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November 1961

Transverse Mass and Gravitational Mass

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A problem suggested by Professor Gamow deals with the relationship between the transverse mass and the gravitational mass: A steamroller of mass m moves horizontally, in the $+x$ direction, with velocity v, in a region of space in which there is a gravitational field intensity g vertically downward. Find the weight of the moving steamroller.

NOTES AND DISCUSSION

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A PROBLEM suggested by Professor Gamow deals with the relationship between the transverse mass and the gravitational mass: A steamroller of mass m moves horizontally, in the $+x$ direction, with velocity v, in a region of space in which there is a gravitational field intensity g vertically downward. Find the weight of the moving steamroller.

Following Schiff[1] we assert that gravitational effects can be incorporated into special relativity by use of the equivalence principle, and that accelerations do not affect the applicability of the Lorentz transformations. Consider three observers: A is at rest in the gravitational field, B

is on a second frame in field free space which is accelerated upward ($+z$ direction) with acceleration g with respect to an inertial frame on which observer C is located. By the equivalence principle, B is equivalent to A. We consider a steamroller of mass m_0 which is moving in the x direction with velocity v in B's frame. The steamroller is observed by inertial observer C for whom it is instantaneously at rest in the z direction but is accelerated with acceleration g.

C knows that in first approximation Newtonian mechanics is correct, but that he must amend it for transverse accelerations by use of the transverse mass. He infers that the steamroller must be experiencing an upward force $F_z = m_0 g / (1 - v^2/c^2)^{\frac{1}{2}}$. Since B is instantaneously at rest with respect to C he agrees with C's conclusion. And since B is equivalent to A, A must conclude that the weight of a moving steamroller is determined by its transverse mass in this case, rather than by its rest mass. That is, a steamroller moving in the horizontal direction with speed v weighs $m_0 g / (1 - v^2/c^2)^{\frac{1}{2}}$ instead of $m_0 g$ which it weighed when at rest.

[1] L. I. Schiff, Am. J. Phys. **28**, 340 (1960).