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[20]Relation (10) is rather sensitive to the values chosen for α_{ABC}. A preliminary calculation indicates that (10) will be satisfied with $\alpha_{ABC} \cong 0.5$. Such a value would not be inconsistent with the data on total cross sections at high energy [B. M. Udgaonkar (private communication)]. I an thankful to Dr. P. G. Burke for helping with the numerical calculation.

DIRECT TEST FOR THE STRONG EQUIVALENCE PRINCIPLE*

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The strong equivalence principle asserts that in a freely falling, nonrotating laboratory, not only do all free particles move with constant velocities—this is the weak equivalence principle—but all the laws of physics are the same in that laboratory, independent of its position in space and time.[1,2] While it is the strong form of the equivalence principle which leads to general relativity, it is often stated that only the weak form is supported by the Eötvös-Dicke experiments[3] and that one can only raise indirect arguments for believing that the strong equivalence principle also holds.[1] The purpose of this note is to show that a simple modification of these experiments, namely, using test bodies with aligned nuclei, would represent a very severe direct test for the strong equivalence principle.

First, we note that in an accelerated coordinate system, all bodies do not fall at the same rate, because inertial forces are velocity dependent. This is well known for the Coriolis forces that appear in a rotating coordinate system, and this is also true for a coordinate system in uniform linear acceleration. Indeed, in such a system, the metric is[4]

$$g_{00} = -[c + (gz/c)]^2, \quad \text{other } g_{\alpha\beta} = \delta_{\alpha\beta}, \tag{1}$$

where g is the constant acceleration rate. The geodesic equation

$$(dv^\gamma/dt) + (\Gamma_{\alpha\beta}{}^{\gamma} - \Gamma_{\alpha\beta}{}^{0} v^\gamma) v^\alpha v^\beta = 0 \tag{2}$$

(where $v^\alpha = dx^\alpha/dt$, $v^0 = 1$) then gives

$$F_z = m\,dv_z/dt = -mg[1 + (gz/c^2)][1 + 2(v_z^2/g_{00})], \tag{3}$$

and shows that the d'Alembert forces are velocity dependent. (Note that this result is just a mathematical consequence of the transformation law to an accelerated coordinate system and is quite independent of the validity of general relativity.)

Thus, if we consider a hot and a cold body in a uniformly accelerated coordinate system, then the inertial forces on the particles of the hot body will be, on the average, smaller than those acting on the particles of the cold body. Nevertheless, both bodies will "fall" at the same rate, as may easily be seen by considering the coordinate transformation which restores the original inertial frame in which they are at rest. This "paradox" is easily resolved if we note that the internal forces within each body have also to be transformed from the inertial frame to the accelerated one, and their law of transformation is such that the change in the internal forces exactly compensates the difference between the inertial forces in the hot and cold bodies. That it must be so is evident without detailed calculations, if we just remember that we are only describing the same physical situation in two different coordinate systems.

Let us now stop doing "pencil and paper physics," and let us consider a hot and cold body in a true gravitational field (caused by the attraction of other masses).[2] Here, the weak equivalence principle cannot be invoked, since the particles in each body are not free. However, the strong equivalence principle still asserts that both bodies will fall at the same rate, if initially at rest, because both will be seen at rest in a freely falling coordinate system. This, however, requires not only gravitational forces to be velocity dependent in exactly the same way as inertial forces, but also the gravitational field must interact with all the internal forces (molecular, nuclear, etc.) in precisely such a way as to be exactly compensated by the transformation law of these forces to the freely falling coordinate system.

The last point has hitherto been tested with accuracy[3] only in the case of random internal motions. We still can conceive the possibility that the gravitational field does not affect the internal forces as an inertial field does, but that the difference averages to zero in the case of random motions. A possible test on that hypothesis would be to perform the Eötvös-Dicke experiments with oriented nuclei, so that the internal motion would no longer be random. Of course, nuclei are not classical systems, to which Eq. (3) can apply, but the same kind of effect should be expected, at least qualitatively. Discrepancies, if found, could well be of the order of the mass defect of the nuclei, i.e., 10^{-3}. On the other hand, a negative result would represent an extremely severe test for general relativity.

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