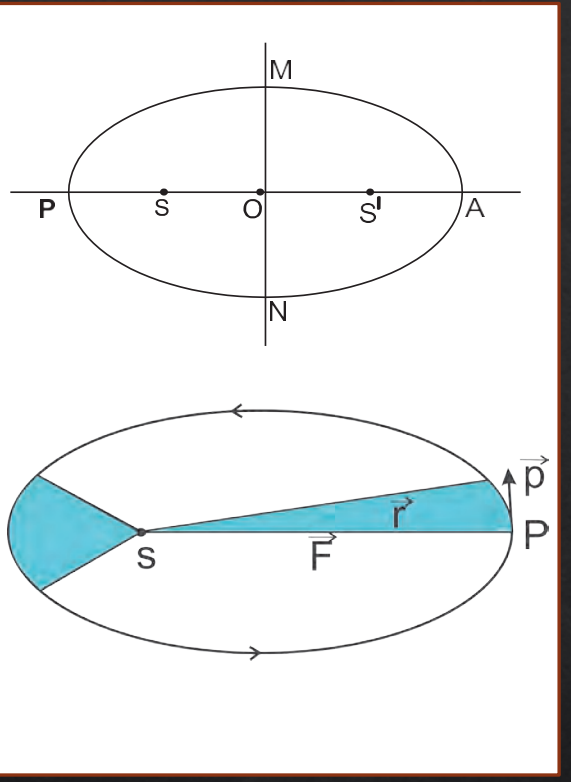
Gravitation

Chap-05

Introduction

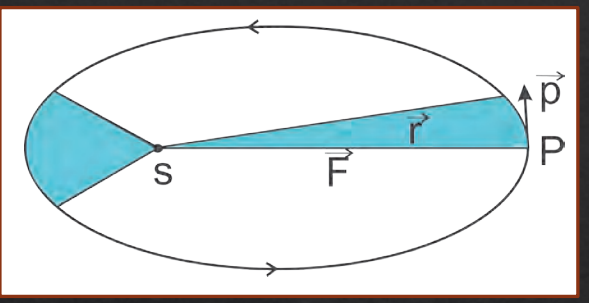
- Every MASSIVE object in the universe experiences GRAVITATIONAL force
- It is the force of MUTUAL ATTRACTION between ANY two objects by virtue of their MASSES
- It is ALWAYS AN ATTRACTIVE force with infinite RANGE
- It does not depend upon intervening medium
- It is much WEAKER THAN other FUNDAMENTAL forces

Kepler’s LAWS



- **1st law (Law of Orbit): All PLANETS revolve around sun in ELLIPTICAL orbits with the Sun situated AT one of the foci of the ellipse.**
- **As shown in fig.** S AND S’ ARE the foci of the ellipse the Sun being AT S
- P is the closest point ALONG the orbit from S AND is, CALLED ‘Perihelion’
- A is the FARTHEST point from S AND is, CALLED ‘Aphelion’
- **LAW of AREAS: The line THAT joins A PLANET AND the Sun** sweeps EQUAL AREAS in EQUAL INTERVALS of time
- Kepler observed THAT PLANETS do not move AROUND the Sun with uniform speed.
- They move FASTER when they ARE NEARER to the Sun while they move slower when they ARE FARTHER from the Sun
- Fig 2 shows, The SHADED AREAS ARE the AREAS SWEPT by SP, the line joining the PLANET AND the Sun, in fixed INTERVALS of time
- These ARE EQUAL ACCORDING to the second LAW

Out come of Kepler’s law of area



- The LAW of AREAS CAN be understood AS AN outcome of CONSERVATION of ANGULAR momentum
- It is VALID for ANY CENTRAL force
- As shown in fig, the Sun is AT S, The position of PLANET is denoted by *r* AND the perpendiculAR component of its momentum is denoted by *p* (component *r*)
- The AREA SWEPT by the PLANET of MASS *m* in given INTERVAL t is which is given by,= (
- = (
- Since linear momentum p = mV, hence, V = p/m
- = (, but =
- For CENTRAL force the ANGULAR momentum is conserved
- hence, = = constant
- This proves the LAW of AREAS

Kepler’s 3rd law (**LAW of periods**)

- The SQUARe of the time period of **revolution of A PLANET ARound the Sun is prOPORTIONAL to the cube of the SEMI MAJOR** AXIS of the ellipse TRACED by the PLANET
- If r is length of SEMI MAJOR AXIS then, this LAW STATES THAT $T^2 \; r^3$
- Kepler’s LAWS WERE BASED on REGULAR OBSERVATIONS of the motion of PLANETS
- Kepler did not know why the PLANETS obey these LAWS,. i.e. he HAD not derived these LAWS

UNIVERSAL LAW of GRAVITATION

- When objects ARE RELEASED NEAR the SURFACE of the EARTH, they ALWAYS FALL down to the ground, i.e., the EARTH ATTRACTS objects TOWARDS itself
- GALILEO (1564-1642) pointed out THAT HEAVY AND light objects, when RELEASED from the SAME height, FALL TOWARDS the EARTH AT the SAME speed, i.e., they HAVE the SAME ACCELERATION
- Newton went beyond (the EARTH AND objects FALLING on it) AND proposed THAT the force of ATTRACTION between MASSES is UNIVERSAL
- Newton STATED the UNIVERSAL LAW of GRAVITATION which led to AN EXPLANATION of TERRESTRIAL GRAVITATION
- It ALSO EXPLAINs Kepler's LAWS AND provides the REASON behind the observed motion of PLANETS AROUND the Sun

Motion of moon around earth

- Newton studied the motion of moon AROUND the EARTH
- The motion of the moon is in ALMOST A CIRCULAR orbit AROUND the EARTH with CONSTANT ANGULAR speed .
- As it is A CIRCULAR motion, A force directed TOWARDS the EARTH which is AT the centre of the circle.
- This force is the CENTRIPETAL force, AND is given by F=mr where m is mass of the moon and r is distance between centre of moon and centre of earth
- As per newton's law of motion, F = ma
- Hence, ma=mr

a = r

But hence, a = r

Since, r = 3.85×10^{5} km and T = 27.3 after substituting these values on SI

a = 0.0027 m / s^{2}

- This is the ACCELERATION of the moon which is directing TOWARDS the centre of the EARTH
- As this ACCELERATION is much SMALLER THAN the ACCELERAtion felt by bodies NEAR the SURFACE of the EARTH, he concluded THAT the ACCELERATION felt by AN object due to the GRAVITATIONAL force of the EARTH must be DECREASING with DISTANCE of the body from the EARTH

Newton’s law of gravitation with explanation

- Since, = 0.0027 m / s^2
- Hence, =
- =
- Thus from the ABOVE two EQUATIONS we get, =
- Newton therefore concluded THAT the ACCELERATION of AN object TOWARDS the EARTH is inversely PROPORTIONAL to the SQUARE of DISTANCE of object from the centre of the earth i.e. a
- But F = m.a
- Therefore, the force exerted by the EARTH on AN object of MASS *m* AT A DISTANCE *r* from it is F
- Similarly, AN object ALSO exerts A force on the EARTH which is F
- Hence Newton concluded THAT the GRAVITATIONAL force between the EARTH AND AN object of MASS *m* is F
- Statement: Every PARTICLE of MATTER ATTRACTS every other PARTICLe of MATTER with A force which is directly prOPORTIONAL to the product of their MASSES AND inversely prOPORTIONAL to the SQUARe of the DISTANCE between them.
- This LAW is APPLICABLE to ALL MATERIAL objects in the universe
- Hence it is known AS the UNIVERSAL LAW of GRAVITATION