A total solar eclipse happens whenever the New Moon comes between the Earth and the Sun. For thousands of years, humans have marveled at this daytime sight, which is both a beautiful, and for some, a terrifying event. Although on the ground these solar eclipses are rather rare, in space that can be much more common. With satellites that depend on solar power to operate, the momentary blockage of the sun by the Earth is a predictable reason for concern. Satellite designers have to include this kind of solar eclipse into their plans for creating a satellite and operating it in space.

1 – On a regular 8 ½ x 11-inch sheet of paper, use a compass to draw a circle with a radius of 1-inch centered on the page. This represents Earth, and the radius of Earth in this scaled drawing is 6,378 kilometers.

2 – Draw a second circle with a radius of 6.6 inches centered on the Earth circle. This represents the orbit of the geosynchronous communication satellites. You are looking down at the Earth from above its North Pole. These 'GEO' satellites take 24-hours to orbit Earth.

3 – Draw a third circle with a radius of 1.2 inches. This is the orbit of a Low Earth Orbit (LEO) satellite which takes 1.8 hours or 112 minutes to orbit Earth.

4 – Draw a fourth circle with a radius of 3.0 inches. This is the orbit of a Mid-Earth-Orbit (MEO) satellite, which takes 7.3 hours to orbit Earth.

5 – With the sunlight entering the drawing from the left side of the page, shade-in the shadow of Earth as it stretches into space beyond the orbit of the GEO satellites. Draw this shadow as two parallel lines separated by 2-inches extending to the edge of the page.

Question 1 – From this scaled drawing, what are the orbit radii of the GEO, MEO and LEO satellites? What are the satellite altitudes above Earth's surface?

Question 2 – From the formula for the circumference of a circle, what are the circumferences for the three orbits above?

Question 3 – From the satellite orbit times given above, what is the speed of each satellite in its orbit in units of kilometers per hour?

Question 4 – From your scale drawing, how long in kilometers is Earth's shadow along each orbit?

Question 5 – From the speed of each satellite in its orbit, how long will it take the satellite to traverse the Earth's shadow as it crosses each satellite's orbit?

Question 6 – If a satellite requires 300 watts of solar power to operate, what do think will happen to the satellite during each of its orbits as it passes through Earth's shadow?

Question 7 – What simple solution can you come up with that would let the satellite operate even during solar eclipses?

Extra Credit – GEO satellites orbit the Earth directly above the Equator. During which times of the year will eclipses be the most common for GEO satellites?

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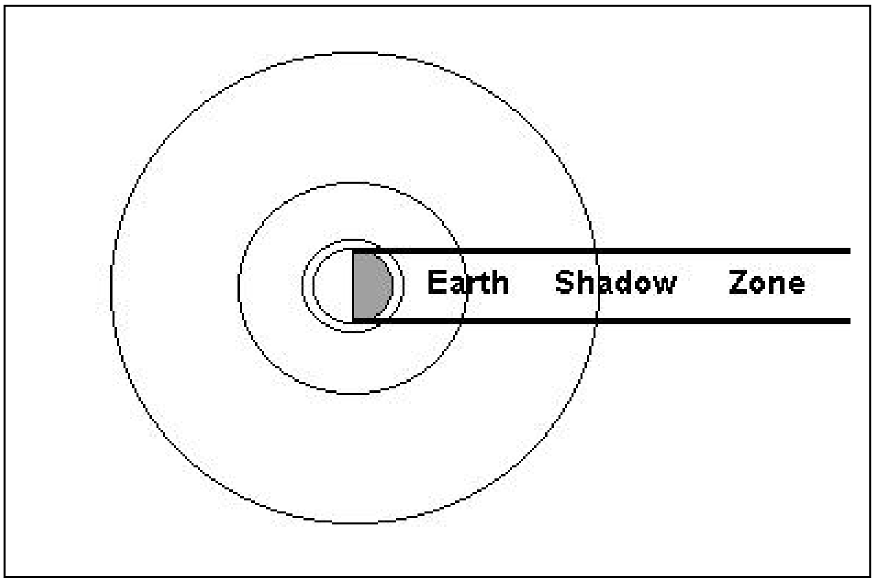
In this activity, students will examine the orbits of three satellites and from their speeds and the size of Earth's shadow, calculate how long the satellite will be within Earth's shadow. They will be presented with an engineering problem of how to supply power to a satellite when there is no sunlight to supply its solar panels with light. This inquiry-based activity will have students discover a second, very important, ingredient to most satellite power systems, and show how solar eclipses are still an event that satellite designers and operators have to deal with today!



After the construction phase, the students should have a diagram like the one above. Note the night-side of Earth has been shaded. The Earth shadow zone should be filled-in with pencil to represent the zone where the sunlight is blocked by Earth.

Answer Key –

1) GEO: R = 6.6 x 6378 = **42,095 km**, MEO: R = 3.0 x 6378 = **19,134 km**, LEO: R = 1.2 x 6378 = **7,653 km**. The satellite altitudes are GEO = 42,095 – 6,378 = **35,717 km**. MEO = **12,756 km**, LEO = **1,275 km**.
2) C = 2 x (3.141)x R so GEO = **264,441 km**, MEO = **120,200 km**, LEO = **48,076 km**.
3) GEO = (264440/24) = **11,018 km/hr**. MEO = (120200/7.3) = **16,465 km/hr**. LEO = (48076/1.8) = **26,708 km/hr**.
4) They are approximately GEO = **10,000 km**, MEO = **11,000 km**, LEO = **13,000 km**.
5) GEO; T = (10000/11018) = **0.91 hours**, MEO; T = (11000/16465) = **0.67 hours**. LEO; T= (13000/26708) = **0.49 hours**.
6) Without sunlight, the solar panels will not generate enough electricity to run the satellite.
7) You can use a battery to store some of the electricity from the solar panels, and then use this stored electricity to run the satellite during its eclipses.

Extra Credit – During the Equinoxes for satellites that orbit above the Equator like the GEOs do. This challenging problem requires the students to think in 3-dimensions and to use a model.