

2.5: Test Particle

ideal tool to probe spacetime without affecting it

Test particle defined

"Test particle." How small must a particle be to qualify as a **test particle**? It must have so little mass that, within some specified accuracy, its presence does not affect the motion of other nearby particles. In terms of Newtonian mechanics, gravitational attraction of the test particle for other particles must be negligible within the accuracy specified.¹

As an example, consider a particle of mass 10 kilograms. A second and less massive particle placed 10 centimeters from it and initially at rest will, in less than 3 minutes, be drawn toward it by 1 millimeter (see the exercises for this chapter). For measurements of this sensitivity or greater sensitivity, the 10 -kilogram object is not a test particle. A particle counts as a test particle only when it accelerates as a result of gravitational forces without itself causing measurable gravitational acceleration in other objects - according to the Newtonian way of speaking.

Free-float frame definable because every substance falls with same acceleration

It would be impossible to define a free-float frame were it not for a remarkable feature of nature. Test particles of different size, shape, and material in the same location all fall with the same acceleration toward Earth. If this were not so, an observer inside a falling room would notice that an aluminum object and a gold object accelerate relative to one another, even when placed side by side. At least one of these test particles, initially at rest, would not remain at rest within the falling room. That is, the room would not be a free-float frame according to definition.²

How sure are we that particles in the same location but of different substances all fall toward Earth with equal acceleration? John Philoponus of Alexandria argued, in 517 A.D., that when two bodies "differing greatly in weight" are released simultaneously to fall, "the difference in their time [of fall] is a very small one." According to legend Galileo dropped balls made of different materials from the Leaning Tower of Pisa in order to verify this assumption. In 1905 Baron Roland von Eötvös checked that the gravitational acceleration of wood toward Earth is equal to that of platinum within 1 part in 100 million. In the 1960s R. H. Dicke, Peter G. Roll, and Robert V. Krotkov reduced this upper limit on difference in accelerations - for aluminum and gold responding to the gravitational field of Sun - to less than 1 part in 100,000 million (less than 1 in 10^{11}). This - and a subsequent experiment by Vladimir Braginsky and colleagues - is one of the most sensitive checks of fundamental physical principles in all of science: the equality of acceleration produced by gravity on test particles of every kind.

It follows that a particle made of any material can be used as a test particle to determine whether a given reference frame is free-float. A frame that is free-float for a test particle of one kind is free-float for test particles of all kinds.

¹ Test particle defined

² Free-float frame definable because every substance falls with same acceleration

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