formation equations for forces are well known[2]. The gravitational force on one of the masses, in their own reference frame, is Gm_1m_2/r^2. In the 'laboratory' frame, with respect to which their velocity is v, the force is again along the line joining the centres of the masses and is $Gm_1m_2/(\gamma r^2)$.

An observer in the laboratory frame would find that the masses were γm_1 and γm_2. If he calculated the gravitational force with the usual formula, he would find it to be $\gamma^2 Gm_1m_2/r^2$, which is larger than the true force by the quantity

$$X = [\gamma^2 - (1/\gamma)]Gm_1m_2/r^2$$

But X is not the gravitational equivalent of the magnetic force. If m_1 carries a charge q_1 and m_2 a charge q_2, the magnetic force on q_2 is q_2vB_1, where B_1 is the magnetic induction resulting from q_1 (ref. 3), or

$$\gamma\beta^2 q_1q_2/(4\pi\varepsilon_0 r^2)$$

If q_1 and q_2 are of the same sign, the electric force on q_2 in the moving frame is repulsive, and the magnetic force in the laboratory frame is attractive. Since the gravitational force in the moving frame is attractive, the gravitational analogue of the magnetic force in the laboratory frame is repulsive. It is given by replacing $q_1q_2/4\pi\varepsilon_0$ by Gm_1m_2 in the expression already given, or by

$$\gamma\beta^2 Gm_1m_2/r^2 \approx \beta^2 Gm_1m_2/r^2$$

where m_1 and m_2 are again the rest masses since in the moving frame the masses are fixed with respect to one another.

The quantities γ_1 and γ_2 (see ref. 4) referred to by Salisbury and Menzel come from general relativity. They cannot be arrived at using only special relativity.

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MENZEL AND SALISBURY REPLY—Professor Lorrain is correct in his assertion that the gyron force between moving masses is repulsive. We show that in our paper. But, his suggestion that the transformation for magnetic forces between moving charges also applies to moving masses is incorrect. The magnetic force between charges is proportional to the product of the equivalent currents, q_1v_1 and q_2v_2. In our simplified presentation, v_1v_2 happens to equal v^2. A similar identity occurs with the increase in mass caused by the kinetic energy of the motion. That increase in mass produces an extra force between the bodies. The force is proportional to the mass–current product, $m_1m_2v^2$ in our simple case, and must be distinguished from the gyron or magnetic-like repulsion.

That the magnetic force and the gyron force cannot have exactly the same coefficients should be clear from the fact that both experimentally and theoretically, electric charge is conserved under a Lorentz transformation, whereas mass increases with velocity.

The criticism that we are solving a problem in general relativity by means of special relativity is not valid. Particle accelerators demonstrate clearly that high accelerations and great mass increases occur. Thus, general relativity can be approached through special relativity; Einstein used the approach to obtain his famous law: $E = mc^2$.

General relativity theory is clearly incomplete because it predicts that mass is conserved in the same way as electric charge. The new Yilmaz theory of general relativity corrects this error and gives a conservation law of mass–energy and momentum that allows for a smooth transition between special and general relativity[1]. Further, the new theory satisfies the experimental criteria.

Any form of relativity must have a firm experimental basis. The invariance of electric charge is well founded experimentally. The change of mass with velocity is known to a high degree of accuracy; it materially affects the design, operation, and observation of a wide variety of particle accelerators.

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Matters arising

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Embryonic chick tibiae in steady electric fields

WATSON *et al.*[1] report that the growth rate of embryonic chick tibiae *in vitro* is enhanced by a pulsed electric field of 1,000 V cm^{-1} but not by a static field. We suggest that there is a simple reason why no enhancement should be expected in the static case. This has to do with the ability of the cultures to sustain a field.

Any field produced within the tissue will decay exponentially with a relaxation time constant[2]

$$\tau = \varepsilon_0 k/\sigma$$
$$= 8.8\times10^{-12}\ \mathrm{C^2\ N^{-1}\ m^{-2}}$$

where σ is the conductivity of tissue, k the dielectric constant of tissue and ε_0 the permittivity of free space.

There seem to be no published data on the conductivities and dielectric constants of uncalcified embryonic bone, but Schwan[3] has published data on the electric properties of other tissues (for example, lung, muscle and liver). Representative values at very low frequencies (1–10 Hz) are $\sigma = 10^{-3}$ mho cm^{-1} and $k = 10^6$. It seems reasonable that values for uncalcified chick tibia should have the same orders of magnitude. Converting σ to m.k.s. we derive a relaxation time constant $\tau \approx 10^{-4}$ s. The corresponding value for a dielectric like fused quartz is in excess of 10^6 s.

This shows why enhancement of growth is not to be expected in a steady field. During the 9-d growth period *in vitro* there is no field within the bone, no charge movement within or on the bone, and so no bioelectric command signal to the bone, except at the instants when the field is switched on or off.

Schwan's values for k may perhaps be treated with caution, but assigning more typical values to the dielectric constant (say $k = 10$) gives essentially the same result—in the steady field there is no transducer mechanism available.

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