MATH AND SCIENCE @ WORK

AP* PHYSICS Student Edition

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IONIZING RADIATION EXPOSURE

Background

The International Space Station (ISS) orbits the Earth at an approximate altitude of 407 km (252 mi). At this altitude, astronauts are not as well protected by the Earth's atmosphere, and are exposed to higher levels of space radiation than what is experienced on the Earth's surface.

Space radiation is different from radiation experienced on Earth and can have very different effects on human DNA, cells, and tissues. Space radiation, created as atoms, is comprised of positively charged ions which accelerate toward the speed of light. Eventually, only the nucleus of each atom remains, and the radiation becomes ionized. This "ionizing radiation" contains such abundance of energy, that it can literally "knock" the electrons out of any atom it strikes, thereby ionizing the atom. This effect can cause damage to the atoms within living cells, leading to potential future health problems, such as cataracts, cancer, and disorders of the central nervous system.

To better understand the long-term effects of space radiation on the human body, NASA is conducting research to identify and quantify types of radiation existing in the space environment. Scientists know that when the ISS travels in low-Earth orbit, it is exposed to ionizing radiation from three main sources: solar eruptions, galactic cosmic rays, and the Van Allen radiation belts. The Van Allen radiation belts are two, donut-shaped magnetic rings surrounding the Earth in which ionized particles become trapped. Open the document, *Ionizing_Radiation*, on your TI-Nspire™ handheld. On page 1.2, use the arrows to rotate the model of the Van Allen radiation belts.

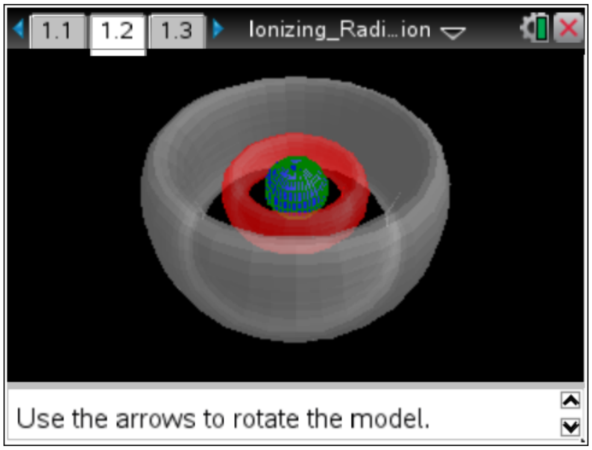

Figure 1: Model of the Van Allen radiation belts

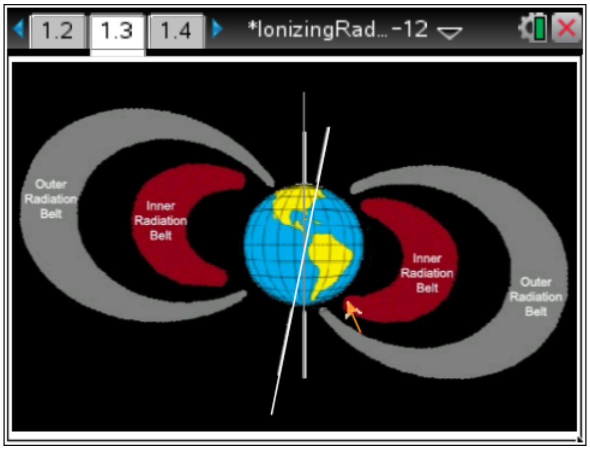

Figure 2: The Van Allen belts in relation to Earth's rotational and magnetic axes

These Van Allen radiation belts are symmetrical about the Earth's magnetic axis, which is tilted with respect to the Earth's rotational axis (Figure 2). This tilt causes the inner Van Allen belt to come closer to the Earth's surface (approximately 200 km, or 124 mi, from the Earth's surface) over the South Atlantic Ocean. In this area (known as the South Atlantic Anomaly), there is an increased flux of energetic particles, as well as increased levels of radiation for any exposed satellites including the ISS.

On page 1.3 of the TI-Nspire document, use your cursor to find Earth's rotational and magnetic axes and the location of the South Atlantic Anomaly.

Scientists and engineers are also working to understand the risks that astronauts face during long-duration exposure to space radiation. Countermeasures are being developed to mitigate (reduce or eliminate) those risks. One type of countermeasure used on the ISS for the protection of ionizing radiation is shielding. Improved shielding in the most frequently occupied locations of the ISS, such as the sleeping quarters and galley, has proven to reduce the crew's exposure to space radiation. Shielding protects both the vehicle and the crew from each source of radiation exposure, including the increased exposure while the orbit is within the South Atlantic Anomaly.

In addition to shielding, all ISS crewmembers must wear physical dosimeters during flight—devices which measure personal exposure to ionizing radiation. Real-time, active monitoring of space radiation levels helps astronauts locate the best-shielded locations on the ISS and can help reduce radiation exposure. Active monitoring can also provide a warning should radiation levels increase due to solar disturbances. To further reduce risks following radiation exposure, crewmembers in-flight undergo physical examinations (blood draws) that measure radiation damage to chromosomes in blood cells. Pre and post-flight, astronauts are encouraged to maintain a healthy lifestyle, including the dietary intake of antioxidants.

Space radiation research also has many Earth-based implications. Advancements in technology have led to better detection and protection from radiation exposure experienced on Earth. Advances in the understanding of nuclear theory and astrophysics have also been made.

Problem

Read the problem situation given on page 1.4 of the TI-Nspire document, *Ionizing_Radiation*, and then complete the questions embedded within the document.

A. What is the momentum of a proton with a kinetic energy of 11.2 MeV?

B. Ignoring relativistic speeds, what is the deBroglie wavelength of this proton?

C. Photons are massless. Their energy does not depend upon their speed and mass, but upon their frequency.

I. What is the wavelength of a photon that has the same 11.2 MeV of energy?

II. Does this correspond to a frequency that is lower than, inside of, or higher than the visible light spectrum? Explain.