Gravitation

Basic Forces and Kepler's Laws

1. **Fundamental forces of the universe**

   a) **Gravitational Force**

   i) These are long range attractive forces.

   ii) These are weak forces and are appreciable only when the interacting objects are massive.

   iii) These are independent of presence of other bodies and the medium between the bodies.

   iv) These are conservative forces and these form action reaction pairs.

   v) Gravitational force exists even when there is no physical contact between them.

   b) **Electromagnetic force**

   i) These are long range forces

   ii) These have intermediate strength between electric and magnetic forces.

   iii) According to quantum field theory electromagnetic force between two charges is mediated by exchange of Photons.

   c) **Nuclear force**

   i) They are a short range, strong force of attraction between nucleons, which provides stability to the nucleons.

   ii) It is the strongest of all the fundamental forces and has a range of 1 Fermi (10^{-15} m).

3. a) **Order of Range**

   Range of Gravitational force > Range of Electromagnetic force > Range of nuclear force

b) The ratio of relative strengths of nuclear, electromagnetic and gravitational forces is

1: 10^{15}: 10^{35}.

4. **Kepler's first law of motion (Law of orbits):** Every planet revolves around the Sun in an elliptical orbits keeping the Sun at one of the foci.

5. **Kepler's second law** (**Law of areas**): The radius vector joining the Sun and the planet sweeps out equal areas in equal intervals of time.

a) The line joining the sun and the earth sweeps out equal areas is equal intervals of time

i.e. areal velocity is constant.

b) Areal velocity is $\frac{dA}{dt} = \frac{1}{2} r^2 \omega$

$\frac{dA}{dt} = \frac{L}{2m}$ L is the angular momentum of the planet of mass m in the given orbit.

c) Kepler's second law is a consequence of law of conservation of angular momentum ($I\omega$ = constant).

d) A planet moves faster when it is nearer to sun and moves slower when it is far away from the sun.

$$V_{max}\, r_{min} = V_{min}\, r_{max}.$$

6. **Kepler's third law(Law of Time Periods)**

a) Square of the period of any planet (T^2) about the sun is proportional to cube of the mean distance (R^3) of the planet from the sun. $T^2 \alpha R^3$ or $\frac{T_1^2}{R_1^3} = \frac{T_2^2}{R_2^3}$.

b) According to third law, as the distance of the planet increases, duration of the year of the planet increases.

c) If the gravitational force varies inversely as the n^{th} power of distance R, then the orbital velocity $V \alpha R^{(1-n)/2}$ and the time period $T \alpha R^{(n+1)/2}$.

7. **Newton's law of universal gravitation:** Everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

a) If m_1 and m_2 are the masses of two bodies and d is the distance between them, the gravitational force of attraction F between them is given by

$$F = G\cdot\frac{m_1m_2}{d^2}$$

Where G is called universal gravitational constant and it is equal to 6.67×10^{-11} Nm^2kg^{-2}.

b) G was first accurately determined by Cavendish. It is a scalar quantity.

c) G is independent of the properties of intervening medium and the presence of other particles.

8. Properties of gravitational force

a) The gravitational force of attraction between two particles from an action and reaction pair i.e. equal in magnitude and opposite in direction.

b) Gravitational force is a central force i.e. it acts along the line joining the two particles.

c) Gravitational force between two particles is independent of the properties of intervening medium.

d) Gravitational force between two particles is independent of the presence of other particles.

e) **Principle of superposition:** If a number of particles interact with each other, the net force acting on a given particle is the vector sum of the forces acting upon it, due to its interaction with each of the other particles.

f) They are long range attractive forces.

9. Universal law of gravitation cannot explain the reason for gravity between objects and force of attraction between two bodies even when they are not in physical contact.

10. The relation between g and G is given by $g = \frac{GM}{R^2} = \frac{4}{3}\pi R\rho G$ where M is the mass of the planet, R is its radius and ρ is the mean density of the planet.