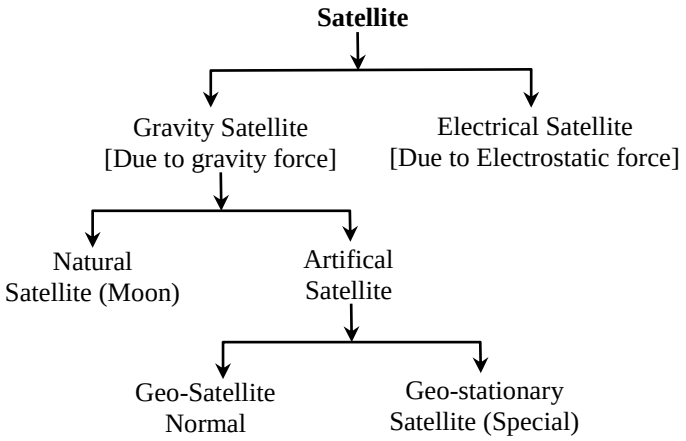
# GRAVITATION

## EARTH SATELLITES

### SATELLITE MOTION

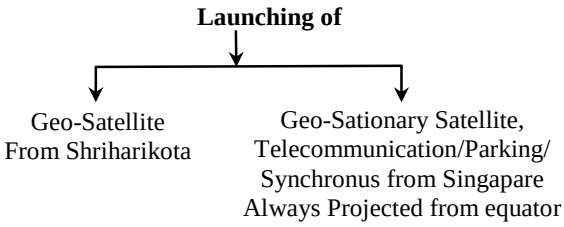



### Essential Condition's for Satellite Motion:-

(1) Centre of satellite's orbit concide with centre of earth.

(2) Plane of orbit of satellite is passing through centre of earth.

(3) Satellite is moves around great circle of earth.



First Satellite of Earth → Sputnik I$^{st}$

**India's Satellite**

- First Geo-satellite of India → Aryabhatt I$^{st}$
- First Geo-stationary satellite of India → Apple I$^{st}$
- Other Satellites of India

| Geo Satellie | Geo-stationary Satellite |
|---|---|
| Bhasker-I | Insat-I(A) |
| Rohini-I | Insat-I(B) |
| Bhasker-II | Other names of G-S-Satellite |

**Special Points about Geo-Stationary Satellite:-**

1. All three essential conditions for satellite motion should be followed.
2. It rotates in equatorial plane.
3. Its height from earth surface is 36000 km.
4. Its angular velocity and time period should be same as that of earth.
5. Its rotating direction should be same as that of earth (West to East).
6. Its orbit is called parking orbit and its orbital velocity is 3.1 km./sec.

**Main Elements of Satellite Motion:-**

**Orbital velocity ($v_0$)**

Condition

$$F_{cp} = F_g \Rightarrow \quad \frac{mv_0^2}{r} = \frac{GMm}{r^2}$$

$$v_0 = \sqrt{\frac{GM}{r}}$$

$$v_0 = \sqrt{\frac{GM}{(R_e + h)}}$$

(Putting $r = R_e + h$)

For near by satellite $h << R_e$

$$v_0 = \sqrt{\frac{GM}{R_e}} = \sqrt{gR_e}$$

8 km/sec. $(\text{on puting } GM_e = gR_e^2)$

**Important Points.:-**

1. If a body is taken at some height from earth and given horizontal velocity of magnitude 8 km/sec. then the body becomes satellite of earth.
2. $v_0$ depends upon
   Mass of planet – Radius of circular orbit of satellite – g (at planet) – density of planet
3. If orbital velocity of a near by satellite becomes $\sqrt{2}\, V_0$ (or increased by 41.4%,or K.E. is doubled) then the satellite escapes from gravitational field of earth

**Time Period of a Satellite:-**

$$\boxed{T = \frac{2\pi r}{v_0} = \frac{2\pi r^{3/2}}{\sqrt{GM}} = \frac{2\pi r^{3/2}}{R\sqrt{g}}}$$

$$\left(T^2 = \frac{4\pi^2}{GM} r^3\right) \Rightarrow T^2 \propto r^3 \quad (\text{here } r = R + h)$$

**For Geostationary Satellite:-**

- $T = 24$ hrs.
- $H = 36{,}000$ km $\simeq$ $6\ R_e$ $(r \simeq 7R_e)$
- $v_0 = 3.1$ km/sec.

**For Nearby satellite**

$$v_0 = \sqrt{\frac{GM_e}{R_e}} \simeq 8 \text{ km/sec.}$$

$$T_{Ns} = 2\pi\sqrt{\frac{R_e}{g}} = 84 \text{ minutes} = 1 \text{ hour } 24 \text{ minutes} = 1.4 \text{ hrs} = 5063 \text{ seconds}$$

In terms of density

$$T_{Ns} = \frac{2\pi(R_e)^{1/2}}{\left(G \times \frac{4}{3}\pi R_e \times \rho\right)^{1/2}} = \sqrt{\frac{3\pi}{G\rho}} \Rightarrow \boxed{T_{Ns} = \sqrt{\frac{3\pi}{G\rho}}}$$

Hence, time period of near by satellite only depends upon density of planet.

**For Moon:-**

$h_m = 380{,}000 \text{ km} \Rightarrow T_m = 27 \text{ days}$

$$v_{om} = \frac{2\Pi(R_e + h)}{T_m} = \frac{2\Pi(386400 \times 10^3)}{27 \times 24 \times 60 \times 60}$$

$v_{om} \simeq 1.04 \text{ km/sec}$

$$\text{K.E.} = \frac{1}{2}mv_0^2 = \frac{GMm}{2r} = \frac{J^2}{2mr^2}$$

$$\text{P.E.} = \frac{-GMm}{r} = \frac{-J^2}{mr^2} = -mv_0^2$$

$$\text{T.E.} = \text{P.E.} + \text{K.E.} = \frac{-mv_0^2}{2} = \frac{-GMm}{2r} = \frac{-J^2}{2mr^2}$$

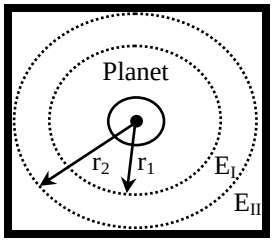
**Binding energy of satellite (system):-**

$$\text{B.E.} = -\text{T.E.}$$

$$\boxed{\text{B.E.} = \frac{1}{2}mv_0^2 = \frac{GMm}{2r} = \frac{J^2}{2mr^2}}$$

Hence $\boxed{\text{B.E.} = \text{K.E.} = -\text{T.E.} = \frac{-\text{P.E.}}{2}}$

**Work done in Changing the Orbit of Satellite:-**



W = Change in M.E. of system

$$E = \frac{-GMm}{2r}$$

$$W = E_{II} - E_I$$

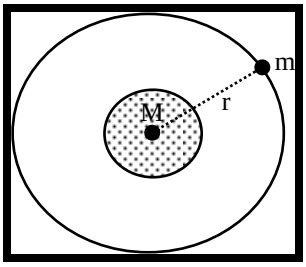
$$\boxed{W = \frac{GMm}{2}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}$$

**Important Points:-**

If a satellite is transferred to a higher order orbit (r increases)

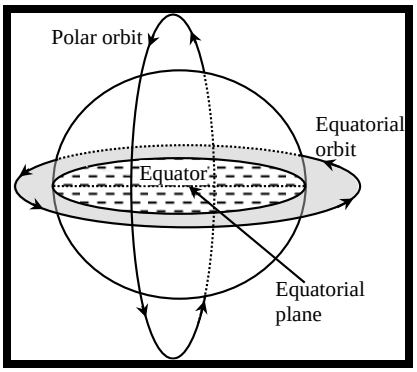
(i) Increases P.E.,T.E., T, J

(ii) Decreases K.E., B.E., $v_0$




**Polar Satellite (Sun – synchronous satellite)**

It is that satellite which revolves in polar orbit around earth. A polar orbit is that orbit whose angle of inclination with equatorial plane of earth is 90º and a satellite in polar orbit will pass over both the north and south geographic poles once per orbit. Polar satellites are sun-synchronous satellites.




Every location on earth lies within the observation of polar satellite twice each day.

The polar satellites are used for getting the cloud images, atmospheric data, ozone layer inthe atmosphere and to detect the ozone hole over Antarctica.