Geostationary orbit: Meteosat

FizziQ activity · Middle school · 35-50 min

Scan to open in FizziQ

Middle school students place a satellite at 36,000 km in the online FizziQ Web orbit simulation, find the circular speed of 3.07 km/s and check its 24-hour period.

Learning objectives

- Configure a geostationary weather satellite at 36,000 km altitude in the Orbits and Gravitation simulation
- Identify the circular speed that gives a stable orbit and measure the corresponding period (≈ 24 hours)
- Understand why the geostationary orbit is crucial for continuous weather and climate monitoring
- Identify orbital regimes by initial speed (fall, ellipse, circle, escape)
- Connect Meteosat or GOES orbits to climate change monitoring

Instruments and sensors

FizziQ Web simulation (Orbits and Gravitation)

Materials

- Computer, tablet or smartphone with FizziQ Web
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any comparable orbital-simulation tool.

Protocol

1. Open the Orbits and Gravitation simulation in FizziQ Web (Experiment → Simulations → Orbits and gravitation).
2. Set the distance scale to 200 km/pixel to see the orbit clearly, and the time scale to 10 minutes per frame to observe several revolutions quickly.
3. Keep body 1 as Earth (mass 1 M⊕, speed 0). Select body 2, choose "Space probe" on the mass slider (~1000 kg) and set the initial angle to -90°.
4. Drag the satellite to about 42,200 km from Earth's centre — use the "distances" panel in the upper right. This altitude (36,000 km above the surface) is that of geostationary weather satellites like Meteosat.
5. Set the initial speed to 3.07 km/s. Click the body 1 centering button to lock the view on Earth.
6. Click the red REC button to start recording. Observe the trajectory: the satellite traces a stable circular orbit around Earth.
7. Measure the period T on the chronometer in the upper-left corner: duration of one full revolution. Find T ≈ 1 day (precisely 23 h 56 min). This is the period of a geostationary orbit.
8. Compare T to the duration of one Earth day: since Earth also rotates on itself in 24 h, the satellite stays constantly above the same point on the ground. This is what enables Meteosat to continuously monitor Europe and Africa.
9. Test 2 — Speed too low: stop, set v = 1 km/s and restart. Observe that the satellite falls to Earth (collision). Without enough speed, it cannot stay in orbit and the monitoring mission fails.
10. Test 3 — Inner ellipse: set v = 2 km/s. Observe an elliptical orbit elongated towards Earth, the starting point becoming the apogee. Altitude varies strongly and the satellite is no longer geostationary.
11. Test 4 — Wider ellipses: try v = 3.5 km/s then v = 4 km/s. Observe ever-larger elliptical orbits; at 4 km/s, the satellite moves very far away before returning.
12. Test 5 — Escape velocity: set v = 4.5 km/s. Observe that the satellite no longer returns: it escapes on an

open trajectory. Escape velocity at this altitude is about 4.35 km/s.

13. Fill in a 3-column table: Initial speed (km/s), Type of orbit observed, Consequence for the weather mission. Conclude that only the circular speed of 3.07 km/s allows continuous monitoring of a region.

14. Compute the v_esc / v_c ratio by taking 4.35 ÷ 3.07. Find a value close to 1.41 (i.e. √2), as at any altitude — this is a universal regularity of orbits.

Expected results

At a distance of 42,164 km from Earth's centre, a speed of 3.07 km/s gives a nearly perfectly circular orbit with a period close to 24 hours, corresponding to a geostationary orbit. At 1 km/s, the satellite falls onto Earth (collision after a few simulated hours). At 2 km/s, it traces an inner ellipse, without impact but with strongly varying altitude. At 3.5 and 4 km/s, the orbit becomes elliptical outward, with an apogee moving clearly away from the geostationary trajectory. At 4.5 km/s, the satellite escapes on an open trajectory (escape velocity at this altitude is about 4.35 km/s). The v_esc / v_c ratio is about 1.41 (= √2), as at any altitude. Numerical deviations remain at a few percent due to symplectic Euler integration. This result illustrates why only precise circular orbits at 36,000 km altitude are suitable for geostationary weather satellites like Meteosat or GOES.

Questions

- Why must a geostationary satellite be at exactly 36,000 km altitude and not at another?
- Why does a geostationary satellite appear stationary in the sky as seen from the ground, even though it actually flies at 3 km/s?
- What would happen if the weather satellite orbited at 800 km altitude (low orbit, like Sentinel) instead of 36,000 km?
- Why are several geostationary satellites needed (Meteosat, GOES, Himawari) to cover the entire globe?
- How does data from these satellites accumulated over decades make it possible to evidence climate change?

Going further

- Reproduce a low-orbit weather satellite like Sentinel (altitude 800 km, speed 7.45 km/s) and compare the period (≈ 100 minutes) to the geostationary one
- Experimentally find the exact distance that gives T = 24 h while keeping the circular speed at each trial (verifying Kepler's third law)
- Reproduce the Meteosat / GOES / Himawari constellation: three satellites at 42,164 km separated by 120° around Earth, forming a geostationary trio covering the globe
- Add the Moon (at 384,400 km, speed 1.022 km/s, mass 0.012 $M_\oplus$) to the system and observe whether it perturbs the weather satellite's orbit
- Compare escape velocity from geostationary orbit (4.35 km/s) with that from Earth's surface (11.2 km/s) and explain why a satellite can "break free" more easily