The effect on rulers, clocks and the speed of light

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Let us now reflect on the energy of elementary charged particles. It is composed of three parts; the energy in their electrical fields, the potential energy due to the separation of positive and negative charges and their kinetic energy stored in the magnetic fields generated by their motion. The equations for the energy content all have the same dimensions [M] $[L]^2[T]^{-2}$ even though their composition is different:

$$E_{el} = \frac{q^2}{8\pi\,\varepsilon_0\,a} \qquad E_{pe} = \frac{q_1\,q_2}{8\pi\,\varepsilon_0\,r} \qquad E_{ke} = \frac{\mu_0\,q^2\,v^2}{12\pi\,a}$$

If these energies vary as $e^{\frac{\Phi}{c^2}}$ then this is a complex set of relationships involving length, velocity, charge, permittivity and permeability. Each of these quantities must be expressed in terms of its dimensions (e.g. v = $[L]\,[T]^{-1}$) and the variation attributed to the effect of gravitational potential on each dimension. The theory of dimensional analysis tells us that each must be affected by a single factor. To obtain a solution, these must all be powers of a single factor. This means that the dimensions [M]: mass, [L]: length, [T]: time and [Q]: charge must map onto themselves as:

$$[M] \leftrightarrow \left(e^{\frac{\Phi}{c^2}}\right)^m [M] \qquad [L] \leftrightarrow \left(e^{\frac{\Phi}{c^2}}\right)^l [L] \qquad [T] \leftrightarrow \left(e^{\frac{\Phi}{c^2}}\right)^t [T] \qquad [Q] \leftrightarrow \left(e^{\frac{\Phi}{c^2}}\right)^q [Q]$$

where m, l, t and q are to be determined.

The symbol ↔ has been used to indicate that these factors are involved in a set of relationships between the quantity, the unit and the number of units in the quantity. If we consider a rod, it has an original length in the absence of a gravitational field. Gravitational potential causes it to contract, so its length becomes less, but the unit of length defined in terms of the wavelength of light also contracts, so that the locally made measurement of the rod's length remains unaltered. Likewise, the speed of light slows and the unit of speed decreases so that the locally measured value of the speed of light remains equal to the universal constant.

All we need to do is to find four physical properties for which we know the effect of gravitational potential and form four equations using dimensional analysis, then solve for m, l, t and q. We have derived the effect on Energy, we know from experiment the effect on clocks and radio signals and we make the assumption that charge is invariant.

$$\text{Clocks } [T] \leftrightarrow [T]\left(1 - \frac{|\Phi|}{c^2}\right)^{-1} \qquad \text{Speed of light } [L]\,[T]^{-1} \leftrightarrow [L]\,[T]^{-1}\left(1 - \frac{|\Phi|}{c^2}\right)^2$$

$$\text{Charge } [Q] \leftrightarrow [Q] \qquad \text{Energy [M]}\,[L]^2\,[T]^{-2} \leftrightarrow \text{[M]}\,[L]^2\,[T]^{-2}\left(1 - \frac{|\Phi|}{c^2}\right)^1$$

In the weak gravitational fields of the solar system, clocks run slow because the length of the unit of time is increased by a factor $\left(1 - \frac{|\Phi|}{c^2}\right)^{-1}$ and the speed of light is decreased by a factor of $\left(1 - \frac{|\Phi|}{c^2}\right)^2$. In a weak gravity field, the function $e^{\frac{\Phi}{c^2}}$ need only be expanded to its first two terms so that $e^{\frac{\Phi}{c^2}} = \left(1 - \frac{|\Phi|}{c^2}\right)$. This allows us to equate the GR expressions for weak gravitational fields into powers of $e^{\frac{\Phi}{c^2}}$, e.g. $\left(1 - 3\frac{|\Phi|}{c^2}\right)^{-2} = e^{-6\frac{\Phi}{c^2}}$, allowing us to form four equations in m, l, t and q and solve them for l and m.

$$(i) \quad t = -1 \qquad (ii) \quad l - t = 2 \qquad (iii) \quad q = 0 \qquad (iv) \quad m + 2l - 2t = 1$$

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two are answers and the other two solve easily to give

$$l = 1 \qquad m = -3 \qquad OH!$$

This is our first indication that all is not as simple it looks. Dimensional Analysis predates relativity and comes from an innocent age when mass was mass. In most instances the dimension [M] refers to inertial mass. We can interpret the result $m = -3$ as meaning that in the non relativistic situation, the inertial mass $m_i = m_p e^{-3\frac{\Phi}{c^2}}$. The analysis below will show us that gravitational potential affects both electric and magnetic fields. When an object is in free fall in a gravitational field, loss in potential energy = gain in kinetic energy so there is a simple transfer of energy from the electric fields to the magnetic fields. There is every reason to assume that the kinetic energy contributes to the gravitational mass and that we should write $m_i = \gamma m_p e^{-3\frac{\Phi}{c^2}}$ to take into account the effect of relativistic velocities.

An object in free fall has a constant energy content. Its total energy $E = m c^2$ is unaltered. Only when we arrest its fall and make the kinetic energy do work against the arresting force does the $E = m c^2$ energy become less.

We can see the effect of gravitational potential on the permittivity and permeability of space whose dimensions are $[M]^{-1} [L]^{-3} [T]^{2} [Q]^{2}$ and $[M]^{1} [L] [Q]^{-2}$ respectively:

$$-m - 3l + 2t + 2q = -2 \qquad \Rightarrow \varepsilon_0 \rightarrow e^{-2\frac{\Phi}{c^2}} \varepsilon_0$$

$$m + l - 2q = -2 \qquad \Rightarrow \mu_0 \rightarrow e^{-2\frac{\Phi}{c^2}} \mu_0$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \qquad \Rightarrow c \rightarrow e^{2\frac{\Phi}{c^2}} c$$

Which, if we remember that Φ is negative, means that permittivity and permeability are increased by a factor $e^{-2\frac{\Phi}{c^2}}$ with the result that the speed of light calculated from the transit time between planets is slower by a factor of $e^{2\frac{\Phi}{c^2}}$ than the local measurement of the speed of light.

Dicke and Puthoff separately argued that gravitational potential has a physical effect on the permittivity and permeability of space and that this affects the velocity of light, the physical dimensions of matter and the rate of time dependant processes. The author is inclined to go one step further and say that the permittivity and permeability of space relate to the ability of electric and magnetic fields to store energy and that they change because of the loss of energy. Which ever is correct, the net effect is that the equations of physics remain valid and control the physical dimensions of material objects and the rate of time dependent processes.

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$e^{3\frac{\Phi}{c^2}}$	$e^{2\frac{\Phi}{c^2}}$	$e^{\frac{\Phi}{c^2}}$	1	$e^{-\frac{\Phi}{c^2}}$	$e^{-2\frac{\Phi}{c^2}}$	$e^{-3\frac{\Phi}{c^2}}$	$e^{-6\frac{\Phi}{c^2}}$
Acceleration	Ang. acc.	Elec. potential	Charge	Time	Energy density	Inertial Mass	Density $_{im}$
Mag. mom.	Speed	Current	Force	Capacitance	Permittivity	Density$_{pm}$	
	Area	Energy	E	Inductance	Permeability		
		Length	H	MI	D		
		Ang. vel.	Ang. mom.		B		
		Torque	h		Stress		
		Einstein mass	Φ (mag. flux)				
		Gravitational mass	Ψ (el. flux)				
			Physical mass				

This table gives the power of $e^{\frac{\Phi}{c^2}}$ to be used in understanding the effect of gravitational potential on physical quantities, as calculated by dimensional analysis. Remember Φ is negative so these factors are less than 1 unless they include a minus sign. The smallest multiplying constant is on the left of the table. To describe the effect of gravitational potential on an object multiply by the factor shown.

The methods of dimensional analysis are not entirely reliable because of the different properties which are all called mass. For instance, density is [M] $[L]^{-3}$ but mass in this context is usually measured with a beam balance, so density is physical mass per unit volume. The [M] of dimensional analysis is inertial mass so the calculated factor for density of $e^{-6\frac{\Phi}{c^2}}$ needs interpreting with care and we give two entries density$_{pm}$ (physical mass per unit volume) and density$_{im}$ (inertial mass per unit volume) depending on the way the mass is measured.

These problems relating to the various meanings of mass in dimensional analysis make it impossible to get direct results for gravitational mass and the gravitational constant. The results given above are deduced in the section *Strong gravitational fields*.

[Younger readers who will only have used electronic scales which measure weight not mass are left to speculate on the effect of gravitational potential as measured with ruler and electronic scales.]

Magnetic moment for a current loop is Area x current. The current is reduced by a factor of $e^{\frac{\Phi}{c^2}}$ because less electrons pass due to the slowing of time dependant processes and the area is obviously reduced by a factor of $e^{2\frac{\Phi}{c^2}}$. If a current loop has magnetic moment M in the absence of gravitational potential, it will be reduced to $e^{3\frac{\Phi}{c^2}} M$.

Inertial mass is *force* ÷ *acceleration*. Force is unaltered and acceleration is increased by a factor $e^{-3\frac{\Phi}{c^2}}$. We can interpret this result in the following way. If we could watch from outside a region of high gravitational potential as a mass falls into it, we would see that its acceleration did not increase as we might expect form our calculation of the force of gravity. We would attribute this to an increase in inertial mass. While we cannot perform this observation, what we can do is send a mass through a region of high gravitational potential on a hyperbolic orbit and measure how much longer it takes than the calculated time. Then check this against an integration over its path of the effects on velocity and acceleration. More simply, we might consider a simple oscillator and how an increase in inertial mass by this factor results in the observed increase in the period of oscillation.

Of the things which are unaffected, charge, electric flux and magnetic flux are fundamental quantised

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elements of nature. Plank's constant $h = 2\,e\,\Phi_0$ is unaffected because its components are unaffected. Force is not a fundamental property of nature. Forces result from the exchange of energy in the process of doing work; *work = force x distance*. Because energy and distance are both reduced, the force remains unaltered.

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