

Lesson 6: Space Weather III

Other Homework Due: *Mission Specialist Log Entry*

Subject

Electromagnetic spectrum: waves & photons
The science of radiation

Description of Student Activities

Complete the *Article Review* activity started in Lesson 5.

Teacher presents the electromagnetic spectrum and related topics.

Duration

10 min. Complete Article Review Activity
30 min. Teacher Presentation / Discussion
5 min. Assign Homework

Main Topics

- 1) The atom and the behavior of atomic particles link the main topics of e-Mission: Space Station Alpha. How the sun works, how radiation affects the human body, electricity, and how the space station's systems maintain a critical atmospheric balance are all related at the atomic level.
- 2) The sun is the major external source of energy. The energy for life primarily derives from the sun.
- 3) Waves, including infrared waves, light waves, radio waves, microwaves, X-rays, and gamma rays are forms of energy and tend to transfer some of their energy when they interact with matter.
- 4) Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat) visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets, called photons, whose energy is inversely proportional to their wavelength and directly proportional to their frequency.

Materials

Article review questions and answers

Materials necessary for Presentation & Discussion

Outcomes

Students discover that electromagnetic radiation comes in many forms, that it is a form of energy, and that it is related to atomic processes.

Special Comments

The purpose of the teacher presentation is to clear up some misunderstandings that may exist. The outline on the next page represents facts that, along with some simple drawings on the board, graphics from a website, or PowerPoint™ presentation should help the students pull together some of the ideas to which they have been introduced..

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Procedure

- 1) Article Review conclusion (15 minutes). Allow for all student groups to conclude their reports from the previous class.
- 2) Teacher presentation and discussion (25 minutes). An outline is attached. You will not have time to cover everything on the outline. The entire outline is given here to help you as the teacher see what is necessary and not. The items on the outline are the important points. Review anything that you feel needs more coverage, but leave enough time for the third segment of the class that ties this Unit to the next Unit. We advise using a yellow marker on your copy to highlight what you want to cover before you begin.
We have provided a PowerPoint™ presentation which has many of these points in it.

Homework for Lesson 7

- Read
The Human Recipe
In the Kitchen with Poly
Measuring Exposure to Radiation

The students will be answering questions in an *Article Review* activity on all of the readings for Radiation Health. They should come prepared to find the answers quickly and prepare their reports.

Space Weather: Everything You Need to Know for a Successful Mission

LOOSE ENDS: This introduces some concepts not yet presented to the students. These are concepts best presented by the teacher in an informal way.

I. Science words and phrases can cause a lot of confusion. Consider the following groups of words:

- A. Electromagnetic, Electromagnetism, Electromagnetic energy, Electromagnetic spectrum, Electromagnetic radiation, Light, Ionizing radiation, Non-ionizing radiation, Radiation, and Radioactivity.
 - 1) All these words, but one, are talking about the same thing. That one word is radioactivity. Even the word "light" is sometimes used to represent all the electromagnetic energies, as in the "speed of light." The word "light," therefore, is, in this sense, different from "visible light." All forms of electromagnetic energy move at the speed of light.
 - 2) We shall return to electromagnetism in one moment. First, another set of words that causes confusion.
- B. Ion, Ionized, Ionize, Ionizing, Non-ionizing.
 - 1) All these words share a single root word "ion." All of these words are related through that one word. An ion is an atom that has an electrical charge, either because it has at least one too many or one too few electrons. A proton, in the plasma phase, is an ionized hydrogen atom with a net positive electrical charge in that it is a hydrogen atom without its electron. (Protons have a positive charge.)
 - 2) Three of the words in this group refer to a process, however, and two of these words refer to the outcome or the results of the process,. Try this sentence to see if it helps make some sense of "ion" words. "Ions are atoms that have been ionized by ionizing radiation. Non-ionizing radiation cannot produce ions."
 - 3) Radioactive particles, by the way, emit both more radioactive particles and ionizing radiation.

REVIEW: This is a summary of the last two lessons and all articles. Review as quickly as possible.

II. The earth-sun relationship

- A. Along with all the good it does for planet earth and life thereon, the sun constantly emits dangerous radiation and radioactive materials.
- B. The earth's magnetic field and atmosphere help to protect the earth and its inhabitants.
 - 1) Solar electromagnetic energies and radioactive particles are intercepted by the earth's magnetic field lines. These emissions from the sun spiral down these lines to the poles causing the Northern and Southern lights.
 - 2) The Van Allen belts located between the magnetic field lines of the earth absorb radioactive particles.
 - 3) The ozone layer in the earth's ionosphere serves to de-energize the sun's dangerous electromagnetic energies.
- C. Extreme forms of solar activity, called solar proton events, occur during solar maximum and emit dangerous forms of electromagnetic energy so intense that they can interrupt electrical, communications, and navigation systems on earth and in earth-orbiting satellites and space stations.

III. An overview of the atom, its structure and interaction with various forms of energy

- A. Studying the behavior of atoms and molecules (chemical bonding of two or more atoms) allows scientists to explain many common, everyday phenomena relevant to Space Station Alpha. Among these phenomena are the role of light, magnetism, electricity, the behavior of gases, and the functions of the human body.
- B. For the reasons just stated, becoming sensitive to the idea of atoms, their "history," and their behaviors can help students appreciate many of the facets of Mission Specialist training.
- C. Atoms were first imagined by philosophers (the name used to describe thinkers before the term "scientist" was created) 2500 years ago to explain the world around them.
- D. The scientific revelations of Copernicus and Galileo freed scientists of the restraints imposed upon them by both church dogma and popular myth. These 2 scientists bravely paved the way for the eventual exploration of gravity (Newton), electricity, optics (light/electromagnetism),

astronomy, and magnetism, all scientific concepts that together opened the doors to the exploration and understanding of the atom.

- E. Atoms form molecules. Molecules form matter.
- 1) All matter can be found in one of four phases or states.
 - a) In all four phases atoms/molecules are in constant motion.
 - b) Solids have fixed volumes. The molecules in solids are bound in rigid lattice-like or crystalline molecular structures. The "internal" motion of the molecules is restricted by this structure yet affected to one degree or another by various forms of energies and forces: mechanical, chemical, electrical, magnetic, gravitational, nuclear, etc.
 - c) Liquids have fixed volumes. The molecules in liquids move about at random, but they are quite close to one another and their motion is hindered.
 - d) Gases have no fixed shape or volume. The molecules in gasses move independently of one another.
 - e) Plasma has no fixed shape or volume. Plasma consists of hydrogen and helium nuclei and free electrons. Plasma is found in the sun or in discharge tubes (a gas-filled or evacuated glass tube with a pair of sealed-in electrodes)
- F. Atoms respond to and can be altered by different forms of energy.
- 1) Mechanical energy, rubbing or friction, can increase the heat of an object. Heat is both a reaction to and a function of molecular and atomic motion.
 - 2) Electromagnetic energies can affect atoms in many ways.
 - a) Gamma rays can ionize an atom – strip it of its electron(s).
 - b) X-rays, ultraviolet, microwave, and infrared energies can increase the energy levels of subatomic particles.
 - c) Light and radio waves can cause some atoms to emit, in turn, their own light energies.
- G. By building a model of an atom, we gain insights into an atom's relative dimensions and structure.
- 1) A model of a hydrogen atom with only a single proton as its nucleus becomes the size of the Superdome if the proton is only 3mm in diameter. (However, a model may lead students to believe that atomic particles have physical dimensions. They don't, they only have mass and an electrical charge.
 - a) "Particle" definition: "Particle" is an abstract simplification of a real object—the mass is concentrated at the object's electron, proton, neutron, etc.; *it's volume is zero.*
 - 2) Protons and neutrons form the nucleus of the atom.
 - a) Protons and neutrons are bound together by the Strong Force.
 - b) The Strong Force is unstable in the nucleus of uranium, plutonium, boron atoms, etc.
 - 3) Electrons orbit (according to the Bohr model) the nucleus. They, too, are miniscule, dimensionless atomic particles with negative electrical charges.
 - 4) The space between the nucleus and the electron is a perfect vacuum.
 - 5) All matter in all states consists of atoms joined as molecules that are nothing more than electrically charged, subatomic particles, vacuum, and magnetic fields.
- H. Molecules consist of an atom or atoms joined by chemical bonds. A molecule is the smallest unit of a chemical compound that can have an independent existence.
- I. Einstein made a scientific leap when he linked energy, mass, and the speed of light into a seemingly simple formula that explained both the thermonuclear energy at the center of the sun (fusion) and the workings of nuclear power plants (fission), and the atomic (fission) and hydrogen bombs (fusion). The mass he was formulating was the mass of atoms, the energy is electromagnetic, and the speed of light was the constant that enables the equation.
- J. Atoms and the space station:
- 1) Electricity is the flow of electrons through a wire.
 - 2) In some solids atoms align forming domains. Aligned domains in some forms of matter (solids and plasma) create magnetic fields.
 - 3) For breathing to occur, oxygen molecules must be under enough pressure from the presence of other gas molecules in the atmosphere to penetrate the molecular structure (alveolar membrane) that lines the lungs.
 - 4) The collision of light photons from the sun with the atoms in silicon molecules frees electrons and creates the electrical supply of the space station. The presence of impurities within the solar cell keeps the electrons from returning to their original atomic energy fields.
 - 5) The interplay within a human cell between the atoms and molecules and high-energy radioactive particles and ionizing electromagnetic radiation can determine the fate of a cell's genetic code, or DNA.

IV. The Sun

- A. The sun is a complex, mid-sized star.
- 1) The sun consists of a number of layers or zones.
 - a) The core is hot, 15 million degrees celsius. It consists of atomic particles [plasma] packed together 20 times denser than the atoms in lead. Thermonuclear fusion takes place here. Hydrogen protons fuse to become helium nuclei. The process releases energy in the form of gamma rays. Every second, it is estimated that 700 tons of hydrogen protons fuse in a two-step process to become 695 tons of helium nuclei. Five tons of matter is turned into electromagnetic energy [gamma rays] in accordance with Einstein's formula, $E=mc^2$.
 - b) The radiative zone insulates and sustains the core Its magnetic fields contain the thermonuclear explosions of the sun.
 - c) Convective Zone consists of plasma that heats up, rises, cools, and sinks.
 - d) Photosphere is 5700 degrees Kelvin (Celsius temperature plus 273.15 degrees). It is the part of the sun that is most visible. Sunspots appear on the photosphere. They are cooler in temperature than the rest of the sun's surface. They form the poles of writhing, solar magnetic fields.
 - e) Chromosphere is the area above the surface of the sun in which prominences (coronal mass ejections) are observed. It cannot be seen except during an eclipse or by a specially designed telescope called a coronagraph.
 - f) Corona is 2 million degrees K. One of the unexplained mysteries of the sun is why the corona is so much hotter than the photosphere. The solar wind is essentially the sun's corona expanding outwards. Radioactive plasma ejected by solar eruptions [prominences, coronal mass ejections, solar proton events] is transported on the solar wind.
 - g) Outer Corona is the sun's magnetic fields extending far out past the earth and into the solar system.
- B. The sun's magnetic fields are generated by the turbulent flow of solar plasma.
- 1) Solar magnetic fields are separate, interact, twist, bend, snap, and reconnect creating flares or prominences.
 - 2) They are commonly associated with sunspots.
 - 3) In terms of quantity and levels of violence they wax and wane through twelve-year periods of greater and lesser intensity, from solar maximum to solar minimum.
 - 4) The student exploration, *Sheer Magnetism*, is designed to familiarize the students with magnetism, interacting magnetic fields, and the relationship between electricity and magnetism that plays such an important role in the functionality of the technology aboard the space station.

Looking Ahead: The following information forms a transition between this Unit and the next. Spend as much time as possible on this section.

V. Electromagnetic Energy

- A. Electromagnetic energy: What is it? What do all forms of it have in common? How does one form differ from another? Where does electromagnetic energy or radiation come from?
- 1) Electromagnetic energy can be described both in terms of waves and of particles, or photons.
 - 2) Electromagnetic radiation consists of both electrical waves and magnetic waves in that they are formed by an interaction of electrical charges and magnetic charges. You will learn in the Power Systems chapter coming up that magnetism and electricity are very closely related.
 - 3) In that all forms of electromagnetism act like waves, they have a wavelength and a frequency.
 - 4) All the forms of electromagnetism also behave as if they were small energy packets, called photons. As such they can penetrate an atom and, if they hit an electron, they can either ionize it (ionizing radiation can remove an electron) or energize it (non-ionizing radiation such as light can do this). If the electron is simply energized, and not removed from the atom, it "leaps" up to a new energy level. But it doesn't stay at the new level because energy "spreads out." (The scientific term is entropy.) When this happens the electron moves back to its original energy level and in so doing emits a photon of a lesser form of electromagnetic energy, in most cases, visible light.

- a) Electromagnetic energy that collides with an electron also loses some energy (because the first law of thermodynamics states that the amount of energy in the universe remains constant or always the same). This explains the long journey of the gamma rays that are created in the core of the sun. Their collisions with particles in the sun's plasma causes a loss of energy to the gamma rays. As they lose energy they become X-rays, ultraviolet, and infrared (and all the rest of the spectrum). Finally they escape from the sun. Space weather forecasters measure the emission of all of the forms of energy as they try to determine trends in solar weather.
- b) We now see that some forms of electromagnetic energy come from the interplay of atomic particles and electromagnetic energy. We also recall that electromagnetic energy is created during thermonuclear reactions, fusion and fission.

B. Looking ahead:

- 1) Ionizing electromagnetic radiation, gamma rays and X-rays, erroneously called simply "radiation," can ionize atoms. It is, thus, dangerous to humans and can alter our DNA, as we will learn in the Unit on Radiation Health coming up next.
- 2) Radioactive particles (primarily alpha particles or helium nuclei and beta particles which are positively charged electrons (Yes, there are such "creatures.") and plasma protons also cause great damage to humans if they are allowed to penetrate the body. That's why one team will track the density of protons as they are recorded by the GOES satellite during the e-Mission.
- 3) Some forms of radiation are also beneficial. Radiation (infrared or microwave or visual light) cooks food, heats our homes, allows us to see all the colors of the rainbow, produces electricity on the space station by hitting silicon atoms in the solar cells thus releasing electrons which flow through wires and power the space station's life support systems. We'll study about this in the Power Systems and Life Support Units.