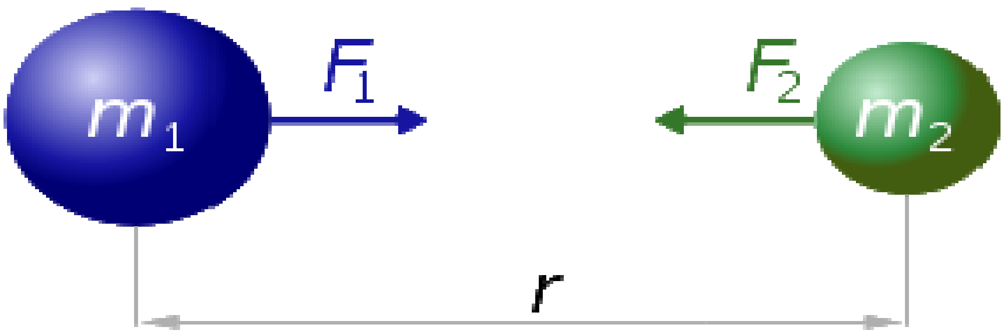
Introduction to Gravity

The gravitational constant denoted by letter *G*, is an empirical physical constant involved in the calculation(s) of gravitational force between two bodies. It usually appears in Sir Isaac Newton's law of universal gravitation, and in Albert Einstein's theory of general relativity. It is also known as the universal gravitational constant, Newton's constant, and colloquially as Big G. It should not be confused with "little g" (*g*), which is the local gravitational field (equivalent to the free-fall acceleration), especially that at the Earth's surface.



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

Laws and constants

According to the law of universal gravitation, the attractive force (*F*) between two bodies is proportional to the product of their masses(m_1 and m_2), and inversely proportional to the square of the distance, *r*, (inverse-square law) between them:

$$F = G\frac{m_1 m_2}{r^2}$$

The constant of proportionality, *G*, is the gravitational constant.

The gravitational constant is a physical constant that is difficult to measure with high accuracy. In SI units, the 2010 CODATA-recommended value of the gravitational constant (with standard uncertainty in parentheses) is:

$$G = 6.67384(80) \times 10^{-11}\ \mathrm{m}^3\ \mathrm{kg}^{-1}\ \mathrm{s}^{-2} = 6.67384(80) \times 10^{-11}\ \mathrm{N}\,(\mathrm{m}/\mathrm{kg})^2$$

with relative standard uncertainty 1.2×10^{-4}

Dimensions, units, and magnitude

The dimensions assigned to the gravitational constant in the equation above—length cubed, divided by mass, and by time squared (in SI units, meters cubed per kilogram per second squared)—are those needed to balance the units of measurements in gravitational equations. However, these dimensions have fundamental significance in terms of Planck units; when expressed in SI units, the gravitational constant is dimensionally and numerically equal to the cube of the Planck length divided by the product of the Planck massand the square of Planck time.

In natural units, of which Planck units are a common example, *G* and other physical constants such as *c* (the speed of light) may be set equal to 1.

In many secondary school texts, the dimensions of G are derived from force in order to assist student comprehension:

$$G \approx 6.674 \times 10^{-11}\ \mathrm{N}\,(\mathrm{m}/\mathrm{kg})^2.$$

In cgs, G can be written as:

$$G \approx 6.674 \times 10^{-8}\ \mathrm{cm}^3\mathrm{g}^{-1}\mathrm{s}^{-2}.$$

G can also be given as:

$$G \approx 0.8650\ \mathrm{cm}^3\mathrm{g}^{-1}\mathrm{hr}^{-2}.$$

Given the fact that the period *P* of an object in circular orbit around a spherical object obeys

$$GM = 3\pi V/P^2$$

where V is the volume inside the radius of the orbit, we see that

$$P^2 = \frac{3\pi}{G}\frac{V}{M} \approx 10.896\ \mathrm{hr}^2\mathrm{g\ cm}^{-3}\frac{V}{M}.$$

This way of expressing G shows the relationship between the average density of a planet and the period of a satellite orbiting just above its surface.

In some fields of astrophysics, where distances are measured in parsecs (pc), velocities in kilometers per second (km/s) and masses insolar units ($M_\odot$), it is useful to express *G* as:

$$G \approx 4.302 \times 10^{-3}\ \mathrm{pc}\, M_\odot^{-1}\, (\mathrm{km/s})^2.$$

The gravitational force is extremely weak compared with other fundamental forces. For example, the gravitational force between anelectron and proton one meter apart is approximately 10^{-67} newtons, while the electromagnetic force between the same two particles is approximately 10^{-28} newtons. Both these forces are weak when compared with the forces we are able to experience directly, but the electromagnetic force in this example is some thirty nine orders of magnitude (i.e., 10^{39}) greater than the force of gravity — roughly the same ratio as the mass of the Sun compared to a microgram mass.