Advanced Electronic Communication Systems

Lecture 3

Satellite Orbits

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What keeps the satellite in place?

- The ability to launch a satellite and keep it in orbit depends upon following well-known physical and mathematical laws that are referred to collectively as **orbital dynamics.**

- ✓ If a satellite were launched vertically from the earth and then released, it would fall back to earth because of gravity.
- ✓ For the satellite to go into orbit around the earth, it must have some forward motion.

For that reason, when the satellite is launched, it is given both vertical and forward motion.

https://www.youtube.com/watch?v=mbeoS0o_fNw

• What keeps the satellite in place?

- ✓ **The forward motion produces inertia, which tends to keep the satellite moving in a straight line.**
- ✓ **However, gravity tends to pull the satellite toward the earth.**
- ✓ **The inertia of the satellite is equalized by the earth's gravitational pull.**
- ✓ **The satellite constantly changes its direction from a straight line to a curved line to rotate about the earth..**

If a satellite's velocity is too high, the satellite will overcome the earth's pull and go out into space.

At lower speeds, gravity constantly pulls the satellite toward the earth.

The goal is to give the satellite acceleration and speed that will exactly balance the gravitational pull.

Kepler’s laws

- The laws that govern satellite motion are called “Kepler’s Laws”
- These laws depends on laws of planetary motion that describe:
  - ✓ The shape of the orbit,
  - ✓ The velocities of the planet,
  - ✓ The distance a planet is with respect to the sun.

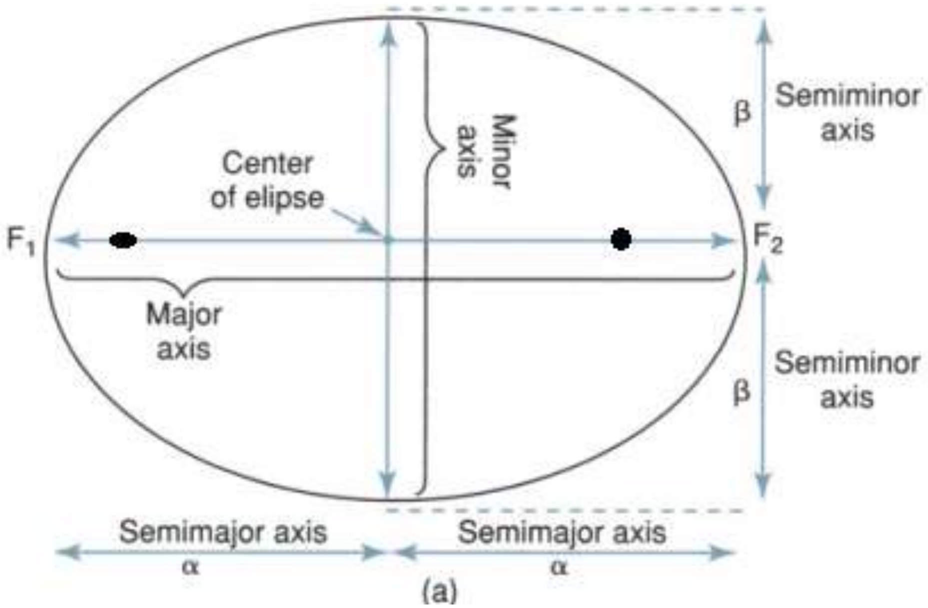
- Kepler’s laws can be applied to any two bodies in space that interact through gravitation.
- The larger of the two bodies is called the primary, and the smaller is called the secondary or satellite.

Kepler's Three laws

1. The orbit of a planet is an ellipse with the Sun at one of the two foci.
2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Kepler's First law

- States that the path followed by a satellite around the primary will be an ellipse.



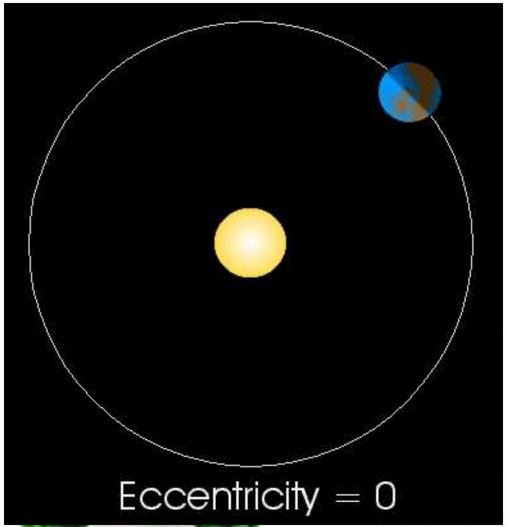
- ✓ The center of mass (called the barycenter) of a two-body system is always centered on one of the foci.
- ✓ Because the mass of Earth is substantially greater than that of the satellite, the center of mass will always coincide with the center of Earth

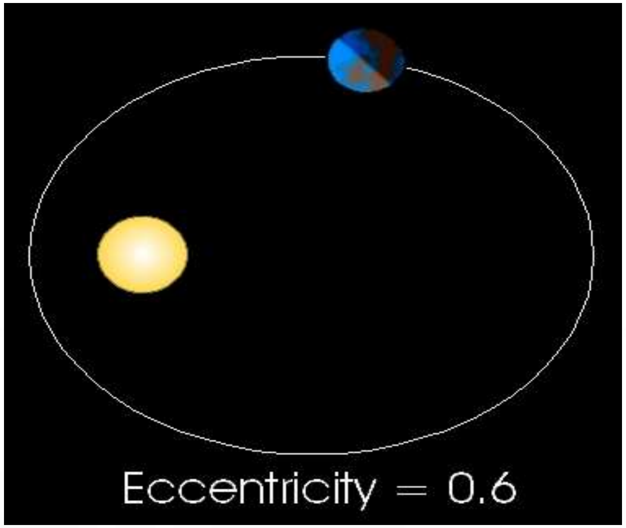
Kepler’s First law

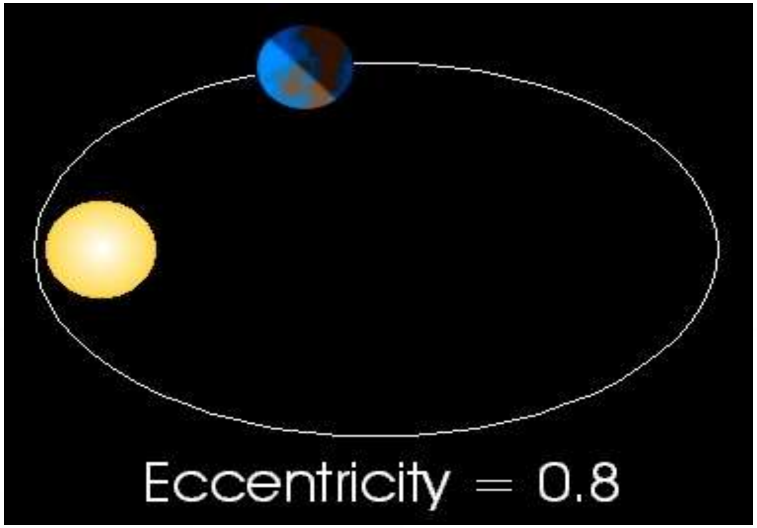
- Elliptical Orbit Eccentricity:

$$\epsilon = \frac{\sqrt{\alpha^2 - \beta^2}}{\alpha}$$

- ✓ For a circle, e = 0
- ✓ The range of values of the eccentricity for ellipses is 0 < e < 1
- ✓ The higher the value of e, the longer and thinner the ellipse

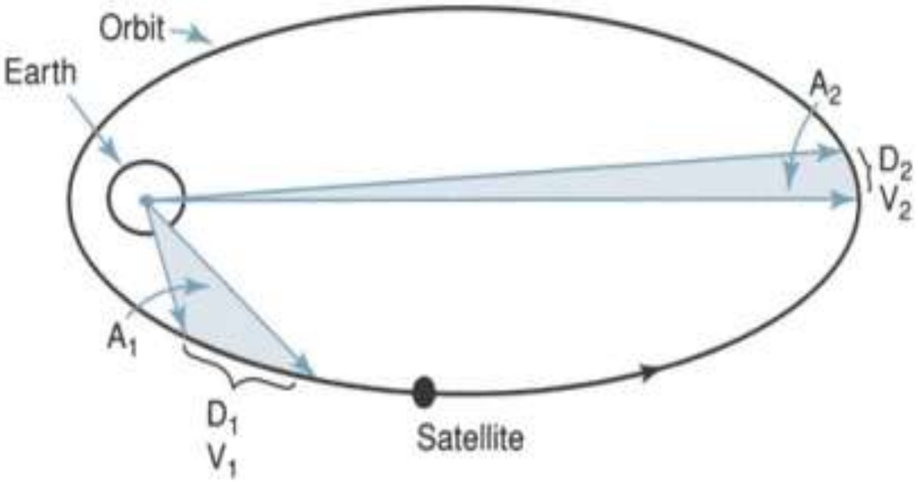


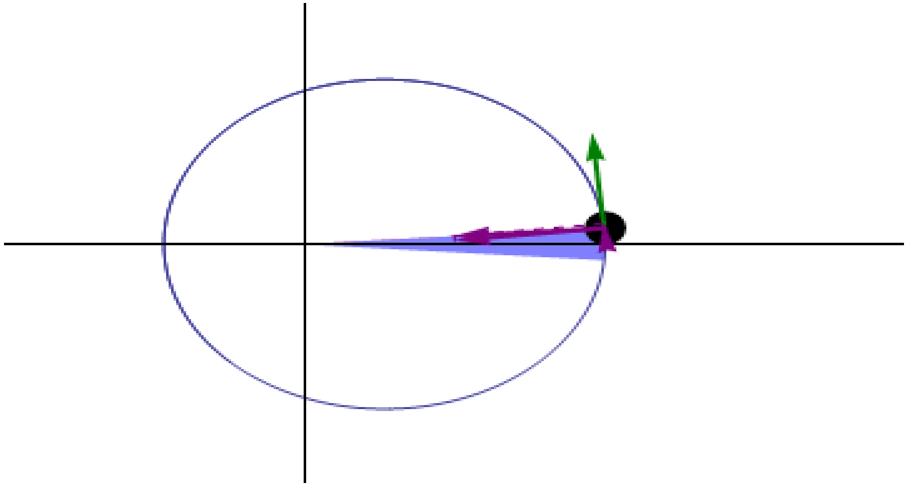




Kepler’s Second law (the law of Areas)

- Kepler’s second law states that for equal intervals of time a satellite will sweep out equal areas in the orbital plane, focused at the barycenter.

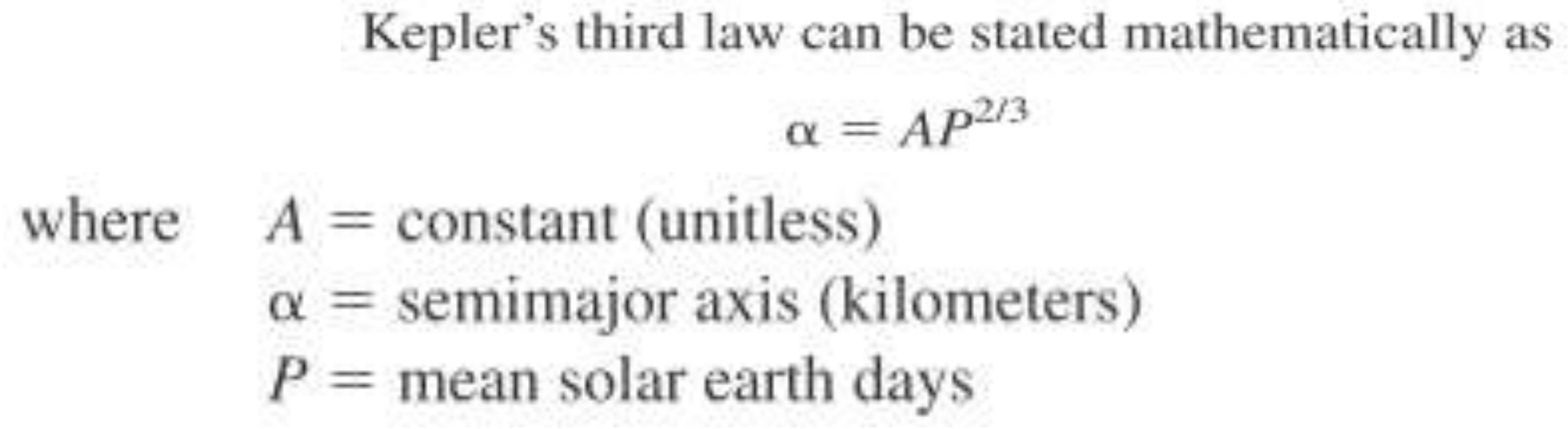




- ✓ for a satellite traveling distances D1 and D 2 meters in 1 second,
- ✓ Areas A1 = A2
- ✓ Because of the equal area law, distance D1 > distance D2 , and, therefore,
- ✓ Velocity V1 must be greater than velocity V2 .

Kepler’s Third law (the harmonic law)

- The square of the periodic time of orbit is proportional to the cube of the mean distance between the primary and the satellite.
- This mean distance is equal to the semimajor axis (α)



Kepler’s third law can be stated mathematically as

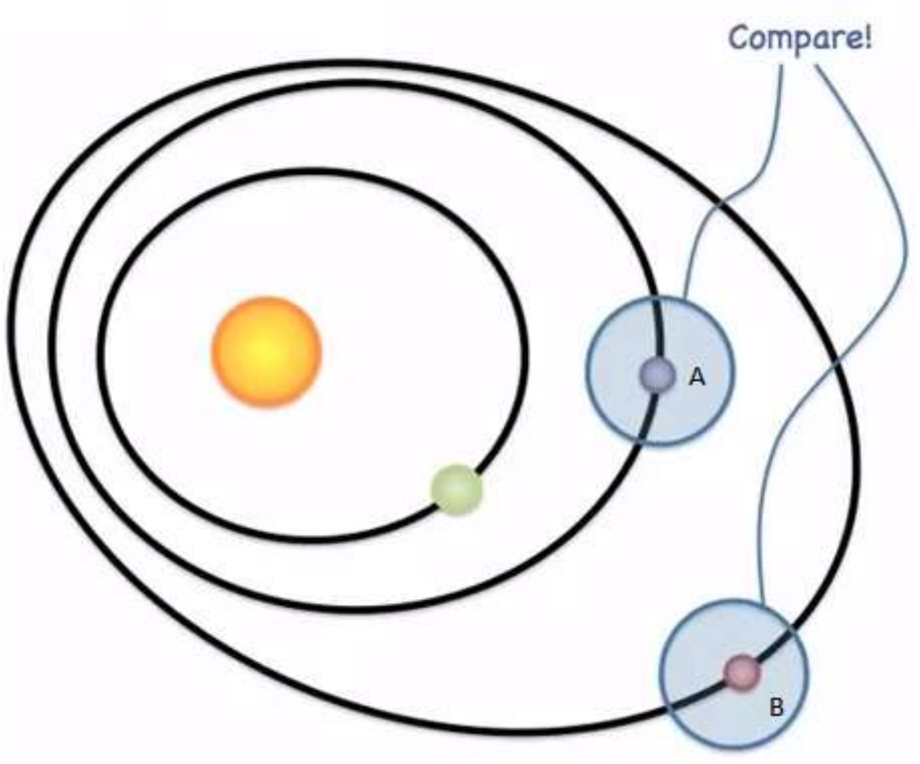
$$\alpha = AP^{2/3}$$

where A = constant (unitless)
α = semimajor axis (kilometers)
P = mean solar earth days

Kepler’s Third law (the harmonic law)

- Comparison between multiple orbiting objects:

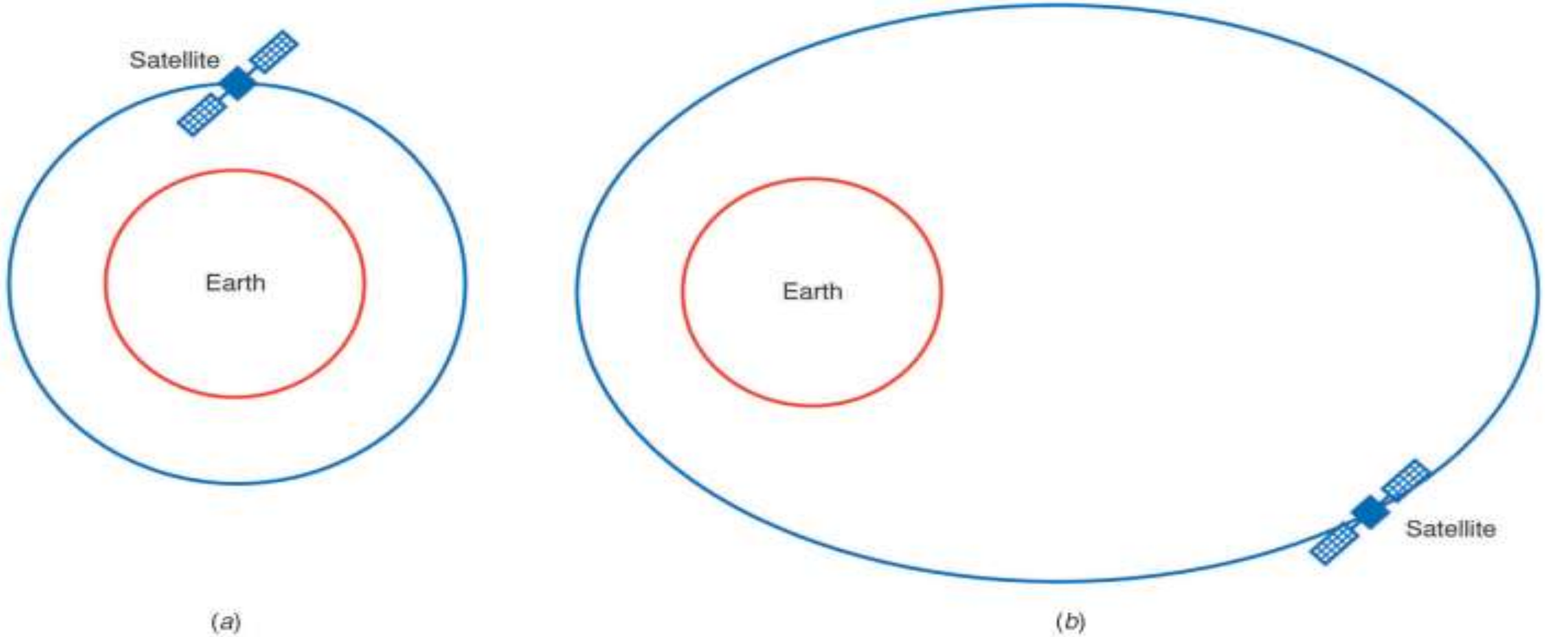
$$(P_A/P_B)^2 = (\alpha_A/\alpha_B)^3$$



Definitions of Terms for Earth-Orbiting Satellites

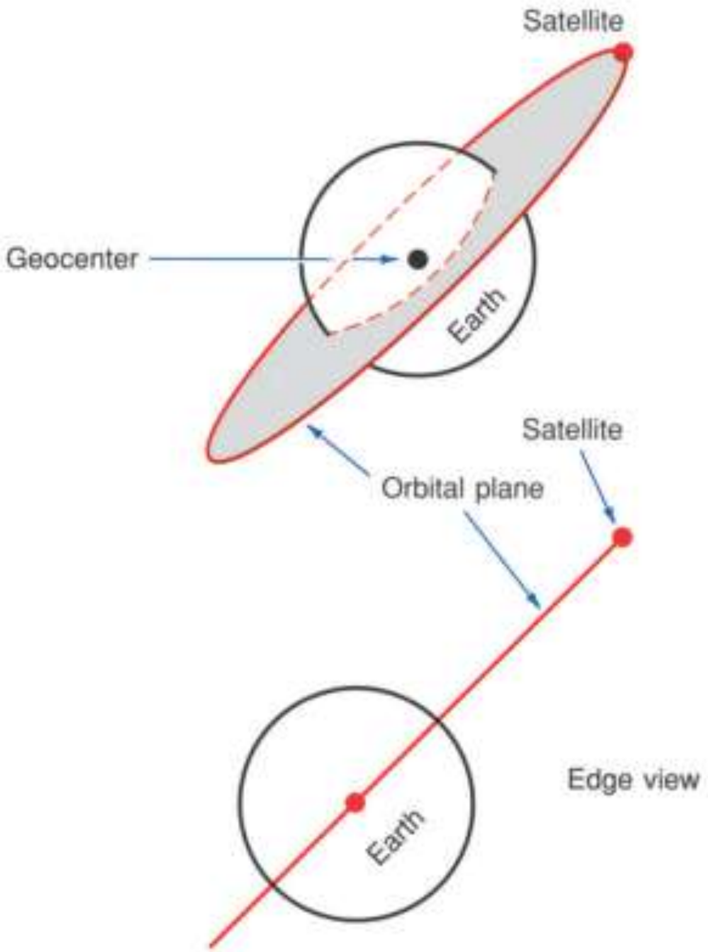
Orbital Satellites

- The satellites mentioned – thus far are called orbital or nonsynchronous satellites.
- Nonsynchronous satellites rotate around Earth in a low-altitude elliptical or circular pattern.

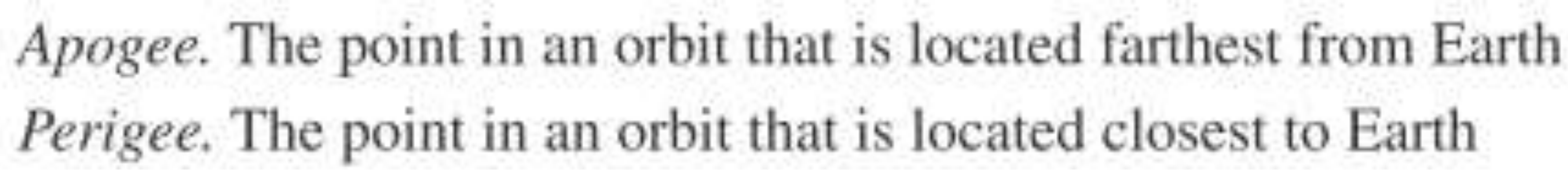


Definitions of Terms for Earth-Orbiting Satellites

- A satellite rotates in an orbit that forms a plane passing through the center of gravity of the earth (The Geocenter)

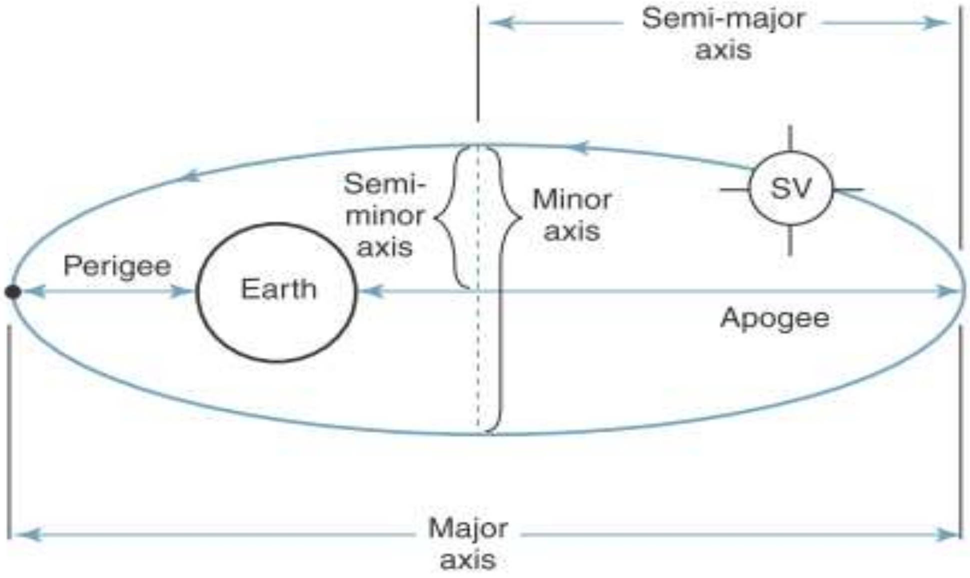


Definitions of Terms for Earth-Orbiting Satellites



Apogee. The point in an orbit that is located farthest from Earth

Perigee. The point in an orbit that is located closest to Earth



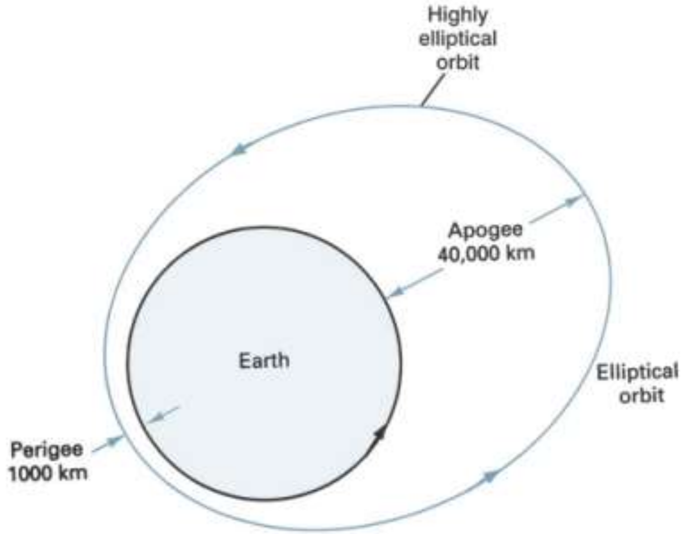


FIGURE 6 Soviet *Molniya* satellite orbit

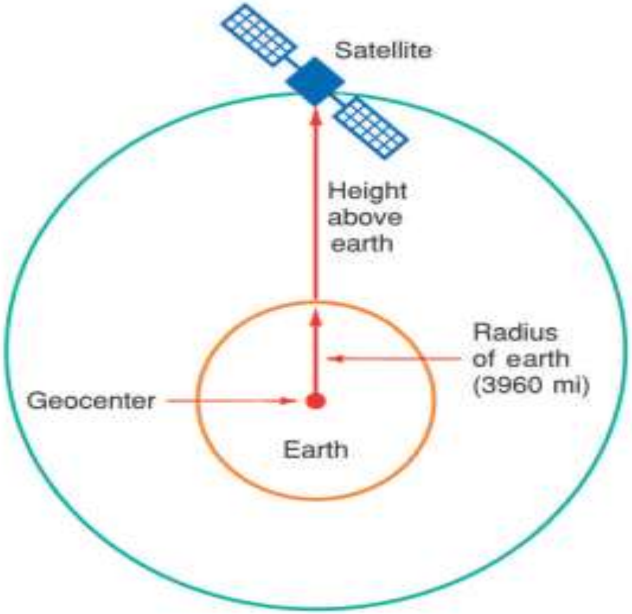
The Satellite Speed varies according to:

1. The distance of the satellite from the earth (For Elliptical Path)

- The velocity will be greatest at the point of closest approach to Earth (the perigee),
- The velocity will be least at the farthest point from Earth (the apogee).

2. The Height of the satellite above the earth(For Elliptical and Circular Paths)

- The closer the satellite is to earth, the stronger the effect of the earth's gravitational pull. So in low orbits, the satellite must travel faster to avoid falling back to earth.



- ✓ The **satellite height** is simply the distance of the satellite from the earth.
- ✓ That distance includes the radius of the earth, (3960 mi or 6373 km).
- ✓ A satellite that is 5000 mi above the earth in circular orbit is (3960 + 5000 = 8960) mi from the center of the earth

In a circular orbit, the speed or rotation is constant;