Gravitational Potential (V)

The gravitational potential (V) is the gravitational potential energy (U) per unit mass: where m is the mass of the object. Potential energy is equal (in magnitude, but negative) to the work done by the gravitational field moving a body to its given position in space from infinity.

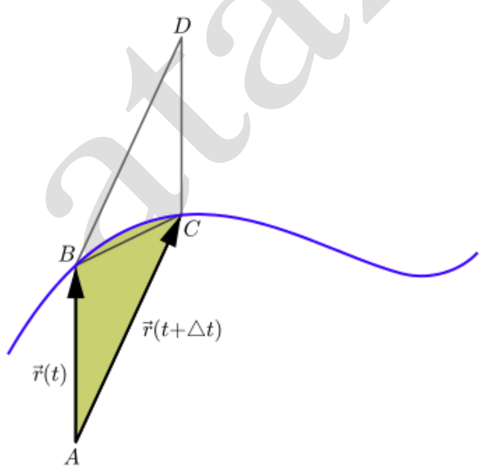
Gravitational Potential Energy between two point masses

Definition: Gravitational potential energy is energy an object possesses because of its position in a gravitational field. The most common use of gravitational potential energy is for an object near the surface of the Earth where the gravitational acceleration can be assumed to be constant at about 9.8 m/s^2. Since the zero of gravitational potential energy can be chosen at any point (like the choice of the zero of a coordinate system), the potential energy at a height h above that point is equal to the work which would be required to lift the object to that height with no net change in kinetic energy.

Definition of Binding Energy

Definition: A gravitational binding energy is the minimum energy that must be added to a system for the system to cease being in a gravitationally bound state. A gravitationally bound system has a lower (i.e., more negative) gravitational potential energy than the sum of its parts this is what keeps the system aggregated in accordance with the minimum total potential energy principle.

Aerial Velocity



Areal velocity (also called sector velocity or sectorial velocity) is the rate at which area is swept out by a particle as it moves along a curve. In the adjoining figure, suppose that a particle moves along the blue curve. At a certain time *t*, the particle is located at point *B*, and a short while later, at time $t + t$, the particle has moved to point *C*. The area swept out by the particle is the green area in the figure, bounded by the line segments *AB* and *AC* and the curve along which the particle moves. The areal velocity equals this area divided by the time interval *t*in the limit that *t* becomes vanishingly small.

Kepler's Law

The orbit of a planet is an ellipse with the Sun at one of the two foci.

Kepler's Second Law

A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.

Kepler's Third Law

The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Newton's Conclusions From Kepler's Laws

Kepler's laws and Newton's laws taken together imply that the force that holds the planets in their orbits by continuously changing the planet's velocity so that it follows an elliptical path is (1) directed toward the Sun from the planet, (2) is proportional to the product of masses for the Sun and planet, and (3) is inversely proportional to the square of the planet-Sun separation. This is precisely the form of the gravitational force, with the universal gravitational constant *G* as the constant of proportionality. Thus, Newton's laws of motion, with a gravitational force used in the 2nd Law, imply Kepler's Laws, and the planets obey the same laws of motion as objects on the surface of the Earth.

Relative motion of geostationary satellite with respect to earth

Example: What is the relative velocity of geostationary satellite with respect to the spinning motion of the Earth?

Solution: Geostationary satellites remain at the same position with respect to the Earth, so that they scan the same place in a better way. Therefore, the relative velocity of geostationary satellite with respect to the spinning motion of the Earth is 0 m/s.

Time period of polar satellites

Polar satellites are low altitude satellites at the height of 500-800 km, revolving around the poles of the earth in north-south direction. Its time-period is about 100 minutes.

Define Escape Velocity

Escape Velocity:
The minimum velocity with which a body should be projected from the surface of the earth so that it escapes from the earth's gravitational field, is called the escape velocity (V_e) of the body.

Conservation of Angular Momentum of masses in orbits

Two ordinary satellites are revolving round the Earth in same elliptical orbit, comment on the angular momentum of the system of masses. As in the absence of external torque, L(Angular Momentum) is conserved.Thus, L should be conserved for the two satellites revolving in same elliptical orbit round the Earth and angular momentum for both must be same.

Gravitational Force

Gravitational force is defined by Newton's law of gravity which states that gravitational forces between two bodies is directly proportional to product of their masses and inversely proportional to the square of distance between them. It is always attractive in nature.
Mathematically, $F_g \propto m_1 m_2$

$F_g \propto \frac{1}{r^2}$

Example: An apple falling from a tree to earth is due to gravitational force.

Characteristics of Gravitational Force

1. It is a universal attractive force.
2. It is directly proportional to the product of the masses of the two bodies.
3. It obeys inverse square law. It is a long range force and does not need any intervening medium for its operation. Gravitational force between two bodies does not depend upon the presence of other bodies.
4. It is the weakest force known in nature. It is a central force (i.e., it acts along the line joining the centres of the two bodies). It is a conservative force (i.e., work done in moving a body against the gravitational force is path independent). Gravitational- force between two bodies is thought to be caused by an exchange of a particle called graviton.

Gravitational Constant

The gravitational constant (G) is a proportionality constant that appears in the equation for Newton's law of gravitation. The value of G is approximately equal to $6.67\times10^{-11}\ Nm^2kg^{-2}$.

Importance of Universal Law of Gravitation

Following are the importance of the universal law of gravitation:

It explains the force of gravitation acting between two bodies.
It describes the phenomenon of revolution of heavenly bodies.
It determines the downward force on the surface of the earth.

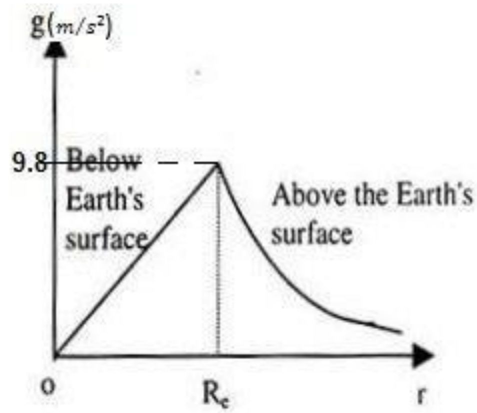
Acceleration due to Gravity

Acceleration due to gravity is the acceleration of a body falling freely under the influence of the Earth's gravitational pull at sea level. It is approximately equal to 9.8 m/s^2. Its measured value varies slightly with latitude(due to rotation of earth) and longitude(due to non-spherical shape of earth) and also with depth and height from the earth's surface.

Weight and Mass

Weight is the force on an object due to gravity. It is given by *W*=*mg*.
Mass is a measure of amount of matter contained in a body. It is a fundamental property of the object and is hence a constant quantity.

Variation in acceleration due to gravity



Value of acceleration due to gravity changes with height and depth from the earth's surface. It is maximum on the earth's surface. Its variation with height (or depth) is shown in the plot.

Effect of non-spherical shape of earth on the value of acceleration due to gravity

Earth is not perfectly spherical in shape. It is flattened at poles and bulging at the equator. Hence, value of acceleration due to gravity is more on the poles than at the equator.

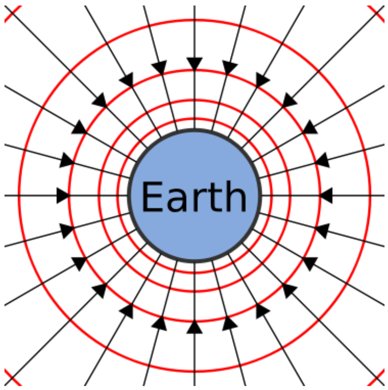
Centre of gravity

Centre of gravity is a point from which the weight of a body or system may be considered to act. Whereas, the center of mass is the point where all of the mass of the object is concentrated. In uniform gravity it is the same as the centre of mass.

Gravitational Field

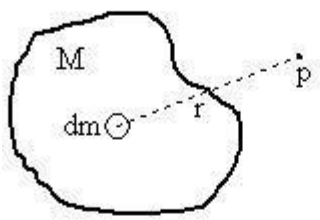
A gravitational field is a model used to explain the influence that a massive body extends into the space around itself, producing a force on another massive body.
Gravitational field has units N/kg.

Gravitational field lines



Gravitational field lines converge to masses and form equipotential surfaces in equal radial distances.

Gravitational Field due to a point mass



$$d\mathbf{g} = \frac{-Gdm}{r^2}\,\hat{\mathbf{r}}$$

Gravitational field due to a point mass is given by the following relation:

Graph for gravitational field due to thin Spherical Shell