$\big(c_0 \; \epsilon_0\big) \; \big(c_0 \; \mu_0\big) = 1 \tag{48}$$

where,

$$c_0 \; \epsilon_0 \equiv c_\infty \; \epsilon_\infty = K \tag{49}$$

$$c_0 \; \mu_0 \equiv c_\infty \; \mu_\infty = \frac{1}{K} \tag{50}$$

with K constant. So it is advisable to suggest that (49) and (50) can be written as follows:

$$c_0 = \frac{K}{\epsilon_0} \tag{51}$$

$$c_0 = \frac{1/K}{\mu_0} \tag{52}$$

with (51) representing *"c with nature ϵ"* and (52) representing *"c with nature μ"*.

The remarkable "symmetry" shown by (49) and (50), makes us think that *dielectric constant and magnetic permeability should represent the same physical characteristics (of space)*!

4. The connection between *Gravity* and *Electromagnetism* indicated here in its fundamental lines with the use of (49) and (50), gives us the opportunity to solve the *problem concerning units of measure* that has been concerning *Electromagnetism* since Faraday and Maxwell.

However, this important subject needs being discussed separately.