

New Gravitational Effects of Rotating Masses

Fran De Aquino

Copyright © 2013 by Fran De Aquino. All Rights Reserved.

Two gravitational effects related to rotating masses are described. The first is the *decreasing of the gravitational mass* when the rotational kinetic energy is increased. In the case of ferromagnetic materials, the effect is strongly increased and the gravitational mass can even become negative. The second is the *gravitational shielding effect* produced by the decreasing of the gravitational mass of the rotating mass.

Key words: Modified theories of gravity, Gravitational Effects of Rotating Masses, Experimental studies of gravity.
PACS: 04.50.Kd, 04.90.+e, 04.80.-y.

1. Introduction

In 1918, H. Thirring [1] showed that a rotating mass shell has a weak dragging effect on the inertial frames within it. In today's literature these results are known as *Lense-Thirring effects*.

Recently, the Lense-Thirring effect has received new interest because it becomes now possible to directly measure this tiny effect [2]. In the years 1959-1960 it was discovered by G. E. Pugh [3] and Leonard Schiff [4,5] that the mentioned dragging phenomenon leads to another effect - called the *Schiff effect* - which might be suited for experimental confirmation: The rotation axis of a gyroscope, inside a satellite orbiting the Earth, in a height of 650 km, suffers a precession of 42 milliarcseconds per year, due to the Earth's rotation [6].

Here, we show new gravitational effects related to rotating gravitational masses.

2. Theory

From the quantization of gravity it follows that the *gravitational mass* m_g and the *inertial mass* m_i are correlated by means of the following factor [7]:

$$\chi = \frac{m_g}{m_{i0}} = \left\{ 1 - 2 \left[\sqrt{1 + \left(\frac{\Delta p}{m_{i0} c} \right)^2} - 1 \right] \right\} \quad (1)$$

where m_{i0} is the *rest inertial mass* of the particle and Δp is the variation in the particle's *kinetic momentum*; c is the speed of light.

That equation shows that only for $\Delta p = 0$ the gravitational mass is equal to the inertial mass.

In general, the *momentum* variation Δp is expressed by $\Delta p = F \Delta t$ where F is the applied force during a time interval Δt . Note that there is no restriction concerning the *nature* of the force F , i.e., it can be mechanical, electromagnetic, etc.

For example, we can look on the *momentum* variation Δp as due to absorption or emission of *electromagnetic energy* by the particle.

In this case Δp can be obtained as follows: It is known that the *radiation pressure*, dP , upon an area $dA = dx dy$ of a volume $dV = dx dy dz$ of a particle (the incident radiation normal to the surface dA) is equal to the energy dU absorbed (or emitted) per unit volume (dU/dV).i.e.,

$$dP = \frac{dU}{dV} = \frac{dU}{dx dy dz} = \frac{dU}{dA dz} \quad (2)$$

Substitution of $dz = v dt$ (v is the speed of radiation) into the equation above gives

$$dP = \frac{dU}{dV} = \frac{(dU/dA dt)}{v} = \frac{dD}{v} \quad (3)$$

Since $dP dA = dF$ we can write:

$$dF dt = \frac{dU}{v} \quad (4)$$

However we know that $dF = dp/dt$, then

$$dp = \frac{dU}{v} \quad (5)$$

From this equation it follows that

$$\Delta p = \frac{U}{v} \left(\frac{c}{c} \right) = \frac{U}{c} n_r \quad (6)$$

where n_r is the index of refraction.

From Electrodynamics we know that when an electromagnetic wave with frequency f and velocity c incides on a material with relative permittivity ϵ_r , relative magnetic permeability μ_r and electrical conductivity σ , its *velocity is reduced* to $v = c/n_r$ where n_r is the index of refraction of the material, given by [8]

$$n_r = \frac{c}{v} = \sqrt{\frac{\epsilon_r \mu_r}{2} \left(\sqrt{1 + (\sigma/\omega\epsilon)^2} + 1 \right)} \quad (7)$$

Substitution of Eq.(6) into Eq. (1) yields

$$m_g = \left\{ 1 - 2 \left[\sqrt{1 + \left(\frac{U}{m_{i0} c^2} n_r \right)^2} - 1 \right] \right\} m_{i0} \quad (8)$$

If the body is *also* rotating, with an angular speed ω around its central axis, then it acquires an additional energy equal to its rotational energy ($E_k = \frac{1}{2} I \omega^2$). Since this is an increase in the internal energy of the body, and this energy is basically electromagnetic, we can assume that E_k , such as U , corresponds to an amount of electromagnetic energy absorbed by the body. Thus, we can consider E_k as an increase $\Delta U = E_k$ in the electromagnetic energy U absorbed by the body. Consequently, in this case, we must replace U in Eq. (8) for $(U + \Delta U)$. Note that the variable U can refer to both the electromagnetic energy of a radiation as *the electromagnetic energy of the electromagnetic field due to an electric current through the rotating gravitational mass*. If $U \ll \Delta U$, the Eq. (8) reduces to

$$m_g \cong \left\{ 1 - 2 \left[\sqrt{1 + \left(\frac{I \omega^2 n_r}{2 m_{i0} c^2} \right)^2} - 1 \right] \right\} m_{i0} \quad (9)$$

For $\sigma \ll \omega\epsilon$, Eq.(7) shows that $n_r = c/v = \sqrt{\epsilon_r \mu_r}$ and $n_r = \sqrt{\mu\sigma c^2 / 4\pi f}$ in the case of $\sigma \gg \omega\epsilon$. In this case, Eq. (9) gives

$$m_g \cong \left\{ 1 - 2 \left[\sqrt{1 + \frac{\mu\sigma\omega^2 I^2}{16\pi f m_{i0}^2 c^2}} - 1 \right] \right\} m_{i0} \quad (10)$$

Note that the effect of the electromagnetic field applied upon the mass is highly relevant, because in the absence of this radiation the index of refraction, present in Eq. (9), becomes equal to 1. Under these circumstances, the possibility of strongly reducing the gravitational mass practically disappears. On the other hand, the equation above shows that, in practice, the decreasing of the gravitational mass can become relevant in the particular case of ferromagnetic materials subjected to electromagnetic fields with *extremely low frequencies* (ELF).

Figure 1 shows a schematic diagram of a *Mumetal disk* ($\mu_r = 105,000$ at 100 gauss; $\sigma = 2.1 \times 10^6 \text{ S.m}^{-1}$) with radius $R = 0.10 \text{ m}$ ($I = \frac{1}{2} m_{i0} R^2$) rotating with an angular velocity $\omega = 2.09 \times 10^4 \text{ rad/s}$ ($\sim 200,000 \text{ rpm}$). Thus, if an ELF radiation or an electrical current with extremely low frequency e.g., $f = 0.1 \text{ Hz}$ is applied on the Mumetal disk, then according to Eq.(10), the expression of the gravitational mass of the disk is given by

$$m_g \cong -0.96 m_{i0} \quad (11)$$

It has been shown that there is an additional effect - *Gravitational Shielding* effect - produced by a substance whose gravitational mass was reduced or made negative [9]. The effect extends beyond substance (gravitational shielding), up to a certain distance from it (along the central axis of gravitational shielding). This effect shows that in this region the gravity acceleration, g_1 , is reduced at the same proportion, i.e., $g_1 = \chi_1 g$ where $\chi_1 = m_g / m_{i0}$ and g is the gravity acceleration *before* the gravitational shielding. Here, according to Eq.(11), we have $\chi_1 = -0.96$. Thus, the gravity acceleration *above* the Mumetal disk is $g_1 = -0.96g$ since the gravity before (below) the gravitational shielding is g .

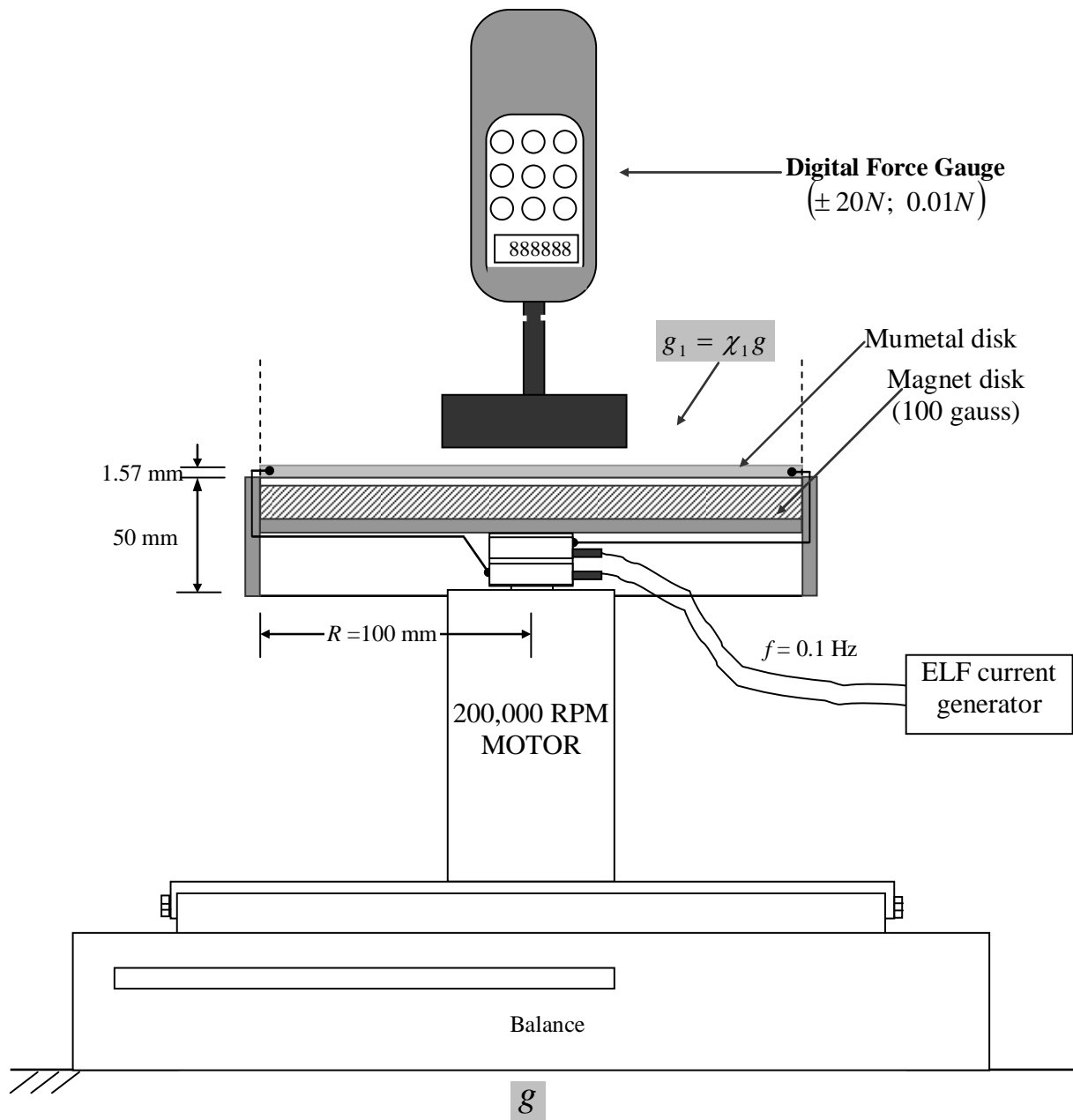


Fig.1 – Schematic diagram of an experimental set-up to measure the decrease of the gravitational mass of the Mumetal disk and the gravitational shielding effect produced by the rotating disk.

References

- [1] Thirring, H (1918) *Über die Wirkung rotierender ferner Massen in der Einsteinschen Gravitationstheorie*. Phys. ZS. **19**, 33.
- [2] Ciufolini, I., and Pavlis, E.C. (2004). *A confirmation of the general relativistic prediction of the Lense-Thirring effect*. Nature, 431, 958-960.
- [3] Pugh, G.E. (1959). *Proposal for a satellite test of the Coriolis prediction of general relativity*. WSEG Research Memorandum No.11. Washington, DC: The Pentagon.
- [4] Schiff, L.I. (1960). *Possible new experimental test of general relativity theory*. Physical Review Letters, 4, 215-217.
- [5] Schiff, L.I. (1960). *Motion of a gyroscope according to Einstein's theory of gravitation*. Proceedings of the National Academy of Sciences of the USA, 46, 871-882.
- [6] Ciufolini, I., and Wheeler, J. A. (1995). *Gravitation and Inertia*. Princeton: Princeton University Press.
- [7] De Aquino, F. (2010) *Mathematical Foundations of the Relativistic Theory of Quantum Gravity*, Pacific Journal of Science and Technology, **11** (1), pp. 173-232.
- [8] Quevedo, C. P. (1977) *Eletromagnetismo*, McGraw-Hill, p. 270.
- [9] De Aquino, F. (2010) *Gravity Control by means of Electromagnetic Field through Gas at Ultra-Low Pressure*, Pacific Journal of Science and Technology, **11**(2) November 2010, pp.178-247, Physics/0701091.