

Physics

Unit 7: Circular Motion, Universal Gravitation, and Satellite Orbits

Newton's Law of Universal
Gravitation

Isaac Newton

- Isaac Newton (1642-1727) hypothesized that the force that causes an apple to fall to Earth from an apple tree is the same force that causes the planets to orbit the Sun.
- Previous descriptions of falling objects and planetary motion had described their motion as due to different causes.

--Newton applied the concepts of circular motion and Kepler's 3rd law to derive the Law of Universal Gravitation:

The gravitational force between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

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

--The constant G is known as the universal gravitational constant;

$$G = 6.67 * 10^{-11} \frac{m^3}{kg \cdot s^2}$$

--The weight of a 60.0 kg person on the Earth's surface:

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

$$F = 6.67 * 10^{-11} \frac{\text{m}^3}{\text{kg} \cdot \text{s}^2} \left(\frac{60.0 \text{ kg} \times 5.98 \times 10^{24} \text{ kg}}{(6.38 \times 10^6 \text{ m})^2} \right)$$

$$F = 588 \text{ N}$$

--Calculate the gravitational attraction, using the law of universal gravitation, for:

a) A person whose mass is 50 kg on the surface of the Earth.

b) compare to the value for a 50 kg person on the Earth's surface obtained from $F=mg$.

c) A 50.0 kg person on the surface of the moon.

- d) A 50 kg person on any other planet.
- e) The gravitational force between two people, each with a mass of 50.0 kg, standing a distance of 1.0 meter apart.

Weightlessness

- Calculate the gravitational attraction acting on a 70.0 kg astronaut in a space shuttle at an altitude of 400 km; compare the value to the astronaut's weight on the surface of the Earth.

	Mass	Weight
Surface	70 kg	686.7 N
Altitude of 400 km	70 kg	607.4 N

--Why do we say that astronauts in orbit are “weightless”? What is meant by “zero gravity”?

- If weight is defined as the force of gravity acting on an object, then the astronaut still has weight.
- If the space shuttle is to remain in orbit around the Sun, there must be a force-a force of gravity-to keep it in orbit and not allow it to fly off into space.

- A person who is in a space shuttle or other orbiting body is in a state of free fall; they are falling around the Earth and constantly missing.
- The feeling of weightlessness comes from the lack of a normal force acting against the force of gravity; it is the normal force that gives us the feeling of weight.