An Artificial Satellite Circling The Earth Completes Each Orbit In 134 Minutes. (The Radius Of The Earth

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Understanding the dynamics of artificial satellites orbiting our planet offers fascinating insights into space technology, physics, and Earth's properties. One intriguing aspect is the orbital period of satellites—specifically, how long it takes for an artificial satellite to complete one full revolution around the Earth. For instance, a satellite completing an orbit in approximately 134 minutes provides a compelling case study to explore orbital mechanics, satellite design, and Earth's dimensions. In this comprehensive guide, we delve into the details of satellite orbits, the significance of orbital periods, and how they relate to Earth's radius, along with related concepts in space science.

Overview of Satellite Orbits and Orbital Periods

Satellites orbit Earth at various altitudes, speeds, and orbital paths, each influencing their orbital period—the time it takes to complete one orbit. The orbital period is fundamental in satellite operations, affecting communication schedules, imaging passes, and scientific data collection.

What Is an Orbital Period?

The orbital period is the duration a satellite takes to travel once around its orbit. It is primarily determined by:
- The altitude of the satellite
- The mass of the Earth
- The shape and size of the orbit

For example, low Earth orbit (LEO) satellites, typically at altitudes of 200-2,000 km, have periods ranging from about 90 to 130 minutes. Geostationary satellites, much higher at approximately 35,786 km, have orbital periods of roughly 24 hours, matching Earth's rotation.

The Significance of the 134-Minute Orbital Period

A satellite completing an orbit in 134 minutes indicates a specific orbital altitude and velocity. This period suggests the satellite is in a low Earth orbit, but at a higher altitude than typical LEO satellites, which often have periods close to 90 minutes. Understanding this period helps in calculating the satellite's orbital radius and velocity, which are critical for mission planning.

Calculating the Orbital Radius from the Orbital Period

To understand how the orbital period relates to Earth's radius, we employ principles from Newtonian physics and orbital mechanics. The key relationship is derived from Kepler's third law and Newton's law of universal gravitation.

Fundamental Equation for Circular Orbits

For a satellite in a circular orbit, the orbital period T relates to the orbital radius r as follows:

$$
T = 2\pi \sqrt{\frac{r^3}{GM}}
$$

where:
- T = orbital period
- r = radius of the orbit from Earth's center
- G = gravitational constant ($6.674 \times 10^{-11} \, \mathrm{Nm^2/kg^2}$)
- M = mass of the Earth ($5.972 \times 10^{24} \, \mathrm{kg}$)

Rearranged to solve for r:

$$
r = \left(\frac{GMT^2}{4\pi^2} \right)^{1/3}
$$

Applying the Formula for a 134-Minute Orbit

Given:
- $T = 134$ minutes $= 134 \times 60 = 8040$ seconds

Plugging in the known constants:

$$
r = \left(\frac{(6.674 \times 10^{-11})(5.972 \times 10^{24})(8040)^2}{4\pi^2} \right)^{1/3}
$$

Calculating step-by-step:

1. Compute the numerator:

$$
(6.674 \times 10^{-11}) \times (5.972 \times 10^{24}) = 3.986 \times 10^{14}
$$

2. Square the period:

$$
8040^2 = 64,646,400
$$

3. Multiply numerator:

$$
3.986 \times 10^{14} \times 64,646,400 \approx 2.577 \times 10^{22}
$$

4. Divide by $4 \pi^2$:

$$
4 \pi^2 \approx 39.478
$$

$$
r^3 = \frac{2.577 \times 10^{22}}{39.478} \approx 6.53 \times 10^{20}
$$

5. Take cube root:

$$
r = (6.53 \times 10^{20})^{1/3} \approx 8.66 \times 10^{6} \, \text{meters}
$$

Thus, the orbital radius from Earth's center is approximately 8,660 km.

Understanding Earth's Radius and Orbit Altitude

The calculated orbital radius includes Earth's radius plus the altitude of the satellite above Earth's surface. To determine the satellite's altitude:

$$
h = r - R_E
$$

where:
- R_E = Earth's radius (~6,371 km)

Using our calculated r:

$$
h = 8,660 \, \text{km} - 6,371 \, \text{km} = 2,289 \, \text{km}
$$

This altitude places the satellite well within low Earth orbit but at a relatively higher altitude compared to many LEO satellites.

Implications of the Satellite's Orbit

- The satellite is approximately 2,289 km above Earth's surface.
- Its orbital velocity can be calculated using:

$$
v = \frac{2\pi r}{T}
$$

- Substituting $r = 8.66 \times 10^{6} \, \mathrm{m}$ and $T = 8040 \, \mathrm{s}$:

$$
v \approx \frac{2\pi \times 8.66 \times 10^{6}}{8040} \approx 6,763 \, \mathrm{m/s}
$$

This high velocity ensures continuous orbiting around Earth.

Orbital Mechanics and Satellite Design

Understanding the relationship between orbital period, radius, and velocity is crucial for satellite engineering and mission planning. Satellite operators need to know these parameters to maintain stable orbits, plan ground station passes, and ensure mission success.

Factors Influencing Satellite Orbits

- Altitude: Higher altitudes increase orbital period and radius.
- Inclination: The tilt of the orbit affects coverage and ground track.
- Eccentricity: Non-circular orbits have varying speeds and distances.
- Drag and Atmospheric Effects: Lower orbits experience more atmospheric drag, requiring adjustments.

Design Considerations for Satellites with ~134-Minute

Orbits

- Propulsion Systems: To adjust or maintain altitude.
- Power Systems: To sustain communication and data collection.
- Stability and Control: To counteract perturbations and maintain the desired orbit.

Real-World Examples and Applications

Satellites with an orbital period around 134 minutes are often used for specific scientific, reconnaissance, or communication purposes. Examples include:

- Earth Observation Satellites: Monitoring climate, agriculture, and urban development.
- Communication Satellites: Providing coverage over specific regions.
- Scientific Satellites: Studying Earth's atmosphere or magnetosphere.

The orbital parameters influence the satellite's capabilities, such as resolution for imaging or coverage area.

Advantages of a 134-Minute Orbit

- Balances between coverage area and revisit frequency.
- Suitable for certain types of Earth observation missions requiring moderate revisit times.
- Lower energy requirements compared to higher altitude orbits.

Challenges and Limitations

- Limited coverage compared to geostationary satellites.
- Increased atmospheric drag at lower altitudes necessitating orbit adjustments.
- More complex ground station scheduling due to faster orbiting.

Conclusion: Connecting Satellite Orbit Periods to Earth's Dimensions

The fascinating relationship between an artificial satellite's orbital period and Earth's radius underscores the elegance of celestial mechanics. A satellite completing an orbit in 134 minutes resides at an orbital radius of approximately 8,660 km from Earth's center, translating to an altitude of about 2,289 km above Earth's surface. This understanding enables scientists and engineers to design effective satellite missions tailored to specific scientific, commercial, or military objectives.

By applying Newtonian physics and orbital mechanics, we gain insights into how Earth's size influences satellite behavior, paving the way for advancements in satellite technology and space exploration. The precise calculation of orbital parameters not only enhances our understanding of Earth's environment but also ensures the success and safety of space missions that rely on these fundamental principles.

References:

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Frequently Asked Questions

What is the significance of the satellite completing an orbit in 134 minutes?

The 134-minute orbital period indicates the satellite's speed and altitude, helping scientists understand its orbit relative to Earth's surface and its potential applications like communication or observation.

How can we determine the radius of Earth using the satellite's orbital data?

Using the orbital period and gravitational laws (Kepler's third law), we can calculate the satellite's orbital radius, which in turn helps estimate Earth's radius when considering the satellite's altitude above the surface.

What is the approximate altitude of the satellite based on its 134-minute orbit?

The satellite's altitude can be estimated using orbital mechanics formulas; typically, a 134-minute orbit corresponds to a low Earth orbit approximately 300-400 km above Earth's surface.

Why do artificial satellites orbit the Earth at specific periods like 134 minutes?

Satellites are designed to have specific orbital periods based on their altitude and mission requirements, balancing factors like coverage area, communication latency, and energy efficiency.

How does the orbital period relate to the satellite's speed?

The orbital period is inversely related to the satellite's speed; a shorter period means a higher orbital speed, which is necessary to balance gravitational pull at a given altitude.

Can the orbital period help in determining the Earth's radius?

Yes, by knowing the orbital period and applying Kepler's third law, we can estimate the Earth's radius, especially when the satellite's altitude is known or negligible compared to Earth's radius.

What factors influence the orbital period of an artificial satellite?

Factors include the satellite's altitude, Earth's mass, and gravitational parameters; higher orbits generally have longer periods, while lower orbits have shorter periods like 134 minutes.

How accurate is the method of calculating Earth's radius using satellite orbital data?

It can be quite accurate when precise measurements of the orbital period and altitude are available, and the calculations account for Earth's mass and gravitational parameters.

What is the typical radius of Earth, and how does the satellite's orbit help verify it?

The average radius of Earth is about 6371 km; by analyzing the satellite's orbital data, scientists can verify and refine this measurement through orbital mechanics calculations.

Additional Resources

An Artificial Satellite Circling The Earth Completes Each Orbit In 134 Minutes. (The Radius Of The Earth)

Understanding the dynamics of artificial satellites orbiting our planet offers fascinating insights into modern technology, space science, and the intricacies of celestial mechanics. The statement that an artificial satellite completes each orbit in approximately 134 minutes provides a window into how satellites are designed, their orbital parameters, and how these factors influence their functionality. This article delves into the significance of this orbital period, explores the underlying physics, and examines how the Earth's radius and other parameters shape satellite behavior.

Introduction to Satellite Orbits and Orbital Periods

Artificial satellites are human-made objects placed into orbit around Earth for purposes ranging from communication and navigation to scientific research and military applications. The orbital period—the time it takes for a satellite to complete one full revolution around Earth—is a fundamental characteristic that influences satellite operations.

The given orbital period of 134 minutes suggests a specific type of orbit, likely a low Earth orbit (LEO), which generally ranges from about 160 km to 2,000 km above Earth's surface. Understanding how this period relates to the Earth's radius and the satellite's altitude provides essential context for satellite design and mission planning.

Fundamentals of Orbital Mechanics

Newton's Law of Universal Gravitation and Circular Orbits

The motion of satellites around Earth is governed primarily by Newton's law of universal gravitation, which states:

$$ F = \frac{G M_e m}{r^2} $$

where:
- F is the gravitational force,
- G is the gravitational constant,
- M_e is Earth's mass,
- m is the satellite's mass,
- r is the distance from Earth's center to the satellite.

For a satellite in a circular orbit, the gravitational force provides the necessary centripetal force:

$$ \frac{G M_e m}{r^2} = \frac{m v^2}{r} $$

Simplifying, the orbital velocity v becomes:

$$ v = \sqrt{\frac{G M_e}{r}} $$

The orbital period T relates to the orbital radius r and velocity v:

$$ T = \frac{2 \pi r}{v} $$

Substituting v:

$$T = 2 \pi r \sqrt{\frac{r}{G M_e}}$$

Calculating the Orbital Period

Using known constants:
- $G = 6.67430 \times 10^{-11} \, \mathrm{m^3\,kg^{-1}\,s^{-2}}$,
- $M_e = 5.972 \times 10^{24} \, \mathrm{kg}$,
- R_e (Earth's radius) ≈ 6,371 km or 6.371×10^6 m.

Suppose the satellite's orbital radius r is:

$$r = R_e + h$$

where h is the satellite's altitude above Earth's surface.

Given the orbital period T is 134 minutes, or 8,040 seconds:

$$T = 8,040\, \text{s}$$

Rearranging the period formula:

$$r^3 = \frac{G M_e T^2}{4 \pi^2}$$

Plugging in the numbers:

$$r^3 = \frac{(6.67430 \times 10^{-11}) \times (5.972 \times 10^{24}) \times (8,040)^2}{4 \pi^2}$$

Calculating:

$$r^3 \approx \frac{3.986 \times 10^{14} \times 6.464 \times 10^7}{39.478}$$

$$r^3 \approx \frac{2.578 \times 10^{22}}{39.478}$$

$$r^3 \approx 6.535 \times 10^{20}$$

Taking cube root:

$$r \approx (6.535 \times 10^{20})^{1/3}$$

$$r \approx 8.66 \times 10^{6} \text{ meters}$$

This is approximately 8,660 km from Earth's center.

Subtracting Earth's radius:

$$ h = r - R_e \approx 8,660\,\text{km} - 6,371\,\text{km} = 2,289\,\text{km} $$

Thus, the satellite orbits roughly 2,289 km above Earth's surface, consistent with high LEO satellites.

The Significance of the Orbital Period

Understanding why a satellite completes an orbit in about 134 minutes involves examining the implications of this period.

Implications for Satellite Operations

- Communication Windows: The orbital period determines how often a satellite passes over specific regions, affecting communication schedules.
- Revisit Time: For Earth observation satellites, the period influences how frequently a particular location can be revisited.
- Data Transmission: Satellites in such orbits can establish predictable passes, optimizing data relay schedules.
- Coverage and Constellations: Multiple satellites with similar periods can be coordinated for continuous coverage.

Comparison with Other Orbits

- Geostationary Satellites: Orbit with a period of 24 hours, fixed over a point on the equator.
- Medium Earth Orbit: Typically 12-hour orbits, used in GNSS systems like GPS.
- Low Earth Orbit (LEO): Periods vary from about 90 to 130 minutes, matching our case.

The 134-minute period indicates an orbit slightly higher than typical LEO satellites, possibly optimized for specific mission needs, such as Earth observation or scientific monitoring.

The Role of Earth's Radius in Satellite Orbit Calculations

The Earth's radius is foundational in defining satellite orbits because it sets the baseline for orbital altitudes and velocities.

Why the Radius Matters

- Determining Altitude: Satellite altitude above Earth's surface is $h = r - R_e$.
- Orbital Velocity: As shown earlier, velocity depends on r, which includes Earth's radius.
- Orbital Energy: The total mechanical energy of the satellite depends on r and influences fuel requirements for orbit adjustments.

Effects of Earth's Radius Variations

While Earth's radius is generally taken as approximately 6,371 km, local variations (due to Earth's equatorial bulge and topography) can influence precise orbital calculations, especially for high-precision missions.

Features, Pros, and Cons of Satellite Orbits with a 134-Minute Period

Features

- High Low Earth Orbit: The orbit is relatively high in the LEO range, providing broader coverage per pass.
- Predictable Orbital Mechanics: Regular 134-minute cycles facilitate scheduling and mission planning.
- Suitable for Earth Observation: The orbit balances altitude for resolution and revisit frequency.

Pros

- Good Coverage: Higher orbits cover larger ground areas per revolution.
- Relatively Stable: Less atmospheric drag compared to lower LEO satellites.
- Predictability: Regular orbit period simplifies ground tracking and communication scheduling.

Cons

- Limited Revisiting Frequency: Longer period means less frequent passes over specific points compared to lower orbits.
- Increased Signal Delay: Greater distance can introduce slight delays in communication.
- Higher Fuel Requirements for Orbit Adjustment: Slightly higher orbits may demand more energy for maneuvers.

Applications and Real-World Examples

Satellites with an orbital period around 134 minutes are typical for certain Earth observation, scientific, and communication missions.

- Earth Observation Satellites: Provide high-resolution imagery with consistent revisit times.
- Scientific Missions: Study Earth's atmosphere, climate, and environmental changes.
- Communication Satellites: Relay signals with predictable passes, ensuring reliable service.

Some satellite constellations are designed with similar orbital periods to ensure global coverage and optimal data collection.

Conclusion

The orbital period of an artificial satellite orbiting the Earth, approximately 134 minutes in this context, encapsulates a wealth of information about the satellite's altitude, velocity, and mission design. Grounded in fundamental physics, the relationship between Earth's radius and orbital mechanics explains how satellites are tailored for specific functions, balancing coverage, revisit times, and operational efficiency. As technology advances, understanding these orbital parameters remains vital for optimizing satellite networks that underpin modern communication, navigation, and scientific exploration. The precise calculation and strategic deployment of satellites in such orbits continue to play a pivotal role in expanding humanity's capabilities to observe and interact with our planet from space.

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