POWERING THE PLANET
Teaching Guidelines

Subject:	Mathematics
Topics:	Algebra: Solving Equations
Grades:	8 - 12

Knowledge and Skills:

- Can identify variables in a real-world situation
- Can determine, in a general way, how variables in a real-world situation are related to each other
- Can use the principles of algebra to solve equations for a given variable (scope: using inverse binary operations)

Procedure

Prepare for presentation the Futures Channel movie, *Powering the Planet*. Tell students that as they watch the movie, you want them to think about this question (which should be posted):

What are some of the variables that you would want to think about in designing and operating a power system like the one described in this video?

At the end of the movie, discuss answers to the question, then tell students that they are going to do an activity which puts them in the roles of scientists and engineers working on this problem. Arrange students in working groups, and distribute the handout.

Have the groups study the first section of the handout, up to Step 1, then discuss this as a class, working through an example or two of the three-step approach described as related to a relatively simple situation that students are familiar with.

Next, show students the Space-based Solar Power Close Up, *Wireless Power Calculation*. Discuss it as needed, to ensure that students understand what is being calculated, and what each of the variables in the equation stands for. Then have the groups work through the rest of the handout, circulating as they do so and asking questions as needed to guide them through the activity.

Powering the Planet

Critical Thinking

Suppose that you were responsible for making a recommendation to the U.S. Congress regarding funding of research on the subject of Space-based Solar Power. How would you go about deciding whether the idea is really feasible?

There's an approach that engineers often use when they are thinking about problems of this nature. It consists of three steps:

1) Determine the variables of the situation—that is, the factors that are part of the problem.

2) Work out how those variables are related to each other, as equations.

3) Use the equations as a mathematical model of the situation that allows you to "try out" some ideas on paper.

You can see an example of this approach to solving the problem of the size of the power receiver, in the Space-based Solar Power Close Up: Wireless Power Calculation.

Step 1:

These are the variables:

- The size of the transmitter, on the satellite, as measured by its diameter, D_t.

- The size of the receiver, on the earth, as measured by its diameter, D_r.

- The wavelength of the electromagnetic waves that carry energy from the satellite to the earth, λ. (For space-based solar power, a wavelength of 12.24 centimeters, or .1224 meters, is usually proposed because that wavelength can pass easily through the earth's atmosphere and is not harmful to living things at the low intensities that would be used.)

- The separation between the satellite and the earth, S. (If the satellite is in an orbit that keeps it always above the same spot on the earth, called a *geosynchronous* orbit, then S must be about 35,800,000 meters.)

Step 2:

Physicists have worked out the equation that relates these variables:

$$D_r \times D_t = 2.44 \times \lambda \times S$$ (all measurements in meters)

Step 3:

Once you have the equation, you can use it to explore how the factors of the problem are related, which can help you to make engineering decisions. To see how that works, answer these questions:

1) Use the equation to find the diameter of the receiver, D_r, if these are the values of the other variables:

   D_t = 1000 meters
   λ = 0.1224 meters
   S = 35,800,000 meters

2) Suppose you wanted to make the transmitter smaller (to save money in building it and getting it into orbit). Looking at the formula, make a prediction about how you would have to change each of the other factors to make this work:

   Would the receiver get smaller, or larger?
   Would the wavelength be shorter, or longer?
   Would the distance to the earth have to be greater, or less?

3) Using the values from question #1, find the value of D_r if D_t is cut in half, and λ and S aren't changed. Does that match your prediction in question 2?

4) Using the values from question #1, find the value of λ if D_t is cut in half, and D_r and S aren't changed. Does that match your prediction in question 2?

5) Using the values from question #1, find the value of S if D_t is cut in half, and D_r and λ aren't changed. Does that match your prediction in question 2?

6) If you decided to use a longer electromagnetic wavelength to transmit the power, how would that affect the sizes of the transmitter and receiver?

7) Do you think it would cost less to build the transmitter and receiver if the satellite were placed into an orbit closer to the earth? Explain your answer.

Challenge

Suppose the cost of building a transmitter and getting it into orbit is estimated as $100,000 per square meter, and the cost of building a receiver on the ground is estimated as $2,000 per square meter. Use the values for S and λ from question 1 to compute the total cost for transmitter and receiver for several different values of D_r and D_t.

To do this, choose a value for D_r, then use the formula to find the value of D_t, then compute the costs for the transmitter and receiver, and add them to find the total cost. Repeat with a different value of D_r, etc.

Based on your calculations, what would you recommend for the sizes of the transmitter and receiver?

Challenge

a) List all of the variables that you can think of that are related to this question:

Can Space-based solar power supply a useful amount of the power that will be needed by the U.S. population in the year 2050?

b) Work out as many relationships between those variables as you can. (Note: You do not need to find actual equations. Instead, pick a variable, and work out the effect of increasing the value of that variable on some of the other variables. Do this for as many relationships between variables as you can).

c) What do you think are the most important variables, and why?