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Research Article

PSEUDOGRAVITY

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ABSTRACT
This paper addresses the equivalence between acceleration and pseudogravity (or *the strong equivalence principle*). It revisits pseudogravity and its pedagogical utility in explaining specific physical phenomena, such as the bending of light beam, weightlessness, and the passage of time in accelerated chambers. It dispels the common notion of centrifugal force as a real force.

Keywords: *Pseudogravity, Equivalence Principle, Centrifugal Force*

INTRODUCTION
The genesis of the strong equivalence principle lies in the following expression (Einstein, 1955):
(Gravitational mass) · (Gravitational field intensity) = (Inertial mass) · (Acceleration);
that is, "a gravitational mass in gravitational field" equates to "an inertial mass under acceleration."

It is well known and accepted that gravitational mass and inertial mass of an object are numerically virtually equal (Eötvös, 1890; Roll, *et al*., 1964; Singh, 2018); this is also known as the weak equivalence principle. Gravitational mass is an intrinsic mass of objects; inertial mass is an as-if (or fictitious, or pseudo) mass of objects. Acceleration, thus, is equivalent to fictitious gravitational field intensity or pseudogravity.

Gravitational force is a *mediated* force; and light interacts with gravitational field (Singh, 2017).

UTILITY OF PSEUDOGAVITY
The principle of equivalence between acceleration and pseudogravity is a powerful *thought-experiment* tool, which may be applied judiciously to address typical physical phenomena. Some salient phenomena, which have been well covered in the literature, are re-addressed here.

Bending of Light Ray
We take an accelerating rocket far from any gravitating mass. In the rocket, there is an observer who is oblivious of the external environment. We then examine what happens to a beam of light propagating across the rocket chamber near the top from one wall to the other – from the point of view of the observer.

As the light beam traverses the rocket chamber, the observer is being accelerated toward it. That is, relatively, the observer finds the light beam tracing a parabolic path and may infer that a mysterious downward gravity is bending the light beam downward. In reality, however, the light beam itself suffered *no* bending as *no* downward gravity was mediated.

Even though physically unnecessary, it is helpful to *imagine* pseudogravity acting in a direction opposite to acceleration to explain the bending of light beams in an accelerated chamber.

Weightlessness
There are two aspects to weight. In one aspect, the *weight* of a body is the force with which the earth attracts it. In the other aspect, *weight* is the "feeling" a body gets in gravitational field from the reaction force from the floor on which it rests; *weightlessness* is the feeling the body has when that reaction force is unavailable.

Weight may be increased or decreased by adding to or subtracting from the reaction force. In an ascending elevator, an observer feels heavier as an external upward force is added to the reaction force from the floor and may infer that additional downward gravity is present. In reality, however, *no new* downward gravity was mediated.

While the elevator is in controlled (free) descent, the gravitational attraction of the earth is working

partially (totally) in accelerating it downward; the observer in it gets reduced (zero) reaction force, feels lighter (weightless), and may infer that the earth's downward gravity has been reduced (cancelled) by a mysterious upward gravity. In reality, however, *no* upward gravity was mediated.

Even though physically unnecessary, it is helpful to *imagine* pseudogravity acting in a direction opposite to acceleration to explain the changes in weight in accelerated frames.

Centrifugal force

A force at an angle to a body's uniform velocity keeps the body on a curved path; that force is called centripetal force.

An astronaut in a satellite around the earth is under the centripetal force of the earth's gravity. The centripetal force is working totally in keeping the satellite and the astronaut in the orbit. Therefore, the astronaut gets no reaction force from any platform and feels weightless and may infer that an outwardly centrifugal force is active and cancelling the earth's inwardly centripetal force. In reality, no centrifugal gravity, in opposition to the earth's centripetal gravity, is being mediated.

On a rotating disk, a centripetal force of correct magnitude must be applied on a body in order to keep it at rest. An observer, however, may infer that a centrifugal force is acting on the body cancelling the centripetal force. If the centripetal force is taken off, the body would move off the disk tangentially with the current velocity.

Centrifugal force is fictitious (pseudo); it does not exist.

Even though physically unnecessary, it is helpful to *imagine* centrifugal force acting in a direction opposite to centripetal force to explain the motion of an object in an orbiting or a rotating frame.

Passage of Time

In an accelerating rocket far from any gravitating mass, an observer in it detects *no gravitationally induced* changes in the time periods of resident atomic clocks, because *no* gravity is being mediated. (Objects, including atomic clocks, do *not* possess potential energy in pseudogravity.)

In a satellite orbiting around the earth, an observer in it measures the time periods of resident atomic clocks relatively contracted. That is, time runs faster in the satellite. This is because the gravitational field at the satellite is weaker than at the earth (Singh, 2017).

CONCLUSION

Gravity is mediated and real, and related theories can be used directly to explain physical phenomena. Pseudogravity is not mediated and not real; however, it may be imagined and used to pedagogically explain typical physical phenomena and to simplify calculations and applications.

Centripetal force is real; centrifugal force is fictitious (pseudo).

Gravity does affect the passage of time; pseudogravity cannot.

REMARKS

Acceleration due to gravity is the same for all objects. (The ratio of gravitational mass to inertial mass is numerically virtually unity.) That is, gravitational forces may be *interpreted* as pseudo, fictitious, or inertial forces. In contrast, acceleration due to an electrical force is not the same for all objects. (The ratio of charge to inertial mass is *not* unity.) That is, electrical forces cannot be *interpreted* as pseudo, fictitious, or inertial forces.

Gamow (1961, 2002; Chapter 9) presents an exposition of pseudogravity and the principle of equivalence. He posits that there is "pseudogravity" in opposition to acceleration and applies it to explain away a few commonly discussed phenomena in the literature, including gravitational aging and the twin paradox.

(Gravitational aging and the twin paradox will be addressed in a separate paper.)

There are true centrifugal forces, however. A true centrifugal force is exerted, as a *reaction*, by the rotating object on whatever is providing its centripetal force (Isaacs, 2003).

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