GRAVITY

Galileo, Newton, Einstein questioned

If all objects do not fall equally fast, a new theory is needed

by Dietrick E. Thomsen

All objects, no matter how they may differ in weight, take the same time to fall to the ground from a given height —as long as air resistance is not a factor. Galileo is supposed to have determined this by dropping balls from the campanile of Pisa cathedral.

But some physicists and natural philosophers have never been entirely happy with Galileo's result. Criticism has been continuous, if not very loud, over the last three centuries, and now experiments of a subtlety Galileo never imagined are being proposed to determine whether he was exactly right.

Galileo's result bothers people because it makes gravitation a special case among natural forces. If two bodies of different mass but the same electric charge are attracted by a third charged body, each will undergo an acceleration proportional to its mass—the more mass, the less acceleration. In the gravitational case, however, two bodies of different mass—so Galileo found—fall toward a third body with exactly the same acceleration.

This anomaly was handled in the theory by postulating that a body's gravitational mass, that is, the source of its gravitational forces, is not a separate property like electric charge, but is identical with its inertial mass, its capacity to resist changes in motion. The algebraic result of this is that when one comes to figure gravitational accelerations, the masses cancel out and the acceleration for any body is a constant with respect to a given attracting body—all objects near the surface of the earth fall toward it with an acceleration of 32 feet per second per second.

This principle of the equivalence of inertial and gravitational mass was adopted by Isaac Newton some years after Galileo and was used as the basis of his theory of gravitation and a whole system of mechanics. There were people who wondered why the equivalence should be taken for granted, but the success of Newton's theory in predicting events—as well as they could be measured—reduced criticism to a mumble.

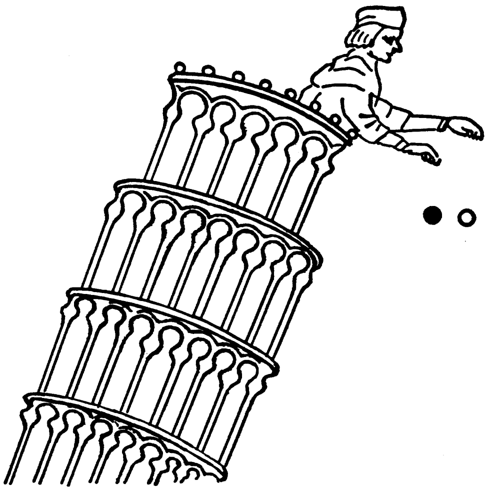
When Albert Einstein found it necessary to revise Newton's gravitational theory and replace it with general relativity, he followed Newton in adopting the equivalence of gravitational and inertial mass as a basic principle of the theory. He did this in the teeth of the critics, whose grumble had become somewhat louder by the end of the 19th century.

Gravitational theories that deny the equivalence of gravitational and inertial mass can be and have been constructed. One that is currently attracting most serious discussion is that put forth a few years ago by Drs. Carl H. Brans, now of Loyola University, and Robert H. Dicke of Princeton University. They contend that Newton's universal gravitational constant is not constant, but changes with time. This involves distinguishing between gravitational mass and inertial mass. The discussion has raised to a fairly high pitch the desire for experimental evidence to decide between the two classes of theory.

Present laboratory experiments demonstrate the equivalence of the two kinds of mass to within one part in 100 million. But a difference, if there is any, as Prof. Kenneth Nordtvedt Jr. of Montana State University contends, would depend on the gravitational self-energy of the bodies, that is, the latent energy involved in maintaining the distances between their atoms against inducements to gravitational collapse. This self-energy—about one part in a million billion billion—should, if differences exist between gravitational and inertial mass, result in a mass increment, by way of $E=mc^2$.

So, Prof. Nordtvedt suggests, if a difference is found, it will show up only in very precise measurements of very large bodies.

His first proposal involves a shift in the Lagrangian libration points of the earth's orbit. These points, one before and one behind the earth, are places where the attractions of the sun and the earth balance, and a body put there will stay and orbit the sun in the same period as the earth does. Prof. Nordtvedt says the libration points should be 500 miles nearer the earth than the presently calculated 95 million or so miles, and an active satellite sent to one of them should prove it.



Physics Today

Galileo's legendary experiment.

Meticulous observation of Jupiter's orbital motion—to detect a difference of two parts in 100 million—is the second suggestion. Finally, failure of the equivalence principle would mean that there is a cyclic fluctuation in the earth-moon distance of 10 meters in 384,000 kilometers. Prof. Nordtvedt suggests laser ranging might detect this.

One can also use the precessions of rotating bodies as a test. Once started, a rotating body is very tenacious in resisting attempts to tilt its rotation axis, and this property can be used for quite precise measurement of small effects. As Prof. William Fairbank of Stanford University describes it, an experiment now under development consists of putting a lead balloon—to shield out magnetic effects—into orbit around the earth. Inside would be a superconducting gyroscope—a suspended spinning niobium sphere. The sphere would have a magnetic field along its spin axis, and changes in the orientation of this field would be sensed by recording equipment. Whether the sphere precessed and how much would depend on whose theory of gravitation prevailed.

Radar observations of the near passage of asteroid Icarus on June 15 may, as Prof. Dicke suggests, show whether there are discrepancies between the actual motion of its orbit and that predicted by Einstein.