The Gravitational Mass at the Superconducting State

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Abstract

It will be shown that the gravitational masses of the electrons of a superconducting material are strongly negative. Particularly, for an amount of mercury (Hg) at the transition temperature, \( T_c = 4.15 \text{ K} \), the negative gravitational masses of the electrons decrease the total gravitational mass of the Hg of approximately 0.1 percent. The weight reduction increase when the Hg is spinning inside a magnetic field or when it is placed into a strong oscillating EM field.

Introduction

We have shown in a previous paper\(^1\) that the gravitational mass and the inertial mass are correlated by a dimensionless factor, which depends on the incident radiation upon the particle. It was shown that only in the absence of electromagnetic radiation this factor becomes equal to 1 and that, in specific electromagnetic conditions, it could be reduced, nullified or made negative.

The general expression of correlation between gravitational mass \( m_g \) and inertial mass \( m_i \), is given by

\[
m_g = m_i - 2 \left\{ \frac{q}{m_i c} \right\}^2 m_i \quad (1)
\]

the momentum \( q \) is given by

\[
q = N\hbar k = N\hbar \omega (\omega / k) = U / (dz / dt) = U / v \quad (2)
\]

where \( U \) is the electromagnetic energy absorbed (or emitted) by the particle; \( v \) is the velocity of the incident (or emitted) radiation, which is

\[
v = \frac{c}{\sqrt{\frac{\mu \varepsilon}{2} \left( \sqrt{1 + \left( \sigma / \varepsilon \right)^2} + 1 \right)}} \quad (3)
\]

where \( \omega = 2\pi f \); \( f \) is the frequency of the radiation: \( \varepsilon, \mu \) and \( \sigma \), are the electromagnetic characteristics of the outside medium around the particle in which the incident (or emitted) radiation is propagating (\( \varepsilon = \varepsilon_e \varepsilon_0; \varepsilon_r \) is the relative electric permittivity and \( \varepsilon_0 = 8.854 \times 10^{-12} \text{ F/m} \); \( \mu = \mu_r \mu_0; \mu_r \) is the relative magnetic permeability and \( \mu_0 = 4\pi \times 10^{-7} \text{ H/m} \)).

The general expression of correlation between gravitational mass and inertial mass (Eq.(1)) was experimentally confirmed by an experiment using Extra-Low Frequency (ELF) radiation on ferromagnetic material. The experimental setup and the obtained results were presented in a previous paper\(^2\). Recently another experiment\(^3\) using UV light on phosphorescent plastic have also confirmed the Eq.(1).
By the substitution of Eqs.(3) and (2) into Eq.(1), we obtain

\[ m_e = -m - 2\left\{ 1 + \left( \frac{U}{m_e c^2} \right)^2 \right\} \frac{\varepsilon \mu_\sigma}{2} \left[ \frac{\varepsilon \mu_\sigma}{2} + 1 \right] \left( \sqrt{1 + \left( \frac{\varepsilon \mu_\sigma}{2} + 1 \right) \sigma / \omega_e} \right)^2 \right\} - 1 \]

(4)

In the equation above, \( n_r \) is the refractive index, which is given by:

\[ n_r = \frac{c}{\nu} = \sqrt{\frac{\varepsilon \mu_\sigma}{2} \left( \sqrt{1 + \left( \frac{\varepsilon \mu_\sigma}{2} + 1 \right) \sigma / \omega_e} \right)^2 + 1} \]  

(5)

c is the speed in vacuum and \( \nu \) is the speed in medium.

It is important to note that the electromagnetic characteristics, \( \varepsilon \), \( \mu \), and \( \sigma \), do not refer to the particle, but to the outside medium around the particle in which the incident (or emitted) radiation is propagating. For an electron inside a body, the incident (or emitted) radiation on this electron will be propagating inside the body, and consequently, \( \sigma = \sigma_{\text{body}} \), \( \varepsilon = \varepsilon_{\text{body}} \), \( \mu = \mu_{\text{body}} \). Thus, according to the Eq.(4), the gravitational mass of the electron is given by

\[ m_{ge} = m_e - 2\sqrt{1 + \left( \frac{U}{m_e c^2} n_r(\text{body}) \right)^2} - 1 \]  

(6)

where \( m_e \) is the inertial mass of the electron and \( n_r(\text{body}) \) is the index of refraction of the body.

Based on the equation above, we will show that the gravitational masses of the electrons of a superconducting material are strongly negative. Particularly, for an amount of mercury \((\text{Hg})\) at the transition temperature, the negative gravitational masses of the electrons decrease the total gravitational mass of the \( \text{Hg} \) of approximately 0.1%.

2. Superconductors

Usually, for superconducting materials, we have \( \sigma \gg \omega_e \). Thus, in that case, the index of refraction given by the Eq.(5), can be written

\[ n_r = \sqrt{\frac{\mu \sigma c^2}{2 \omega_e}} \]  

(7)

The equation above shows that the refractive indices of the superconducting materials are enormous. Consequently, in agreement with Eq.(6), the gravitational masses of their electrons can be significantly reduced even for \( U \) relatively small as, for example, in the case of thermal radiation emitted from a disk of superconducting material at the transition temperature \( T_c \).

In the case of thermal radiation, it is common to relate the energy of photons to temperature, \( T \), through the relation,

\[ \langle h\nu \rangle = kT \]

where \( k = 1.38 \times 10^{-23} \text{J/K} \) is the Boltzmann’s constant. Thus, we can write

\[ U = \eta \langle h\nu \rangle \approx \eta kT \cdot \]

Where \( \eta \) is a particle-dependent absorption (or emission) coefficient. Consequently, we can express Eq.(6) as follows:

\[ m_{ge} = m_e - 2\sqrt{1 + \left( \frac{\eta n_r \mu \sigma kT}{m_e c^2} \right)^2} - 1 \]  

(8)
For electrons $4$, $\eta = \eta_e \simeq 0.1$. Thus, for $T = T_c$ (Transition Temperature) the equation above can be written

$$m_{ge} = m_e - 2\left(1 + 1.2 \times 10^{-22} \sigma T_c^2 - 1\right) m_e \quad (9)$$

From this equation we can conclude that the gravitational masses of the electrons of a superconducting material ($\sigma > 10^{-22} S/m$) are strongly negative.

Let us now consider the $Hg$ at the transition temperature $^5$, $T_c = 4.15$ K. At this temperature, the electric conductivity of the $Hg$ is $\sigma \equiv 10^{-23} S/m$. Consequently, from the Eq.(9) we obtain

$$m_{ge} \equiv -11.25 m_e$$

Thus the total gravitational mass of the $Hg$ is

$$m_{(Hg)} = \left[\frac{-11.25 m_e + m_p + m_n}{m_e + m_p + m_n}\right] m_{(Hg)} \equiv 0.99 m_{(Hg)}$$

This means that the negative gravitational masses of the electrons decrease the total gravitational mass of the $Hg$ of less than 1% percent (approximately 0.1%).

This prediction can be verified in a very simple way, see Fig. 1. In addition, we suggest to check the weights of samples (of different masses and chemical compositions) hung above the $Hg$. Possibly the percentage of weight decrease will be the same of the $Hg$ up to some meters upwards (due to shielding effect produced to the reduction of the gravitational mass of the $Hg$).

It is important to note that, if the $Hg$ cylinder rotates at a strong magnetic field $B$ perpendicular to the cylinder, the weight reduction must increase due to the emission of radiation from the electrons rotating within the magnetic field. At this case, the radiation emitted from each electron has power $P$ which, as we know, is given by

$$P = \frac{\mu_e^4 B^2 V^2}{6 \pi m_e^2 c \left(1 - V^2/c^2\right)} \quad (10)$$

Most of the emitted radiation has frequency $f$

$$f = f_0 \left(1 - \frac{V^2}{c^2}\right)^{\gamma/2} \quad (11)$$

where

$$f_0 = \frac{eB}{2 \pi m_e} \sqrt{1 - V^2/c^2} \quad (12)$$

is the named cyclotron frequency.

To simplify the calculations we can consider only the contribution of the emitted radiation with frequency $f$. Then we can put $U = nhf$ in Eq.(6), where $n$ is the number of emitted
photons from the electron. Thus we can write

\[ m_g = m_v - 2 \left[ 1 + \left( \frac{n \hbar f}{m_v c^2} \right)^2 \right]^{-1} m_v \]  

(13)

But \( P = n \hbar f / \Delta t = nh f^2 \), thus we can write \( n = P / \hbar f^2 \). Substitution of \( n \) into Eq.(13) gives

\[ m_g = m_v - 2 \left[ 1 + \left( \frac{P}{m_v c v} \right)^2 \right]^{-1} m_v \]  

(14)

For \( \sigma \gg \omega \varepsilon \) Eq.(3) reduces to

\[ v = \sqrt{\frac{4 \pi e^2}{\mu \sigma}} \]  

(15)

By the substitution of Eqs.(10) and Eq.(15) into Eq.(14) we obtain

\[ m_g = m_v - 2 \left[ 1 + \left( \frac{e^4 B^2 V^2}{6 \pi e^2 c^2 (1-V^2/c^2)^2} \right) \frac{\mu \varepsilon}{4 \pi f^2} \right]^{-1} m_v \]  

(16)

Note that the momentum \( q \) in Eq.(1) can be also produced by an Electric field or Magnetic field if the particle has an electric charge \( Q \).

In that case, combination of Lorentz's Equation \( \vec{F} = Q \vec{E}_0 + Q \vec{V} \times \vec{B} \) and \( \vec{F} = m \dot{\vec{a}} \) (see reference 1, p.78-Eq.(2.05)) gives

\[ q' = m_g V = m_g \frac{Q(E_0 + \vec{V} \times \vec{B})}{m_g} \Delta t \]  

(17)

In the particular case of an oscillating EM field ( frequency \( f_{osc}, \Delta t = 1 / f_{osc} \) we have

\[ q' = \frac{Q(E_{osc} + \vec{V} \times \vec{B}_{osc})}{f_{osc}} \]  

(18)

Thus, the general expression of \( q \) in Eq.(1) will be

\[ q = \frac{U}{v} + q' = \frac{U}{c} v + \frac{Q(E_{osc} + \vec{V} \times \vec{B}_{osc})}{f_{osc}} \]  

(19)

Consequently, if the Hg cylinder rotates at an oscillating magnetic field \( B_{osc} \) of frequency \( f_{osc} \), perpendicular to the cylinder, then the total value of \( q \) for the electrons of the Hg, according to Eq.(19), will be given by

\[ q = \frac{U}{c} n_r + \frac{e(E_{osc} + \vec{V} \times \vec{B}_{osc})}{f_{osc}} \]  

(20)

where \( \frac{U}{c} n_r \), according to Eq.(16), is given by

\[ \frac{U}{c} n_r = \frac{e^4 B^2 V^2}{6 \pi m_e^2 c^2 (1-V^2/c^2)^2} \sqrt{\frac{\mu^3 \sigma}{4 \pi f^2}} \]  

where

\[ \vec{V} = \vec{V}_{osc} + \vec{V}_{osc} \]

In the equation above \( V_{osc} = \omega R \) and \( V_{osc} \) can be calculated by means of the well-known equations of the Ohm's vectorial Law : \( \vec{J} = \sigma \vec{E} \) and \( \vec{J} = \rho_m \vec{V} \) (J is the current density, in \( A/m^2 \); \( \rho_m \) and \( V \) are respectively, the density (C/m³) and the velocity of charge carriers). Thus we can write

\[ V_{osc} = \left( \frac{\sigma}{\rho_m} \right) E_{osc} = \left( \frac{\sigma}{\rho_m} \right) B_{osc} = \]  

\[ \left( \frac{\sigma}{\rho_m} \right) B_{osc} \sqrt{\frac{2 \omega_{osc}}{\mu \sigma}} = B_{osc} \sqrt{\frac{4 \pi \omega_{osc} \sigma}{\mu \rho^2_m}} \]  

(21)
Thus the Eq. (20) can be rewritten in the following form:

\[
q = \frac{e^4 B^2 \nu_{osc}^2}{6 \pi m c \left(1 - \frac{V^2}{c^2}\right)} \left\{ \frac{\mu^2 \sigma}{4 \pi^3} + \frac{e \left(E_{osc} + \alpha R B_{osc} + V_{osc} B_{osc}\right)}{f_{osc}} \right\}
\]

(22)

Where \( E_{osc} = \nu B_{osc} \) ( \( \nu \) given by the Eq. (3), \( \nu = \sqrt{\frac{2\alpha_{osc}}{\mu \sigma}} \).

By the substitution of Eq. (22) into Eq. (1), we obtain

\[
m_{osc} = m - 2 \left\{ 1 + \frac{X + e \left(E_{osc} + \alpha R B_{osc} + V_{osc} B_{osc}\right)}{m c f_{osc}} \right\} m
\]

(23)

where

\[
X = \frac{e^4 B^2 \nu_{osc}^2}{6 \pi m c^2 \left(1 - \frac{V^2}{c^2}\right)} \left\{ \frac{\mu^2 \sigma}{4 \pi^3} \right\}
\]

For \( H_g \) at the superconducting state we can take \( \mu \equiv \mu_{Hg} ; \sigma \equiv \frac{10^{23}}{m} \) and \( \rho_m \equiv \frac{10^{13}}{C / m^3} \). Thus, when the \( H_g \) cylinder is rotating at angular frequency \( \omega_c \equiv 5000 rpm \), within a magnetic field \( B_{osc} \equiv 0.1T \) of frequency \( f_{osc} \equiv 10 MHz \), a point at distance \( R = 10 cm \) (average radius of the cylinder) from the rotating axis has tangential velocity \( V_{osc} = \omega_c R \equiv 52 m/s \), and consequently the gravitational masses of the electrons at this distance are then

\[
m_{ge} \equiv -160.70 m_c
\]

We can assume this value as the average gravitational mass of the electrons. Thus, the total average gravitational mass can be written as follows

\[
m_{g(Hg)} = \left[ \frac{-160.70 m_e + m_p + m_n}{m_e + m_p + m_n} \right] m_{g(Hg)} \equiv \frac{0.96 m_{g(Hg)}}
\]

This means that the total gravitational mass of the \( H_g \) decreases of approximately 4% percent.

In our opinion, this way Podkletnov's effect may be understood.

When the \( H_g \) cylinder isn't rotating (\( \omega_c = 0 \)) the Eq. (23) reduces to

\[
m_{ge} = m - 2 \left\{ 1 + \frac{e}{m c f_{osc}\left(\frac{4\pi}{\mu \sigma} + \frac{V_{osc}}{f_{osc}}\right)} \right\} m
\]

(24)

By the substitution of Eq. (21) into Eq. (24) we obtain

\[
m_{ge} = m - 2 \left\{ 1 + \frac{e B_{osc}}{m c f_{osc}\left(\frac{4\pi}{\mu \sigma} + \frac{V_{osc}}{f_{osc}}\right)} \right\} m
\]

(25)

Then, if \( B_{osc} \equiv 10T \); \( f_{osc} \equiv 10 MHz \), Eq. (25) gives

\[
m_{ge} \equiv -3700 m_e
\]

Thus, the total average gravitational mass of the \( H_g \) is

\[
m_{g(Hg)} = \left[ \frac{-3700 m_c + m_p + m_n}{m_e + m_p + m_n} \right] m_{g(Hg)} \equiv -0.01 m_{g(Hg)}
\]

Again we suggest to check the weights of samples (of different masses and chemical compositions) above the \( H_g \). Possibly the samples
will float above the Hg (the gravitational masses of the samples will be slightly negative, due to the negative gravitational mass of the Hg).

Let us now consider a static ( \( \omega = 0 \) ) parallel-plate capacitor, where \( d \) is the distance between the plates; \( \Delta V_{AC} \) is the applied voltage; \( E_{osc} = \Delta V_{AC} / d \) is the external electric field. Inside the dielectric the electric field is \( E = \sigma_m / \varepsilon = E_{osc} / \varepsilon \), where \( \sigma_m \) (in C/m²) is the density of electric charge and \( \varepsilon = \varepsilon_0 \varepsilon_r \).

Thus the charge \( Q \) on each surface of the dielectric is given by \( Q = \sigma_m S \) (\( S \) is the area of the surface). Then we have

\[
Q = \sigma_m S = (E_{osc} \varepsilon_0)S \quad (26)
\]

Within the oscillating field \( E_{osc} \) the charge \( Q \) (or “charge layer”) acquire a momentum \( q \), according to Eq.(19), given by

\[
q = \frac{U}{c} \eta + \frac{Q(E_{osc} + \dot{V}_{osc} \times \dot{B}_{osc})}{f_{osc}} = \frac{U}{c} \eta + \frac{Q(2E_{osc})}{f_{osc}} \quad (27)
\]

If \( U = 0 \) then Eq.(27) reduces to

\[
q = \frac{2Q E_{osc}}{f_{osc}} + \frac{2E_{osc} \varepsilon_0 S}{f_{osc}} = \frac{2(\Delta V_{AC}/d)^2 \varepsilon_0 S}{f_{osc}} \quad (28)
\]

Assuming that in the dielectric of the capacitor there are \( N^* \) layers of dipoles with thickness \( \xi \) approximately equal to the diameter of the atoms, i.e., \( N^* = d / \xi \equiv 10^{10}d \) then, according to Eq.(1), for \( q >> m_e c \), the gravitational mass \( m^*_g \) of each dipole layer is

\[
m^*_g \equiv -2 \left( \frac{q}{m_c} \right) m_i \equiv -2q \frac{\varepsilon_0 S}{c} \equiv -4 \left( \frac{\Delta V_{AC}}{d} \right)^2 \frac{\varepsilon_0 S}{f_{osc} c} \quad (29)
\]

Thus, the total gravitational mass \( m_g \) of the dielectric may be written in the following form

\[
m_g = N^* m^*_g \equiv -4 \times 10^{10} \left( \frac{\varepsilon_0 S}{f_{osc} cd} \right) \Delta V_{AC}^2 \quad (30)
\]

For example, if we have \( \Delta V_{AC} = 50KV \); \( S = 0.01m^2 \); \( f_{osc} = 10^7 Hz \) and \( d = 1mm \)

Eq.(30) gives \( m_g \equiv -0.3kg \)

The result above can also be reach by means of the calculation of the gravitational masses of the electrons of the dielectric of the capacitor. Note that the acceleration upon the electrons (due to the field \( E_{osc} \)) is obviously equal to acceleration upon the electric dipoles of the dielectric. Consequently, the momentum \( q \) for the electrons \( q_e \) and for the electric dipoles \( q_{dp} \) are respectively, \( q_e = m_e V \) and \( q_{dp} = m_{dp} V \). Thus, \( q_e = q_{dp} \left( \frac{m_e}{m_{dp}} \right) \).

From Eq.(27), for \( U = 0 \), we can write

\[
q_{dp} = \frac{2Q_{dp} E_{osc}}{f_{osc}} \quad (31)
\]

where \( Q_{dp} \) is the dipole electric charge. Consequently,

\[
q_e = \frac{2Q_{dp} E_{osc}}{f_{osc}} \left( \frac{m_e}{m_{dp}} \right) \quad (32)
\]
\[
\frac{q_e}{m_e} = \frac{2Q_{\text{osc}}E_{\text{osc}}}{m_{dip}c^2f_{\text{osc}}} \left( \frac{m_e}{m_{dip}} \right) = \frac{2Q_{\text{osc}}E_{\text{osc}}}{m_{dip}c^2f_{\text{osc}}} \quad (33)
\]

By the substitution of Eq.(33) into Eq.(1), we obtain

\[
m_{ge} = m_e - 2 \left( \frac{2Q_{\text{osc}}E_{\text{osc}}}{m_{dip}c^2f_{\text{osc}}} \right)^2 - 1 \right) m_e \quad (34)
\]

Assuming \( Q_{\text{osc}} \equiv 2 \times 10^{19} \) C; \( m_{dip} \equiv 1 \times 10^{-26} \) kg

and \( \Delta V_{AC} = 50 \) KV; \( d = 1 \) mm; \( f_{\text{osc}} \equiv 10^2 \) Hz

then Eq.(34) gives

\[
m_{ge} \equiv -133000m_e
\]

Then the total gravitational mass of the dielectric is

\[
m_g = \left[ -133000m_e + m_p + m_n \right] \left[ \frac{m_e}{m_e + m_p + m_n} \right] m_{(\text{He})} \equiv -35m_i
\]

But \( m_i = \rho V = \rho Sd \equiv 10^{-2} \) kg \( \) then

\[
m_g \equiv -0.3 \text{ kg}
\]

Possibly this is the explanation for the Biefeld-Brown Effect.

References

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