Lesson 11: Power Systems III

Preparatory Readings

LP #	Unit 1: Mission Bfg/ App Process	LP #	Unit 2: Space Weather	LP #	Unit 3: Radiation Health	LP #	Unit 4: Power Systems	LP #	Unit 5: Life Support	LP #	Unit 6: Pre-Mission Prep
Mission Briefing		4	Specialist Orientation	**Chapter 2**		**Chapter 3**		**Chapter 4**		13	Overview of Teams
1	The Mission	**Chapter 1**		7	New Frontiers & New Dangers	9	The Energy Supply Problem	12	How I Discovered Air	13	Mission Directives
1	We Need You	4	Here Comes the Sun	8	Electromag Rad: Taming the Wild Energies	9	Rechargeable Batteries	12	A Weighty Discovery	13	Classroom Setup
1	Space Station Alpha	4	Inside the Atom	7	Do You Want the Recipe?	10	All About Power	12	Living in a Bubble	**Team Preparation Introductions**	
opt	Verizon	5	Sheer Magnetism (Hands On)	7	In the Kitchen with Poly	10	Emergency Procedures	12	Breathing on the Space Station	13	STORM Team Overview
How to Apply		5	Dr. Z: Inside the Sun	7	Measuring Exposure to Radiation	10	Practice Ex: Power on the SS (Hands On)			13	Radiation Team Overview
2	Apply Today			**Enrichment Activities**		**Enrichment Activities**				13	Power Team Overview
2,3	Personal Essay			7	Ready, Aim, Mutate! (Hands On)	10	Electrical Current Mag Field (Hands On)			13	Life Support Team Overview
2,3	Class Activity: Station Systems			7	Sweet Dreams are Made of These (Hands On)	10	Electrical Circuit: Quick Guide (Hands On)			13	Communications Team Overview
opt	Mission Patch			7	Are You Too Hot? (Hands On)	10	Nailing Down Energy (Hands On)				
						10	A Shocking Discovery (Hands On)				
						10	Electrolysis (Hands On)				
						10	It's Electric (Hands On)				

Other Homework Due:

- Bring in answers to presentation questions
- Closure questions from hands-on exploration

Subject

Remaining topics from last lesson.

Wrap up and review of main ideas

Description of Student Activities

Each group will present a report on its exploration to the rest of the class. Teacher wraps up the unit using a presentation.

Duration

(20 min) Reports and discussion

(25 min) Teacher presentation

Materials

Teacher presentation materials

Main Topics

1. Electrical circuits on the space station are vulnerable to extreme solar weather.
2. A piece of electrical equipment or a system consisting of an entire electrical circuit requires electrical power, measured in watts, in order to do work.
3. Electricity and magnetism are closely related phenomena. Magnetism induces electricity in a wire. The flow of electricity through a conductor creates a magnetic field.

Outcomes

1. The students will be able to compare and contrast the circuits on the space station with those in their homes.
2. The students will explain that electricity and magnetism are closely related phenomena, that magnetism can induce electricity in a wire, and that the flow of electricity through a conductor creates a magnetic field.

Special Comments:

The quality of the students' reports depends upon clear directions. As the students are conducting their explorations they should be trying to explain what is happening in terms of atoms, molecules, electricity, and magnetism (science terms they have learned). They should make sketches of what is happening in their explorations to help them present the exploration to the rest of the class. They should try and isolate whatever aspect of the exploration they feel may be "measurable." And finally, they should decide in what way and under what conditions this exploration may be relevant to life on board Space Station Alpha during a solar proton event.

Procedure:

(20 minutes)
Begin with student presentations at five minutes apiece.

(25 minutes)
Teacher Presentation / Discussion
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 decides what is necessary to review or clarify. The items on the outline are the important points. We advise using a yellow marker on your copy to highlight what you want to cover before you begin.

Homework for Lesson 12

- Read
  How I Discovered Air (if not yet read)
  A Weighty Discovery
  Living in a Bubble
  Breathing on the Space Station
- Complete entry in *Mission Specialist's Log*

Power Systems:
Everything you Need to Know for a Successful Mission

LOOSE ENDS: This presentation is intended to present several concepts to the students with which they may not be familiar. It is primarily intended to be a review and consolidation of some of the key concepts already discussed, such as circuits.

Connections between circuits and Space Station Alpha

To prepare all the students for the practical demands of the e-Mission, see steps below to draw a "very rough" schematic of 6 circuits with labels and symbols to describe the space station's power system. This may serve as a review. If so, ask the students to name the labels as you proceed with the drawing.

- Draw one major loop (high on blackboard), label "Power Grid," and label "entryway" (or transformer) at bottom, center of loop. Draw 5 other distinct loops for 5 separate circuits below the "Power Grid" yet connected to the transformer. You can label the two poles of each circuit with a "+" and a "-". (We omit a breaker box. Computers monitor and control electrical supply on the space station.)
- Draw two boxes on the power grid and label them each emf. Label 1 of them "PV arrays" and the other "Nickel-Hydrogen batteries."
- Label one of the wires on a circuit "conductor"

- Number and label each of the 5 circuits: 1. Command and Data Handling Circuit, 2. Communications and Tracking Circuit, 3. Life Support System (ECLS) circuit, 4. Flight Crew System Circuit, and 5. Thermal Control Circuit.
- Describe each circuit as requiring so much power, or wattage.

Note: This is a simplification of the space station's electrical systems but meets the needs of the upcoming e-Mission and the unit. You may, if you wish, discuss parallel and serial circuits, but it is not necessary and may only confuse the students. The Power System Calculator found in the Power Team section of the Pre-Mission Preparation segment of the web site is a simulated rheostat that allows the students during the e-Mission to regulate the flow of power to the five circuits that you drew on the board. To see more details about one of the five systems, an action, "click-and-tell," display of the ECLS system and its many components can be found in Chapter 4: Life Support Systems.

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

Energy Supply on Space Station Alpha

- How does the space station generate electricity if…
  - the space station orbits the earth in a vacuum?
  - fossil fuels are too heavy to transport to the station in the shuttle?
  - electrical generators need an energy supply?
- The answers are light, solar cells, and photovoltaic arrays.
- Where does the electrical power come from when the space station is in the shadow of the earth?
  - The answer is rechargeable, Nickel-Hydrogen batteries.
- The photovoltaic arrays are critical to the space station's power supply.
  - How big are they? 32,000 square feet or two-thirds the size of a football field.
  - How do they work?
    - During insolation ("in the sun") electromagnetic energy photons, or energy packets, in the form of visible light, collide with the electrons in the silicon atoms.
    - The light photons energize the electrons and the extra energy causes them to jump from their energy shells. Electricity is, by definition, the flow of electrons.
    - They are kept from returning to the silicon atoms by impurities intentionally injected into the solar cell's silicon crystalline structure. The impurities are individual molecules consisting of boron and phosphorous atoms. The process is called "doping."
    - The electrons flow towards the negative pole of the solar array (just like they would in a battery) and away from the positive pole.
    - From the negative pole of the solar arrays, the electrons flow through the main power grid of the space station, recharging the Nickel-Hydrogen batteries, and flowing, in turn, through the space station's electrical circuits.
- Nickel-Hydrogen batteries are used to supply the space station with electricity during the eclipse portion of its orbit.
  - They have a long lifespan.
  - They can be recharged after they run down.
  - Many batteries strapped together are powerful enough to supply the electrical needs of the space station.
  - Batteries also have two terminals, one positive and one negative (as do solar arrays). The electrons flow through the conductors, or wires, in the circuit from the negative pole of a battery to the positive pole.

- The space station orbits the earth every 90 to 95 minutes. About 30 minutes of this time is spent in the earth's shadow.
- 35% of the batteries stored energy is expended while the space station is in eclipse.
- If anything happens in terms of the flow of electromagnetic energy from the sun to decrease the electricity produced by the photovoltaic arrays, the batteries must work overtime, thus expending their energy reserves below what is considered a safe level.

Electrical circuits and electrical power

- An electrical circuit consists of an electromotive force (emf or power supply), a conductor (wire or cable), and a load (a light bulb, stove, refrigerator, etc.).
  - Some people include a switch within the definition of a circuit.
  - Electricity is the flow of electrons through the conductor in a circuit. Throw a switch or disconnect the circuit from the emf and you "break" the circuit.
  - It takes a certain number of electrons (measured in amps) driven by a large enough electromotive force (measured in volts) to supply the power for a given load (measured in watts). The formula for this is $P = V \times I$. "I" is the symbol for amps.
  - One other factor is also involved in electrical calculations and that is resistance. Resistance is measured in Ohms.
    - Ohms are not a concern during the Mission Specialist training.
    - Ohms come into play when discussing the various materials that make conductors, insulators, and semiconductors.
- Watts
  - Look at the end of a light bulb. Consider a light bulb with a large wattage or power requirement of 150 watts, or even 75 watts. Attach this bulb to a conductor (a wire and socket). The 754 watt bulb would not receive enough power from the amperage (electrons) flowing through the wire from a 1.5 volt C-cell battery (the circuit's emf) to light up; but a flashlight's bulb, with much lower wattage requirements, would.
  - Some hair dryers require, or, as they say, "draw," up to 1500 watts of power.
    - 1500 watts of power = 1.5 kW of power. 1kW = 1000 watts.
    - If you run this hair dryer for one hour you would consume one 1kWh of power.
    - One 1kWh of power would be added to your electric bill for the month.
  - The watts of electrical power required to drive the equipment on board the space station are measured in kilowatts per hour, or kW/hr.
  - On board the space station, a circuit services a variety of electrical equipment that requires enough power, or wattage per hour, to run. Without endangering the crew, the flow of electricity to the following systems on Space Station Alpha must be monitored and adjusted to conserve power during a solar proton event.
    - The ECLSS (environmental control and life support system) requires 6.86 kW/hr when running at full power
    - The communications and tracking systems require 2.94 kW/hr.
    - The FCS, or flight crew system, requires 2.94 kW/hr.
    - The TCS, or thermal control system, a subset of the ECLSS, requires 8.33 kW/hr.
    - The C&DH, or command and data handling system, requires 3.43 kW/hr.
- During the e-Mission, the regulation of the space station's power supply is managed by the Power Team through the use of a master rheostat (The Power System Calculator) that is online on the SSA website.