Investigating the Radiation Belts around Jupiter

In the above NASA artist rendition, we see the inner portions of the elliptical orbits of the Juno spacecraft as it passes close to Jupiter and its intense radiation belts. The orbit was designed to avoid as much of the radiation belts as possible so that the spacecraft could survive long enough to carry-out its science objectives.

As the spacecraft travels along its orbit, high-energy protons and electrons penetrate the spacecraft and degrade its electrical systems and computer systems. A simple, and very approximate, mathematical model for the number of these particles encountered by every square centimeter of the satellite surface area, along the orbit is given by

\[ N = 26,000 \sin^2 \left( \frac{\pi T}{11} \right) \text{ particles per day} \]

**Problem 1** - If the orbital period of the spacecraft is 11.0 days, graph this function for one complete orbit.

**Problem 2** - What is the approximate total number of particles encountered by the spacecraft in one complete orbit?

**Problem 3** - If the JunoCam camera has an unshielded imaging array that has 1 million pixels, and if each radiation particle destroys one pixel, A) how many pixels are lost by the camera each orbit? B) About how many orbits will be required to destroy all of JunoCam's imaging pixels?

Space Math                                http://spacemath.gsfc.nasa.gov
Problem 1 - If the orbital period of the spacecraft is 11.0 days, graph this function for one complete orbit.

![Graph of particle count over time](image)

Problem 2 - What is the approximate total number of particles encountered by the spacecraft in one complete orbit?

Answer: Since the function gives the number of particles per day, the area under this curve gives the total number of particles since the area is: \((\text{particles/day}) \times \text{day} = \text{particles}\). Students can approximate the area by using the inscribed rectangles and compare their answers using rectangles with smaller bases. Using 1 rectangle with a base of 8 days and an average height of \(N = 15,000\) you get \(N = 120,000\) particles. Another method is to take the average between the inscribed rectangle and the circumscribed rectangle. The dimensions of the circumscribed rectangle is width= 11 days, height = 25,000 so \(A = 275,000\) particles. The average is then \(N = (275,000 + 120,000)/2 = 197,500\) particles.

The exact answer using integral calculus (or a LOT of very small rectangles!) is \(N = 137,500\) particles.

Problem 3 - If the JunoCam camera has an unshielded imaging array that has 1 million pixels, and if each radiation particle destroys one pixel, A) how many pixels are lost by the camera each orbit? B) About how many orbits will be required to destroy all of JunoCam's imaging pixels?

Answer: Students answers will differ depending on their answer to Problem 2, but the answer using the three values for \(N\) are \(1\) million/120000 = 8 orbits; \(1\) million/197500 = 5 orbits, and the exact answer would be \(1\) million/137500 = 7 orbits. **Answers between 5 to 8 orbits are acceptable.**

So the JunoCam will not last as long as the entire mission of 33 orbits!