

14: Mass

Mass is a measure of the amount of matter in a body. As discussed earlier, it is measured in units of kilograms (kg) in SI units. In CGS units, mass is measured in grams (g), and in British engineering units, mass is measured in slugs.

Technically, there are two kinds of mass: inertial mass and gravitational mass. Inertial mass is a measure of a body's resistance to being accelerated: you have to push harder on a high-mass body than on a low-mass body to get it to accelerate by a given amount. As we'll see shortly, inertial mass m_i is given by Newton's second law of motion:

$$m_i = \frac{F}{a} \quad (14.1)$$

where F is the force on a body, and a is the resulting acceleration.

Gravitational mass is a measure of how strong a gravitational field a body produces. For example, if two identical bodies each have a gravitational mass m_g and are separated by a distance r , then the gravitational force between them is given by Newton's law of gravity: $F = Gm_g^2/r^2$. The gravitational mass is then

$$m_g = r\sqrt{\frac{F}{G}} \quad (14.2)$$

Experiments have shown that, to the highest accuracy that we can measure, inertial and gravitational mass are the same:

$$m_i = m_g \quad (14.3)$$

Because of this, we normally don't bother to distinguish between the two, and just refer to the "mass" m .

We really don't understand why inertial and gravitational mass are the same; it just turns out that way experimentally. This equivalence between inertial and gravitational mass, called the equivalence principle, was established in a famous experiment that was conducted around 1900 by the Hungarian physicist Loránd Eötvös (*UT*-vush). In the Eötvös experiment, two unequal masses were connected by a rod; the rod was then connected at its balance point by a vertical wire to the ceiling, forming a torsional pendulum. The instrument was set up in such a way that if the gravitational and inertial masses were different, it would set the rod rotating in a horizontal plane, but no such rotation was observed. Today the validity of the equivalence principle has been demonstrated to high accuracy.

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