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Propellantless Propulsion with Negative Matter Generated by Electric Charges

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Forward first pointed out that a gravitational dipole, consisting of ordinary and negative matter, would be self-accelerating thus creating the ultimate propellant-less propulsion system. It would closely resemble the features of a hypothetical space drive which has yet to be designed. Up to now, the key ingredient, negative matter, has not been found to exist in natural form. However, since E=m.c², negative matter may be created in a laboratory using negative energies. Previous studies showed that effective negative inertia exists for neutrons and also for electrons in short transient time intervals. We present two possibilities to create stationary, charged negative effective masses that could be used to test Forward's self-propulsion effect. One is based on the assumption that Weber's electrodynamics is correct predicting a negative mass regime for electrons inside a highly charged dielectric sphere. The other possibility is using asymmetric charge distributions that could be realized using electrets. With proper geometry and charge densities, negative mass regimes are derived which could lead to negative energies many orders of magnitude larger than those obtained from the Casimir effect. Based on these concepts, a negative matter space-drive could be realized in a laboratory environment.

Nomenclature

A	=	area
a	=	acceleration
C	=	capacity
c	=	speed of light = 3×10^{8} m/s
e	=	elementary charge = 1.6×10^{-19} C
ε_0	=	electric constant = 8.854×10^{-12} F.m^{-1}
ε_r	=	relative permittivity
F	=	force
$\hbar$	=	Planck constant / 2π = 1.054×1^{-34} J.s
m	=	mass
m_e	=	electron mass = 9.1×10^{-31} kg
m^*	=	effective mass
N	=	number of charges
Q, q	=	sum of charges, charge
R, r	=	radius
σ	=	charge density
U	=	potential energy
V	=	electric potential
z	=	thickness of dielectric

I. Introduction

TRAVEL to the stars within a human lifetime is impossible using propulsion technologies that were developed so far. All means of propulsion as we know it simply relies on Newton's mechanics and therefore on the consumption of propellant and/or energy. Even with the most exotic and advanced propulsion concepts such as nuclear pulse rockets or beamed energy propulsion, the energy requirements to reach just our next star within a

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decade are many orders of magnitude beyond our technology limits[1]. Additionally, special relativity's limitation to the speed of light prohibits us of exploring more than a couple of stars even if we could travel close to light speed considering the vast distances between stars. This limits space travel to the exploration of our solar system as long as we use rockets (unless we think in terms of generation spaceships and much longer timeframes).

In the 1990s, also stimulated by NASA's breakthrough propulsion physics program, several scientists started to think how those limits could be broken eventually. A famous example is Alcubierre's warp drive concept[2], which proposes to contract and expand space-time around a spacecraft and therefore move space-time itself. This could circumvent the speed of light limitation but on the other hand the concept requires enormous amounts of negative (or sometimes called exotic) energy that still needs to be discovered.

From an engineering perspective, maybe the most straight-forward concept is called negative matter propulsion[3] (or diametric space drive[4]). It consists of a pair of masses, one with an ordinary positive and the other one with a negative mass. Although Forward's paper assumes that the negative mass has both a negative gravitational and inertial mass, we can only concentrate on the effect of negative inertia. According to Newton's second law, the acceleration of a mass is always in the direction of the force that acts on it, $\boldsymbol{F} = m \cdot \boldsymbol{a}$. Negative inertia would therefore always accelerate in the opposite direction of the applied force, which sounds of course totally counter-intuitive. If both types of masses are now coupled e.g. with a spring that tries to attract both masses to each other, it is straight forward to show that this gravitational (or more specifically inertial) dipole is self-accelerating as illustrated in Fig. 1.

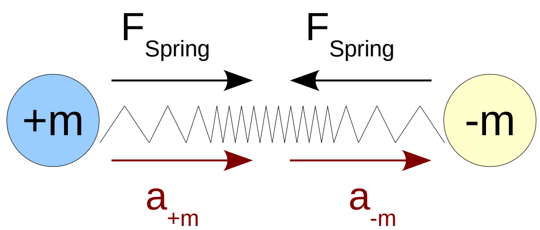

Figure 1. Negative Matter Propulsion and Self-Acceleration.

This self-acceleration propulsion system does not need propellant or energy. Similarly to Alcubierre's warp drive concept[2], it should therefore be able to move at any arbitrary speed (also faster than the speed of light) since no energy is involved. Forward showed in his analysis that negative matter propulsion does not violate the conservation of momentum or energy as negative mass also carries negative momentum and energy and hence the total energy of the self-accelerating dipole is zero (self-acceleration is its ground state). This argument could be even proven for the case if the amount of negative and positive mass is not equal.

So where can we find negative mass? There is no consensus in the physics community if negative mass is even allowed to exist. Most refer to the so-called positive energy theorem[5] that prohibits negative gravitational masses. Others show that negative masses are compatible with general relativity theory (e.g. Ref (6, 7)). However, most arguments center on gravitational masses, which is not our concern here as we will concentrate on negative inertia. Of course, negative inertial mass and positive gravitational mass would be a strict violation of the equivalence principle.

Even if we find negative matter, we don't know if

1. Newton's laws still hold: Does $\boldsymbol{F} = m \cdot \boldsymbol{a}$ also work for negative matter – or is the mass in Newton's equation an absolute value without sign like $\boldsymbol{F} = |m| \cdot \boldsymbol{a}$? That on the other hand would mean that negative inertia does not exist.
2. Self-acceleration is a reality.

Both questions must be answered by experiments, although analysis for negative energy/mass due to the Casimir effect already shows that negative inertia must exist[8]. Since negative mass is not naturally available in an elementary form, we will show that negative matter, apart from the Casimir effect, can be created in a laboratory and the effects of negative inertia may then be studied experimentally. If the two questions above can be answered positively, it would be indeed possible to build a space drive.

II. Negative Inertia in the Laboratory

The highest similarity to negative inertia is a concept in physics which is called effective mass. A particle's effective mass m^* is the mass it seems to carry when it moves through a crystal. Usually, the particle is affected by electric and/or magnetic fields inside the crystal. In the effective mass concept, these field and crystal interactions are put into the effective mass and the particle then behaves like if it would be in vacuum but with a different mass. In semiconductors, the effective mass for electrons usually varies between 0.01-10 times the electron's rest mass, in some circumstances it can be even negative. Note that here only the apparent inertial mass is varied without effecting the electron's gravitational mass. But is the effective mass as real as the usual inertial mass? According to Mach's principle, a popular proposal to explain inertia, the inertial mass is nothing else that the gravitational interaction of a mass with the rest of the universe[9]. This is actually similar to the approach of the effective mass where the action of external forces redefines the new inertial behavior. And if electromagnetic forces lead to an effective mass, it is of no surprise that the equivalence principle would fail as the usual inertial mass is due to the gravitational interaction forces only. So if inertia is indeed related to Mach's ideas, the effective mass is a real as the normal inertial mass and we may use it to investigate Newton's laws.

Indeed, such experiments have already been done. The most thorough analysis to date was carried out by Zeilinger and his team in the 1980s and 1990s using neutrons[10-12]. They calculated the effective mass of neutrons inside a silicon crystal as:

$$m^* = \pm m \cdot \frac{2V(\mathbf{G})}{\hbar^2 \mathbf{G}^2 / 2m} , \tag{1}$$

where $\mathbf{G}$ is the reciprocal lattice vector and V($\mathbf{G}$) the periodic crystal potential. By properly matching the crystal parameters, they could achieve neutrons with a positive or a negative effective mass. For neutrons with a 2.46 Å wavelength diffracted by (220) planes in a silicon crystal, they obtained $m^*/m = \pm 4.72 \times 10^{-6}$. In the case of a positive effective mass, the neutron had a reduced inertial mass by almost five orders of magnitude compared to a free neutron – and this effective mass could be made negative. In a series of experiments, they could show that neutrons with a negative effective mass indeed accelerated against the direction of an applied force. This was verified for magnetic forces acting on the neutron's magnetic momentum[10], the Coriolis force by rotating the crystal[11] and most remarkably by the gravitational force[12].

This is already a good indicator that at least for effective masses, the concept of negative inertia and Newton's laws are compatible and we can cautiously answer the first question in the upper paragraph. Transient negative effective masses were also recently reported for electrons in n-doped GaAs under very high electric fields[13] and short times-scales on the order of a few hundred femto-seconds. Negative inertia was even simulated by a mechanical spring system[14] that can be exploited for advanced damping solutions.

However, the second crucial question is still unanswered: does the self-acceleration effect exist? In order to find this answer too, it would be very advantageous to have stationary charged negative matter where the spring force can be applied by electric means, a case which was also already considered by Forward[3]. This is especially important if we have only small amounts of negative mass. If the mass would be electrically neutral, any gravitational/mechanical effect could be easily masked by the large positive mass. Due to the fact that the constants in the Coulomb-electric and Newton-gravitational force laws differ by 20 orders of magnitude, also small amounts of charged negative mass could show significant effects. Therefore, neutrons with negative inertia or electrons with only short term transient negative inertia are not really useful for propulsion applications. Fig. 2 shows an electric dipole where the positive charge has also a positive mass and vice versa. This inertial/electric dipole should, according to Newton's laws, provide a self-acceleration effect that could be investigated. In the following sections, we will outline two possibilities of realizing an inertial/electric dipole using electrostatics in the laboratory to investigate if self-acceleration is a reality.

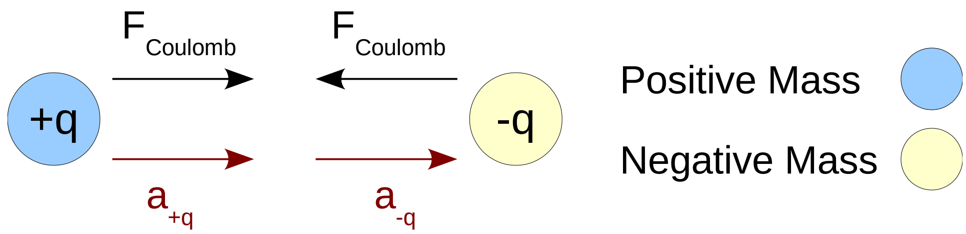

Figure 2. Self-Acceleration of an Inertial/Electric Dipole.

A. Weber's Electrodynamics

In parallel to the development of Maxwell's equations, Wilhelm Weber proposed a force that also covered all known aspects of electromagnetism (Ampere, Coulomb, Faraday and Gauss's laws) and incorporated Newton's third law in the strong form, that is that the force is always along the straight line joining two charges[15] (which also implies the conservation of linear and angular momentum). However, Weber's electrodynamics also gives rise to new effects such as longitudinal forces or the change of the effective inertial mass of a charge inside a charged spherical shell which we could exploit for negative matter propulsion.

Weber's force and the related potential energy is given by

$$\mathbf{F} = \frac{q_1 q_2}{4\pi\varepsilon_0} \frac{\hat{\mathbf{r}}}{r^2}\left(1 - \frac{\dot{r}^2}{2c^2} + \frac{r\ddot{r}}{c^2}\right), \quad U = \frac{q_1 q_2}{4\pi\varepsilon_0} \frac{1}{r}\left(1 - \frac{\dot{r}^2}{2c^2}\right), \tag{2}$$

where q_1 and q_2 are the respective charges and r is the distance between them. If we now consider a single charge inside a charged spherical dielectric shell (in order to ignore eddy currents or mirror charges), we must integrate the force and sum up all the interaction between the single charge inside the shell and all other charges along the shell. Surprisingly, a net force remains that acts on the single charge when it accelerates inside the shell[16] given by

$$\mathbf{F} = \frac{qQ}{12\pi\varepsilon_0 c^2 R} \cdot \mathbf{a} = \frac{qV}{3c^2} \cdot \mathbf{a}, \tag{3}$$

where Q is the charge on the shell, R the shell's radius and V the electrostatic potential inside the shell. Classically, no force is expected on a charge inside a charged shell as the electric potential is constant and therefore no electric and no force acts on charges inside. According to Weber's electrodynamics, this force is proportional to acceleration of the charge and therefore influences the charge's inertial mass. If the total inertial mass is now the sum of the unaffected mass and the Weber mass, we may express the effective mass of the charge as

$$m^* = m - \frac{qQ}{12\pi\varepsilon_0 c^2 R} = m - \frac{qV}{3c^2} \tag{4}$$

The equation predicts that a change in mass should be quite observable in a dedicated laboratory experiment. Considering a dielectric shell with a radius of 0.5 m charged up to 1.5 MV, we could expect to double an electron's mass – or reduce it to zero depending on the shell's charge polarity. Mikhailov published a number of experiments were such an effect was indeed observed. First, he put a neon glow lamp inside a glass shell that was coated by a thin layer of GaIn and an RC-oscillator inside a Faraday shield below[17]. The coated glass shell imitates the charged dielectric shell as originally proposed by Assis. The frequency of the lamp is directly proportional to the electron's mass. Indeed he observed that the lamp's frequency changed if he charged the sphere as predicted by Equ. (4) within a factor 3/2. In a second experiment, the neon lamp was replaced by a Barkhausen-Kurz generator leading to similar results[18]. Finally, the neon-lamp experiment was repeated with two charged concentric shells showing that the frequency/mass effect from charging up the first shell can be counterbalances by oppositely charging the outer shell[19].

Junginger and Popovich[20] repeated the neon glow lamp experiment and implemented an optical counter instead of electrically measuring the frequency of the lamp – and observed a null result. Also Little et al[21] performed a similar replication and observed a null result with optical counters and observed that the electric measurement of the lamp's frequency may be influenced by the Faraday's shield potential depending on the coupling capacitor used (however the signature of the effect was a parabola instead of the linear relationship as obtained by Mikhailov). However, both replication teams used only a metallic Faraday cage to surround the neon lamp and the RC-oscillator and not a dielectric (glass) shell covered with a metallic layer. As outlined by Assis already in his original derivation of the effect, it is crucial to use a dielectric charged shell as mirror charges or eddy currents may completely shield the effect. A new replication attempt using a metal-covered dielectric glass shell similar to Mikhailov's approach and using both electric and optical counters is currently underway at TU Dresden in order to finally prove or disprove the effect.

Assuming that Weber electrodynamics hold, we could realize negative matter propulsion by putting a charged capacitor inside a positively charged dielectric shell as shown in Fig. 3. We are considering only a positively charged shell because the electron's mass is much smaller than the proton's. It may also work with a negatively charged outer shell but at significantly higher potential. The positive electric potential from the charged shell would decrease the electron's mass on the negative side of the capacitor and increase the mass of the electron's hole (the proton) on the positive side of the capacitor. Moreover, the Coulomb force between the capacitor charges would act as a spring. The effect should occur once the outer potential is high enough to make the electron's effective mass negative. The thruster's force is then only determined by the spring/Coulomb force on the capacitor plates and therefore by the capacitor's area *A*, capacity *C* and potential *V* on the plates. By using high-k dielectrics, the critical voltage on the outer shell may be reduced and the effect would start to occur probably at already lower voltages.

Considering the force between two plates of a capacitor,

$$F = \frac{(CV)^2}{2\varepsilon_0 \varepsilon_r A} \ , \tag{5}$$

and using realistic values for off-the shelve high voltage capacitors (e.g. V=20 kV, C=10 nF, ε_r=5000, A=0.001 m^2, F=451 N), the force can easily get several hundred Newtons or higher which should be readily measureable using a balance as shown in Fig. 3. But is this realistic? The Coulomb force should act as a spring to exert a force on the charges and Equ. (3) assumed that the effective mass changes for charges under acceleration inside the sphere. However, the charges in a capacitor are not accelerating/moving in a steady state, they accumulate on the side of the plates and are counterbalanced by mechanical/internal forces so that they are standing still. We may expect forces

- during charging and discharging of the capacitor when the charges move and accelerate,
- with proper positioning by putting the capacitor plates apart and charge them while removing the mechanical fixation,
- due to thermal vibrations, the charges will in fact oscillate a little and feel acceleration and the Coulomb force, however the resulting force should be much less than expected from Equ. (5) and even level out to zero.

Maybe the implementation of a spring between one capacitor plate and the dielectric could solve this issue, however the acceleration of the charge carriers will be much smaller than in the Coulomb attraction-spring case. The exact amount of force is therefore difficult to calculate, however the large maximum value according to Equ. (5) should be stimulating enough to investigate such an effect experimentally.

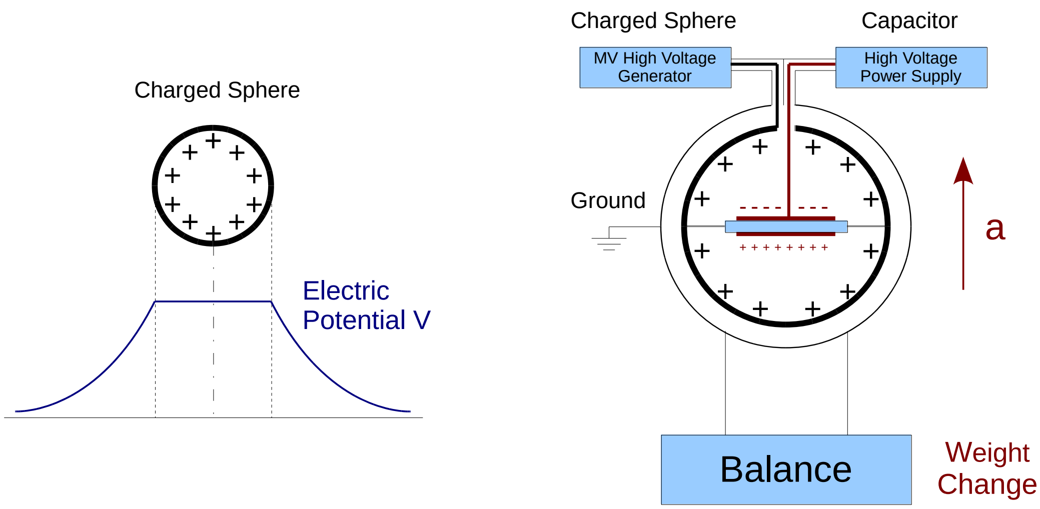

Figure 3. Self-Acceleration of a Capacitor inside a Positively Charged Dielectric Shell.

B. Asymmetric Charge Interactions - Electret Capacitors

Another possibility to change the electron's inertial mass without any introduction of new physics is using the electrostatic potential energy. According to Einstein's famous equation $E = mc^2$, all non-gravitational sources of energy contribute to mass (the energy of the gravitational field cannot be localized according to the equivalence principle[22]). Boyer[23] showed that two opposite charges should lose weight as the electrostatic potential energy between dissimilar charges is always negative. Considering two charges, the energy of the whole system is given as:

$$U = m_1 c^2 + m_2 c^2 + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} \ , \tag{6}$$

where r is the separation distance between the charges, and m and q is the respective mass and amount of charge. It is now straightforward to see that if the two charges have opposite signs, the electrostatic potential energy is reducing the total mass of the system by

$$\Delta m = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{rc^2} \tag{7}$$

The key question here is: Does the mass change only exist for the whole system or can we localize it to the two charges (in this case each charge's mass would change by half of the amount in Equ. (3))? In support of the whole system view, we may say that we are free to choose our reference point (charge 1, charge 2 or both) to assign the mass change and that the mass change is due to the Coulomb interaction between the charges that cannot be separated between the charges. On the other hand, the mass change must localize somewhere and where else should it manifest than equally on each charge? There may be even already an experimental indication that this mass change interpretation is correct following an analysis to explain the motion synchronization of ions between two electrostatic traps[24]. If ions are injected into such a trap, the size of the ion cloud usually stretches out due to Coulomb repulsion. It was however noted that a certain geometry and electrostatic potential leads to a stabilization (or self-bunching) of the ion cloud that was interpreted as being due to the ion's mass turning negative originating from the negative electrostatic interaction energy with the mirror walls.

Suppose that indeed electrostatic potential energy can cause a mass change at the individual charges, we could use this energy to reduce the electron's mass below zero and create negative matter propulsion as in the example above. As we will show, this does not only require positive and negative charges, but there must be an unequal charge distribution with much more positive than negative charges to create an excess of negative interaction potential energy on the electron.

Consider a simple two-plate capacitor with equal and opposite charges on the plates. The energy stored in a capacitor is usually expressed by integrating the energy stored in the electric field over the volume of the dielectric which leads to a function of charge/potential and capacity as

$$U_{Capacitor} = \int_{V_{Dielectric}} \frac{1}{2}\varepsilon E^2 \cdot dV = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 \ , \tag{8}$$

where $\varepsilon=\varepsilon_0\varepsilon_r$. However, instead of evaluating the energy inside the dielectric, we can also calculate $U_{Capacitor}$ by summing up all electrostatic interaction energies between each charge with all other charges on both plates which should give the same result. In this approach, the energy is composed of a self-energy term from the interaction of similar charges on each plate and an interaction-energy term from the interaction between the charges from one plate with the charges on the opposite plate as illustrated in Fig. 4a. We can express the energy stored in the capacitor now as

$$\begin{aligned} U_{Capacitor} &= U_{Self-Energy} + U_{Interaction-Energy} \\ &= \frac{1}{4\pi\varepsilon} \cdot \left(\sum_{i \neq j}^{N} \frac{q_i \cdot q_j}{r_{ij}} - \sum_{i,j}^{N} \frac{q_i \cdot q_j}{\sqrt{r_{ij}^2 + z^2}} \right) , \end{aligned} \tag{9}$$

where r_{ij} is the distance between each charge on a plate, N the number of charges on each plate, and z is the thickness of the dielectric between the plates. We can see that the left self-energy term is a positive contribution to the overall energy due to the similar polarity of charges on each plate, and that the right interaction-energy term is a negative contribution to the overall energy due to the dissimilar polarity of the charges from both plates. It is also clear that the positive self-energy term is always greater than the negative interaction-energy term due to the finite gap size z of the dielectric between the plates. Therefore, the total energy stored in a classical two-plate capacitor is always positive and should sum up to the usual Equ. (8). Equ. (9) is a sum of the self- and interaction-energy term of both plates, so the electrostatic potential energy on each plate is just half of that value and also always positive.

On the other hand, if we now consider two plates which do not have equal charges, we may create a scenario where the negative interaction-energy is larger than the positive self-energy on one plate and therefore the charges on that plate should loose mass accordingly. This could be achieved for example by using real-charge electrets, which are dielectrics that contain single-polarity charges either on the surface or inside its volume (from high-energy particle beams or discharges). Teflon (PTFE) based electrets[25] show a very high long-term stability and are available up to surface charge densities in the range of 20 nC/cm². By combining a positive and a negative real-charge electret (we may call this an electret-capacitor), an asymmetric charge distribution can be achieved as illustrated in Fig. 4b.

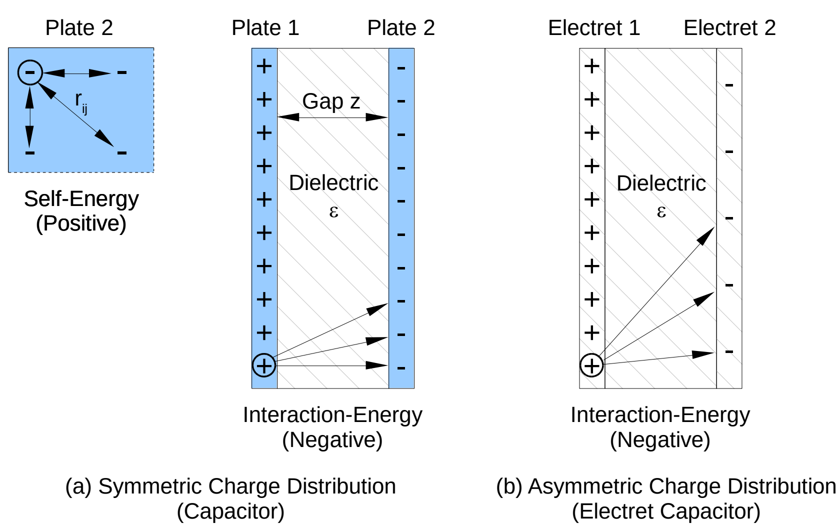

Figure 4. Self- and Interaction-Energy Contribution to the Total Energy Stored in a Capacitor or Electret-Capacitor.

The total energy of such an electret-capacitor can be calculated similar to Equ. (9). For simplicity, we assume that the dielectric in the electrets as well as in the gap is the same. We will now split the total energy in the electrostatic energy contained in the charges of both electrets as follows

$$U_{ElecCap} = U_{Electret_1} + U_{Electret_2} = \left(U_{Self-Energy} + U_{Interaction-Energy}\right)_1 + \left(U_{Self-Energy} + U_{Interaction-Energy}\right)_2$$
$$= \frac{1}{4\pi\varepsilon}\left[\left(\frac{1}{2}\sum_{i\neq j}^{N_1}\frac{q_{1,i}\cdot q_{1,j}}{r_{ij}} - \frac{1}{2}\sum_{i}^{N_1}\sum_{j}^{N_2}\frac{q_{1,i}\cdot q_{2,j}}{\sqrt{r_{ij}^2+z^2}}\right)_1 + \left(\frac{1}{2}\sum_{i\neq j}^{N_2}\frac{q_{2,i}\cdot q_{2,j}}{r_{ij}} - \frac{1}{2}\sum_{i}^{N_1}\sum_{j}^{N_2}\frac{q_{1,i}\cdot q_{2,j}}{\sqrt{r_{ij}^2+z^2}}\right)_2\right] \tag{10}$$

The negative interaction-energy between both electret plates is the same and evenly split. However, the positive self-energy term can be very different on both plates. In case $N_2 << N_1$, the negative interaction-energy on electret 2 can be dominant creating negative energy which would lead to a mass loss on the charge carriers on that plate. We can express the effective mass for the charge carriers on both plates as

$$m_{1,2}^* = m_{1,2} + \frac{\left(U_{Self-Energy} + U_{Interaction-Energy}\right)_{1,2}}{c^2}\cdot\frac{1}{N_{1,2}} \tag{11}$$

We will now try to calculate the effective mass and electrostatic potential energy contribution to the electret plates. The self-energy term can be solved analytically and is given for a disc geometry with radius R and charge density σ for a single disc as[26]

$$U_{Self-Energy} = \frac{2\sigma^2 R^3}{3\varepsilon} \tag{12}$$

Unfortunately, the interaction-energy term cannot be solved analytically but needs to be approximated. If the radius is much larger than the gap size, we can express it as an interaction between two charge densities (which are equal in absolute value for a normal capacitor) as

$$U_{Interaction-Energy} = \frac{\sigma_1\sigma_2 R^3\pi}{2\varepsilon}\cdot\left\{\frac{8}{3\pi} - \frac{z}{R}\right\} \tag{13}$$

Each disc will assume half of this value as the energy needs to be evenly split between the charge densities. Here we basically neglected edge effects which only play a role when the gap size approaches the radius of the disc[27]. For our analysis, we will fix the positive charge density σ_1 with 20 nC/cm² and vary the negative charge density σ_2. Fig. 5 shows how the different energy terms vary for both electret plates for R=300 mm and z=5 mm and Teflon dielectric (ε_r=2).

For the case of Electret 1, the self-energy remains stable throughout the variation as it only concerns σ_1 which was fixed. The interaction-energy term varies linearly with the charge density σ_2 as expected from a Coulomb interaction. $U_{Electret1}$ gets negative if $|\sigma_2| > \sigma_1$ (plus a small offset). It's interesting to see that the minimum total energy of the Electret capacitor is just when the absolute value of σ_2 equals σ_1, however, it is always positive and larger than zero.

For the case of Electret 2, we see the same linear interaction-energy variation and a parabolic variation for the self-energy due to its dependence on σ_2. We also see that here the plate energy gets negative if we have less charges on Electret 2 compared to Electret 1 creating net negative energy on the charge carriers. However, this does not necessarily lead to charge carriers with negative mass because the amount of negative energy per charge needs to equal at least the electrons rest mass energy in that case. Combining Equs. (11)-(13), we can express the effective electron mass for the charges on Electret 2 as

$$m_2^* = m_e - \left[\frac{2\sigma_2}{3} + \frac{\sigma_1 \pi}{4} \cdot \left\{ \frac{8}{3\pi} - \frac{z}{R} \right\} \right] \cdot \frac{R \cdot e}{\varepsilon \pi c^2} \ , \tag{14}$$

where we used $q = -e$. Fig. 6 plots the ratio of the electron effective mass to the normal electron mass. We can see that we only approach the negative mass regime with a certain combination of charge and geometry. The negative mass condition can be expressed as

$$\frac{2\sigma_2}{3} + \frac{\sigma_1 \pi}{4} \cdot \left\{ \frac{8}{3\pi} - \frac{z}{R} \right\} > \frac{\varepsilon \cdot \pi \cdot m_e c^2}{R \cdot e} \tag{15}$$

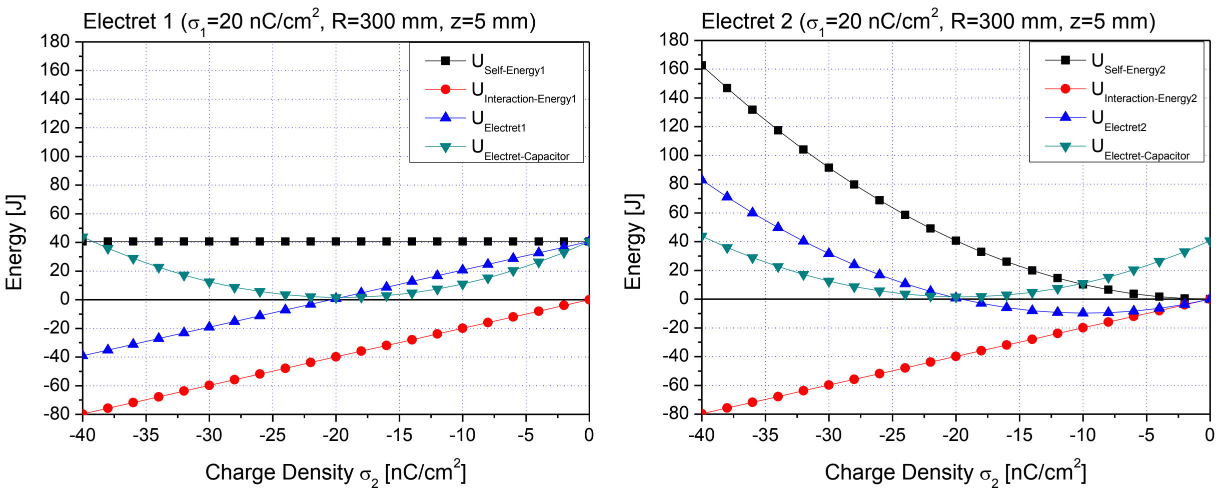

Figure 5. Dependence of Electret Plates Energy on Charge Density σ_2.

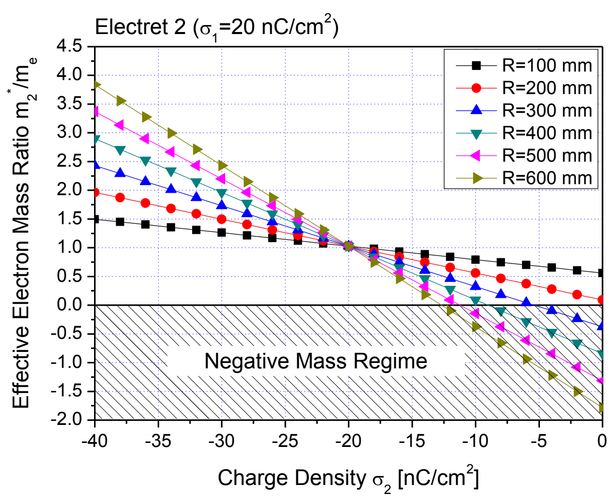

Figure 6. Effective Electron Mass Ratio Dependence on Disc Radius and Charge Density σ_2.

Therefore, in order to obtain negative mass charge carriers, the electret capacitor should have

- a high positive charge density σ_1,
- a low negative charge density σ_2,
- a large radius R,
- and a low relative dielectric constant ε_r.

Especially the last bullet point is important because a high dielectric will make it basically impossible to obtain a negative mass regime. However, with available Teflon-based electrets and charge densities, it should be possible to test this effect if the electret diameter is sufficiently large (R > 200 mm in our example). The total maximum amount of negative mass generated with the R=300 mm electret capacitor is -8.1×10^{-18} kg (equal to -0.73 J) for a charge density of -2.7 nC/cm², if we sum up all negative mass charge carriers on plate 2. Such a small effect cannot be seen by weight measurements or by applying mechanical spring forces.

We will face an even harder challenge to see if the self-propulsion effect exists as in the Weber's electrodynamics example since we cannot vary the amount of charges in the electret or move them inside the dielectric. The only possibility is to realize a spring with electric forces for instance by bringing another electret plate close to electret 2 and leaving a gap between as shown in Fig. 7. The maximum force generated by such a three-plate electret capacitor assuming electric spring forces is

$$F = \frac{\sigma_2 \sigma_3}{2\varepsilon} \cdot R^2 \pi \tag{16}$$

Further pursuing our example and assuming that $\sigma_2=\sigma_3$ in order to not disturb the balance in our electret capacitor, the corresponding force would be F=5.8 N. This is equal to large-scale electric propulsion thrusters and would provide a constant and long-term steady acceleration without consuming fuel or energy. Even if an acceleration scheme as shown in Fig. 7 can be realized, it is not clear how the negative mass electron would communicate the force to its dielectric surrounding (the back-reaction to the crystal atoms is also reversed due to the negative inertia). All that needs to be investigated and answered by experiments.

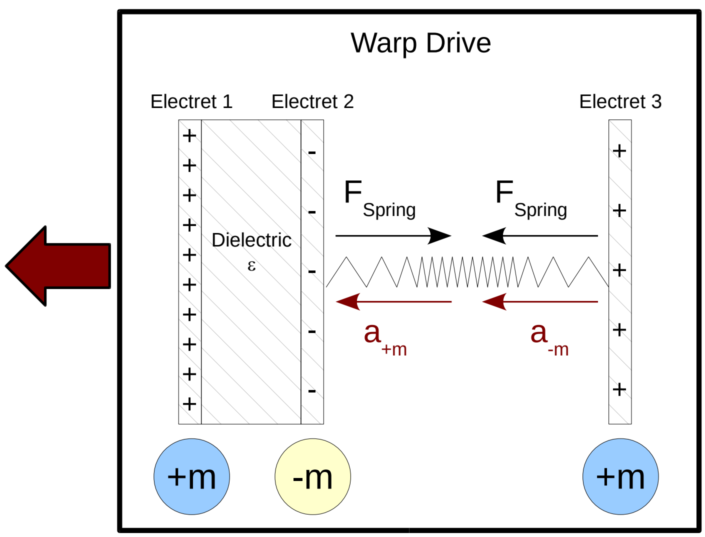

Figure 7. Space Drive Concept based on 3-Plate Electret Capacitor.

Although the amount of negative energy seems small, it is enormous compared to what could be expected e.g. from Casimir energies. The Casimir effect[28] was verified down to a distance of 150 nm which corresponds to an energy, if spread over the same area as our electret capacitor, of -3×10^{-8} J. Even at a distance of only 20 nm the Casimir energy is only -3×10^{-5} J and thus 5 orders of magnitude below our electret capacitor effect. If our hypothesis that the Coulomb energy-mass localizes at the charge carriers is correct, maybe this negative energy/mass can also be used for other space-drive schemes.

III. Conclusion

The space drive concept is based on the idea of building a self-accelerating, propellantless propulsion system which requires negative (inertial) mass. Experiments with neutrons that had a negative effective mass inside a dedicated crystal, showed, that the concept of negative inertia as defined by Newton's laws is real. However, for propulsion applications, it would be very beneficial to have charged negative mass which can be coupled to ordinary matter by electric forces to form the technology basis of a self-accelerating propulsion system as envisioned by Forward[3]. In this paper we showed two examples of how such a negative matter drive may be realized:

The first possibility of based on the assumption that Weber's electrodynamics is correct. Here we may then utilize a prediction from Assis[16], that the mass of a charge which is accelerated inside a charged dielectric sphere should change depending on the outside charge. A simple capacitor inside a charged dielectric sphere could then already show a self-propulsion effect, at least during charging and discharging when the charges move/accelerate or with the help of a spring between the plates and the dielectric.

The second possibility is based on the hypothesis that the energy of electrostatic interactions can localize as mass changes on the individual charges involved. We showed that asymmetric charge distributions (i.e. large positive charge density opposite to small negative charge density) can then lead to significant negative energies on the plate with the smallest charge density, many orders of magnitude higher than negative energies predicted by the Casimir effect. This could be realized for example by two electret plates with different charge densities and opposite polarities (called an electret-capacitor). A criterion was derived that shows that a certain geometry and charge density is required to obtain this negative mass regime. Analysis shows that significant forces in the range of Newtons could be produced using available electret technology.

Both possibilities could be used to investigate if such a self-propulsion effect exists. If at least one of our assumptions is correct, it should be possible to build a propulsion system in the laboratory that closely resembles the characteristics of a real space drive.

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