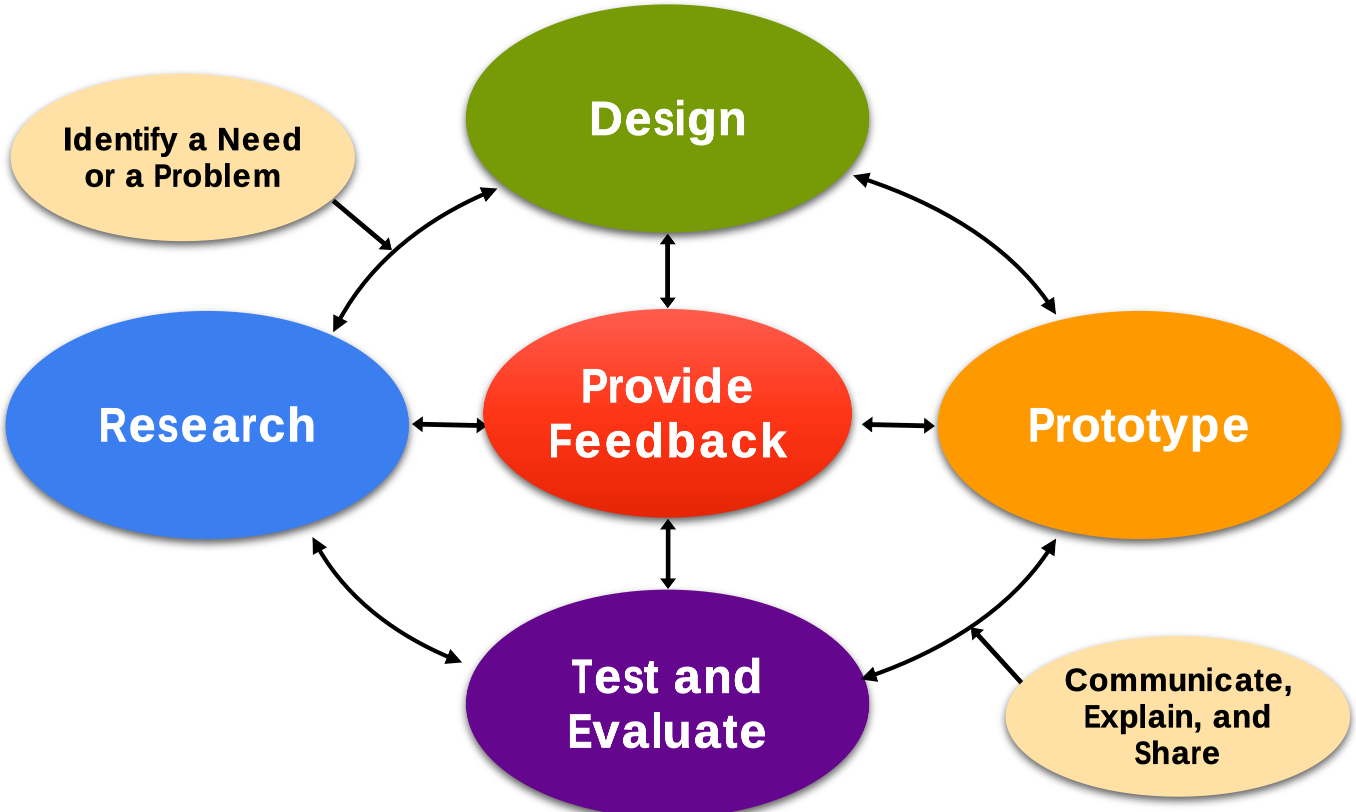
National Aeronautics and Space Administration

NASA Glenn Research Center Engineering Design Challenge

EDC-03: Powered and Pumped Up

The Engineering Design Process



Introductory Video

https://youtu.be/eQa9B1BlkUw

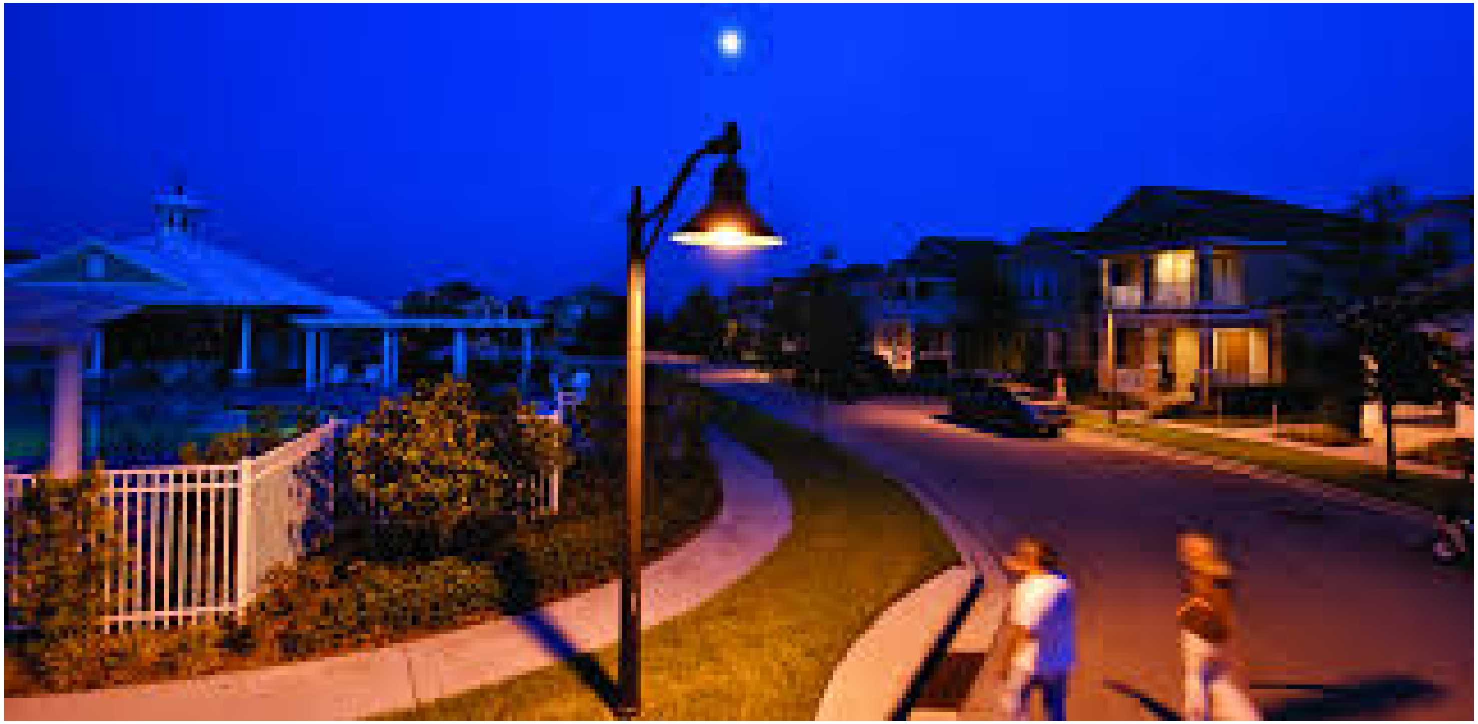
Supporting Science Investigations

Powered and Pumped Up includes three Supporting Science Investigations to assist students in understanding the science behind the challenge.

- Investigation 1: How Intense Are You?
- Investigation 2: What's the Point?
- Investigation 3: Shed Some Light

Supporting Science Investigation 1: How Intense Are You?

The intensity of light waves changes as the waves move away from the source.



Supporting Science Investigation 1: How Intense Are You?

Procedure

1. Insert the flashlight into the foam pipe insulation, or attach it to the insulation, so that the light will pass vertically down the pipe when the flashlight is on. Secure with tape.
2. Place the graph paper provided on a flat surface. Student 1 will hold the flashlight in a vertical position at a 90° angle to the paper (or as close to 90° as possible) so that the light is centered on the yellow circle.

Supporting Science Investigation 1: How Intense Are You?

Procedure

3. Student 1 will position the flashlight above the graph paper at the following heights, measuring from the light-emitting end of the foam pipe insulation: 4 cm, 8 cm, 12 cm, 16 cm, and 20 cm. For each position, Student 2 will measure the diameter of the circle of light.

4. Turn on the flashlight and begin your observations. The flashlight should only be directed toward the paper and NOT toward any person.

5. Use the data table to record (in cm) the diameter of the circle of light at each height.

Supporting Science Investigation 1: How Intense Are You?

Procedure

6. Observe the brightness of the light. Determine the brightness at each measurement and indicate on the graph how the brightness compares with the 4-cm brightness value.
7. Have students complete the additional tasks on the Data Collection Sheets.

Supporting Science Investigations Discussion

Investigation Discussion 1: How Intense Are You?

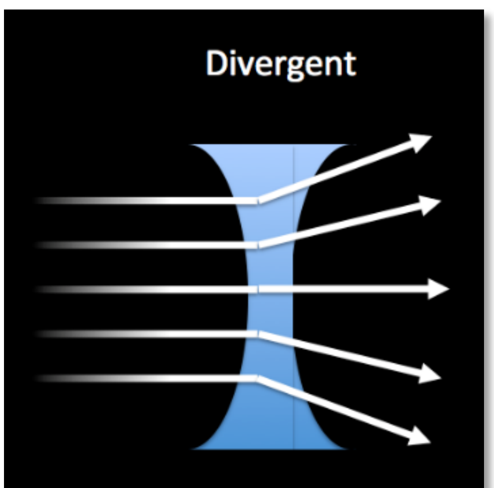
In the "How Intense Are You?" activity, we learned that wave energy from the Sun spreads out as it travels away from the Sun.

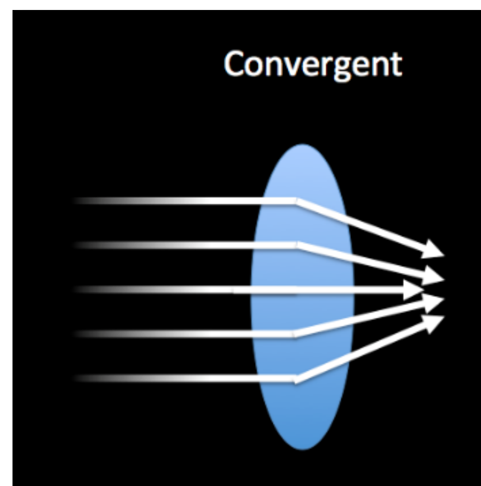
- If our challenge is to collect as much of this energy as possible, what could we do to reverse the impact of this light dispersion?
- Would being on another planet, such as Mars, make it easier or more difficult to reverse the impact of light dispersion?

Supporting Science Investigation 2: What's the Point?

Lenses can be used to manipulate light. One surface must be curved; the other surface may be curved or flat.

- **Divergent lenses** are thinner in the center than on the edge. These lenses **disperse** light.
- **Convergent lenses** are thicker in the center than on the edge. These lenses **concentrate** light.

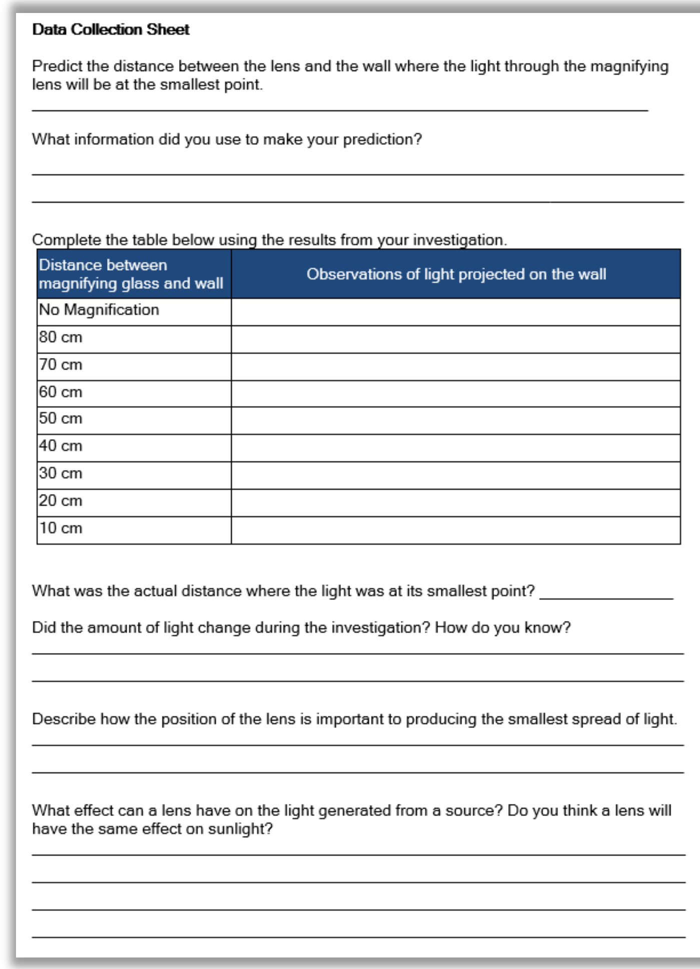




Supporting Science Investigation 2: What's the Point?

Procedure

1. Position the flashlight 1.5 m from a plain wall. This position is to replicate the position of the Sun. The light should NOT move.
2. On your Data Collection Sheet, predict the distance between the lens and the wall where the light through the magnifying lens will be at the smallest point.



Data Collection Sheet

Predict the distance between the lens and the wall where the light through the magnifying lens will be at the smallest point.

____

What information did you use to make your prediction?

____

____

Complete the table below using the results from your investigation.

Distance between magnifying glass and wall	Observations of light projected on the wall
No Magnification	
80 cm	
70 cm	
60 cm	
50 cm	
40 cm	
30 cm	
20 cm	
10 cm	

What was the actual distance where the light was at its smallest point? ____________

Did the amount of light change during the investigation? How do you know?

____

____

Describe how the position of the lens is important to producing the smallest spread of light.

____

____

What effect can a lens have on the light generated from a source? Do you think a lens will have the same effect on sunlight?

____

____

____

____

Supporting Science Investigation 2: What's the Point?

Procedure

3. Hold the magnifying lens between the light and the wall at 80 cm from the wall. Observe any changes to the light that is projected on the wall.
4. Continue to move the magnifying lens closer to the wall at 70 cm, 60 cm, 50 cm, 40 cm, 30 cm, 20 cm, and 10 cm. Use the Data Collection Sheet to record your observations of the changes that are occurring to the light on the wall.
5. Complete the additional tasks on your Data Collection Sheets.

Supporting Science Investigations Discussion

Investigation Discussion 2: What's the Point?

In this activity, we determined that for each lens there was a specific distance between the light source and the lens that would generate the smallest circle on the wall.

- What kind of setup would focus the greatest possible amount of sunlight into the smallest possible area? Draw your proposed setup, label it, and be prepared to explain your idea to others.
- How would you modify the setup to focus the light into an area exactly 5 cm in diameter?

Supporting Science Investigation 3: Shed Some Light

- Light waves travel in a straight line until they encounter an object. Based on the object encountered, the light waves can be absorbed, refracted, or scattered. When light encounters a smooth, flat surface, it can be reflected. The direction the light will travel next depends on the angle that reaches the surface. Even spread-out light can be reflected.
- Mirrors provide the smooth, flat surface that light requires in order to be reflected. Objects that are white can also reflect light, but not as directly.
- Telescopes, microscopes, and binoculars use reflected light to change the way we observe objects.

Supporting Science Investigation 3: Shed Some Light

Procedure

Part 1

1. Score the cardboard at 5 cm along the long edge and fold this section up at a right angle. Cut the landscape pictures on the dotted line and tape them to the 5 x 55 cm edge of the cardboard. Set the cardboard on a table so the landscape illustration is at a right angle to the table.
2. Place the flashlight on the table parallel to and left of the landscape picture. The flashlight should be 15 cm in front of the picture. The light-projecting end of the flashlight should point to the right and be aligned with the “A” edge of the landscape picture. Tape the flashlight in place.

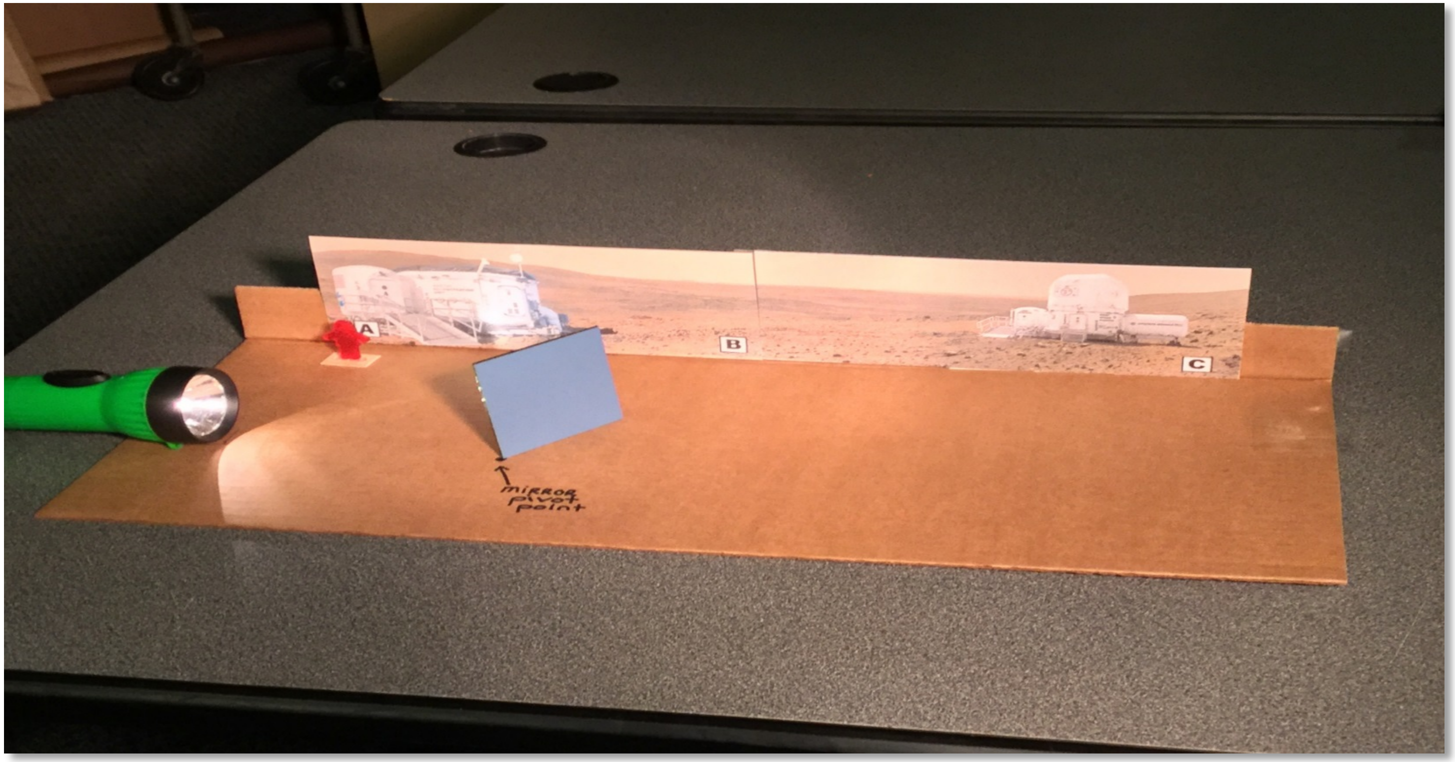
Supporting Science Investigation 3: Shed Some Light

Procedure

Part 1 (continued)

3. Measure 15 cm from the light-emitting end of the flashlight and draw a black mark on the cardboard. This will be the pivot point for the mirror during this part of the investigation. Turn on the flashlight. Place the astronaut figure at position A and place the corner of the mirror on the pivot point. Rotate the mirror to get the light beam to illuminate the astronaut. Make your observations for position A on your data sheet.

Supporting Science Investigation 3: Shed Some Light



Supporting Science Investigation 3: Shed Some Light

Procedure

Part 1 (continued)

4. Student 1 will keep the corner of the mirror at the pivot point while Student 2 moves the astronaut to position B. Rotate the mirror so the light is reflected and illuminates the astronaut. Make your observations for position B on your data sheet.
5. Repeat for position C and record your observations on your data sheet.

Supporting Science Investigation 3: Shed Some Light

Procedure

Part 2

1. Place the platform (4-oz paper cup) in front of position A. Place the astronaut on top of the platform. Turn on the flashlight. Using the same pivot point from Part 1, rotate the corner of the mirror to reflect the flashlight beam off the mirror to illuminate the astronaut.
2. Move the platform and the astronaut to position B. Using the pivot point, rotate the corner of the mirror to reflect the light off the mirror to illuminate the astronaut.
3. Repeat for position C. On your data sheet, describe what you noticed about the position of the mirror and how it had to be moved to illuminate the astronaut at positions A, B, and C.
4. Remove the flashlight from the cardboard.

Supporting Science Investigation 3: Shed Some Light

Procedure

Part 3

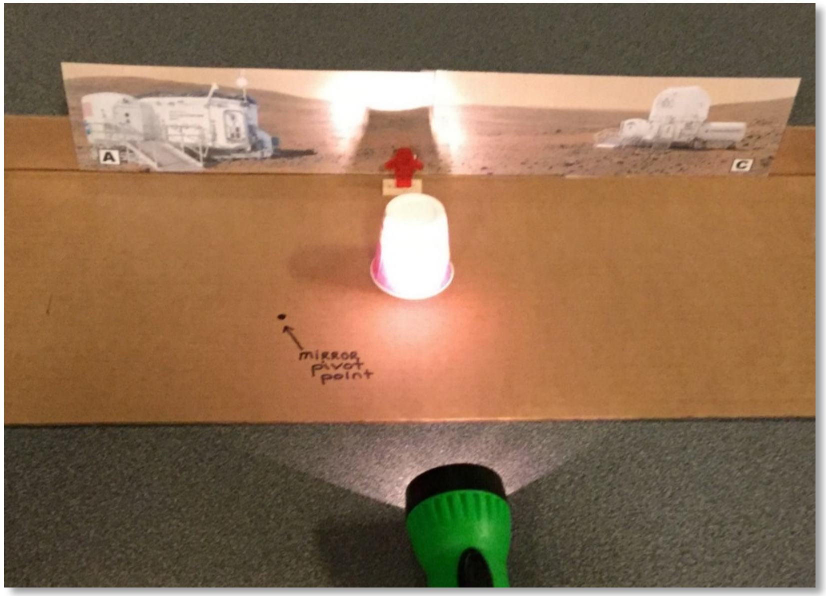
1. Place the astronaut at position B. Place the platform (4-oz paper cup) 5 cm in front of the astronaut. Place the flashlight 20 cm in front of the platform.
2. Turn on the flashlight. The astronaut should be in the shadow of the platform, and you should be able to see the dispersed light projected onto the landscape picture. On your data sheet, draw a diagram that shows the shape of the light from the flashlight that you see on the base of the cardboard landscape. Include the location of the astronaut and the platform.

Supporting Science Investigation 3: Shed Some Light

Procedure

Part 3 (continued)

3. Each team member has a mirror. Position the mirrors anywhere within the dispersed light to guide the reflection from the dispersed light onto the astronaut.
4. Add the position of the mirrors to the diagram you made in step 2. Describe what you did to manipulate the light.



Supporting Science Investigations Discussion

Investigation Discussion 3: Shed Some Light

When light encounters a smooth, flat surface, it can be reflected. The direction the light will travel next depends on the angle that reaches the surface. Even spread-out light can be reflected.

- What kind of changes to the reflected light did you observe as you went through this activity?
- How could this information help you design improvements to the pumping system for the challenge?

Creating a Solution Presentation

Presentation submissions should showcase solutions and the process from initial design to final solution. A Student Presentation Rubric is included to assess and score each presentation based on the following criteria:

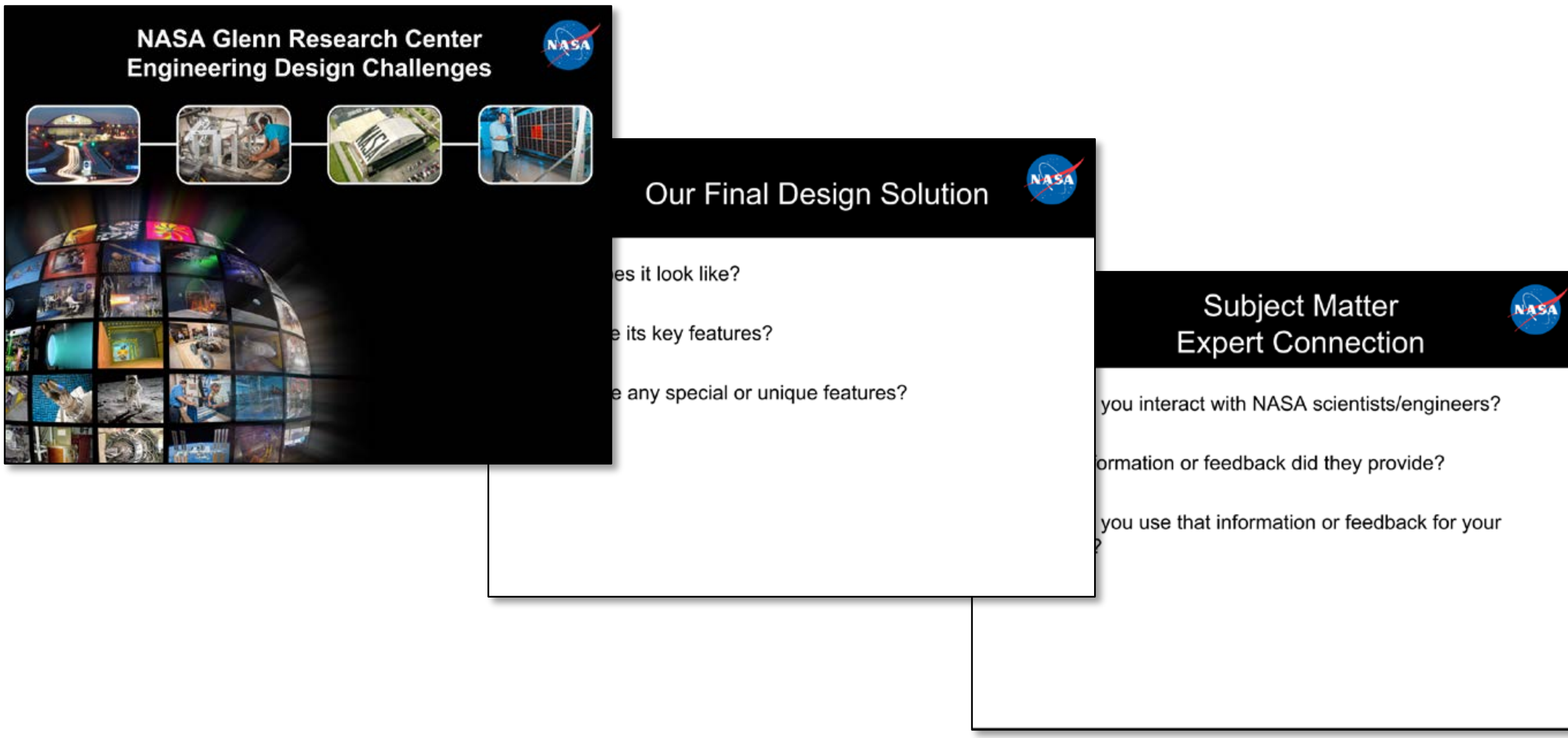
1. Introduce the presentation:
   - "This is team (team name) and we worked on the 'Powered and Pumped Up' challenge. The title of our presentation is _____________."
   - Do not identify the name of any student, teacher, school, group, city, or region.
2. The presentation should document every step teams took to complete the challenge, including Supporting Science Investigations.
3. Identify information provided by NASA scientists and engineers.
4. Explain which characteristics of the design provided the most reliable results and why.
5. Keep the total presentation length between 3 and 5 minutes.

This rubric will be used to assess your final presentation. Use it as a checklist to make sure you have included something from every category. Try to achieve as many 3s as you can!

Engineering Design Process Practices	Exemplary = 3	Proficient = 2	Novice = 1	Not Included = 0
We can **identify** the challenge and the criteria.	Challenge restated and all criteria and constraints described.	Challenge restated with only the challenge criteria.	Challenge story only was stated.	Did not include a description of the challenge or the criteria.
We can discuss the results of our **research**, the Supporting Science Investigations, and connections with a NASA scientist or engineer.	Three or more facts relating to the challenge were discussed.	Two facts relating to the challenge were discussed.	One fact relating to the challenge was discussed.	No facts relating to the challenge were discussed.
Each of our team members sketched an original **design** that demonstrated the challenge criteria and constraints.	All criteria and constraints were represented (sketches and photos) in each team member's design.	Two criteria were represented (sketches and photos) in each team member's design.	One criteria was represented (sketches and photos) in each team member's design.	No criteria were represented.
Our final team **design** represented elements from each team member's original design.	The team design includes the best from each member's design to represent the challenge and the criteria.	The team design includes ideas from two team members' designs to represent the challenge and the criteria.	The team design includes ideas from one team member's design to represent the challenge and the criteria.	The team was not able to provide a design to meet the challenge and the criteria.
Our team constructed a **prototype** to represent the challenge criteria and constraints.	A prototype was completed that met all the criteria and the constraints of the challenge.	A prototype was completed that met only two of the criteria and constraints of the challenge.	A prototype was completed that met only one of the criteria and constraints of the challenge.	A prototype was completed that did not meet the criteria or the constraints of the challenge.
Our team collected and recorded data to **test and evaluate** solutions of our model.	Data was collected by testing to represent all the criteria and constraints.	Data was collected by testing to represent only two criteria.	Data was collected by testing to represent only one criteria.	No data was collected and/or no testing was completed.
Our team is able to explain our design, gather **feedback**, and explain how we solved the challenge.	Difficult issues were explained and their solutions described.	Difficult issues were explained with no solutions offered.	Difficult issues were unclear and no solutions were presented.	No difficult issue discussion was included.
Our team made **design** improvements after testing the prototype.	All improvements to the prototype were described.	Two improvements to the prototype were described.	One improvement to the prototype was described.	No improvements to the prototype were described.
Our team followed the **presentation process** to communicate our team **design**.	All the video requirements and procedures were met.	Some of the video requirements and procedures were met.	One of the video requirements and procedures was met.	The video requirements and procedures were not met.

Glenn EDCs Student Presentation Template

http://tinyurl.com/Glenn-EDC-Template



Powered and Pumped Up

The Challenge

- The solar cell must be a minimum of 20 cm from the light source.
- The entire system (not including the light source and water) can have a mass of no more than 750 g.
- The pump must move 200 mL of water in as little time as possible.
- The water must move through tubing a minimum horizontal distance of 50 cm.
- Containers must be at the same level.

$$\text{Percent change} = \frac{(\text{current time} - \text{original time})}{\text{original time}} \times 100$$

Identify a Need or Problem

- State the problem in your own words.

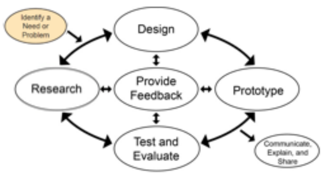
  Example: "How can I design a _________ that will _________?"

- Determine what general scientific concepts you will need to consider before beginning to solve the problem.

- What needs to be solved or improved?

- What are we trying to accomplish?

The Engineering Design Process: Identify a Need or Problem



The Challenge

NASA is currently working on systems to land crewed missions far from Earth (Fig. 46). For these missions to be successful, in situ resources (resources that are already in place) will need to be collected and used wherever possible. By using natural resources that are already at the destination, spacecraft could carry less weight, use less fuel, and be more cost effective.

Since past space missions have sent back data confirming that water is present in Martian soil, NASA plans to send a robotic system to Mars ahead of humans. Astronauts will need enough water for drinking, washing, and growing food to eat for long periods of time. Research is currently being conducted to create a reliable and efficient system to harvest these resources so that they are ready when humans arrive. Such a system could use solar power to collect resources, such as water, from the soil or atmosphere and store them until humans arrive some time later.

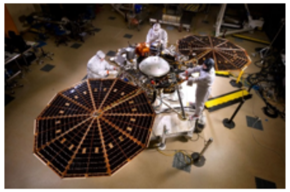


Figure 46.—Technicians work on NASA's InSight lander during a solar array deployment test. The lander will use solar power to operate its science equipment on the surface of Mars. (NASA)

Using the engineering design process, you will develop, build, and improve a stand-alone solar-powered pumping system to move water as quickly as possible from a storage tank to a habitat tank. You will work in a team using materials, shapes, and structures to maximize the collection of simulated solar energy into a solar cell to power the system. The solar cell must be a minimum of 20 cm from the light source. The entire system (not including the light source and the water) can have a mass no more than 750 g. The pump must move 200 mL of water in as little time as possible. Finally, the water must be moved through tubing a minimum horizontal distance of 50 cm.

Based on this information and the challenge's introductory video, answer the following questions.

1. Using your own words, restate the problem in this form: "**How can I design a _________ that will _________?**" Be sure to include all expected criteria and constraints.

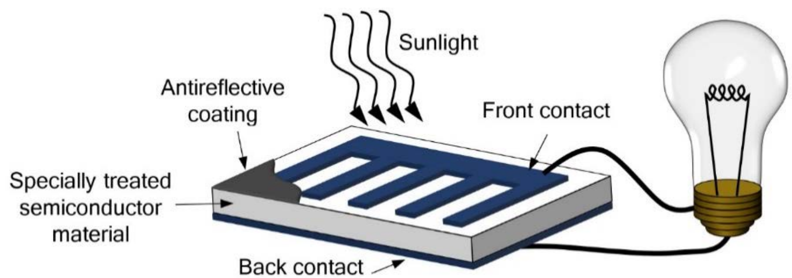
____
____
____

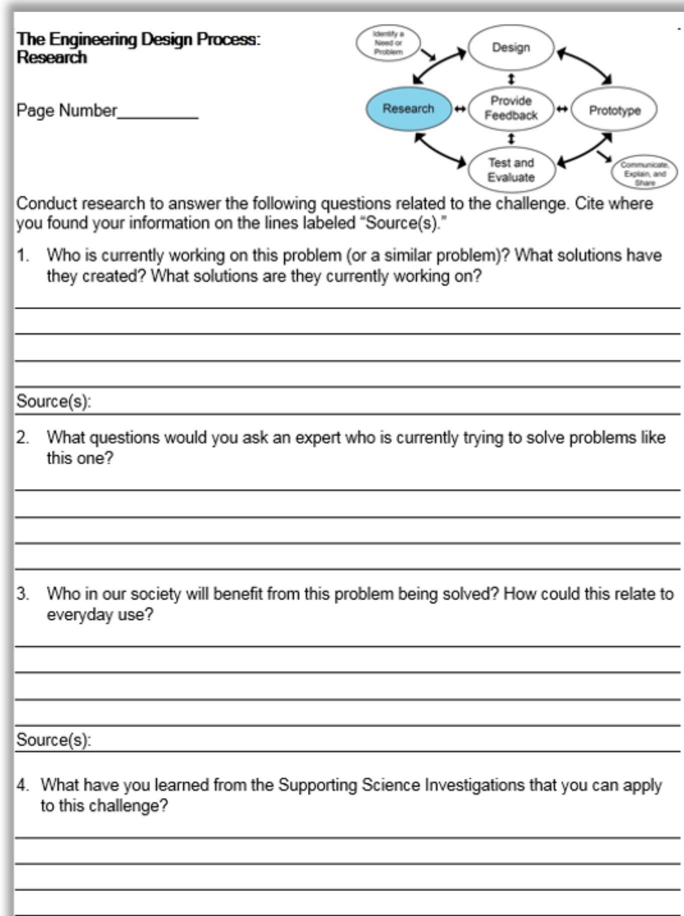
2. What general scientific concepts do you and your team need to consider before you begin solving this need or problem?

____
____

Research

- Examine how this problem is currently being solved or how similar problems are being solved.





The Engineering Design Process: Research

Page Number________

Conduct research to answer the following questions related to the challenge. Cite where you found your information on the lines labeled "Source(s)."

1. Who is currently working on this problem (or a similar problem)? What solutions have they created? What solutions are they currently working on?

Source(s):

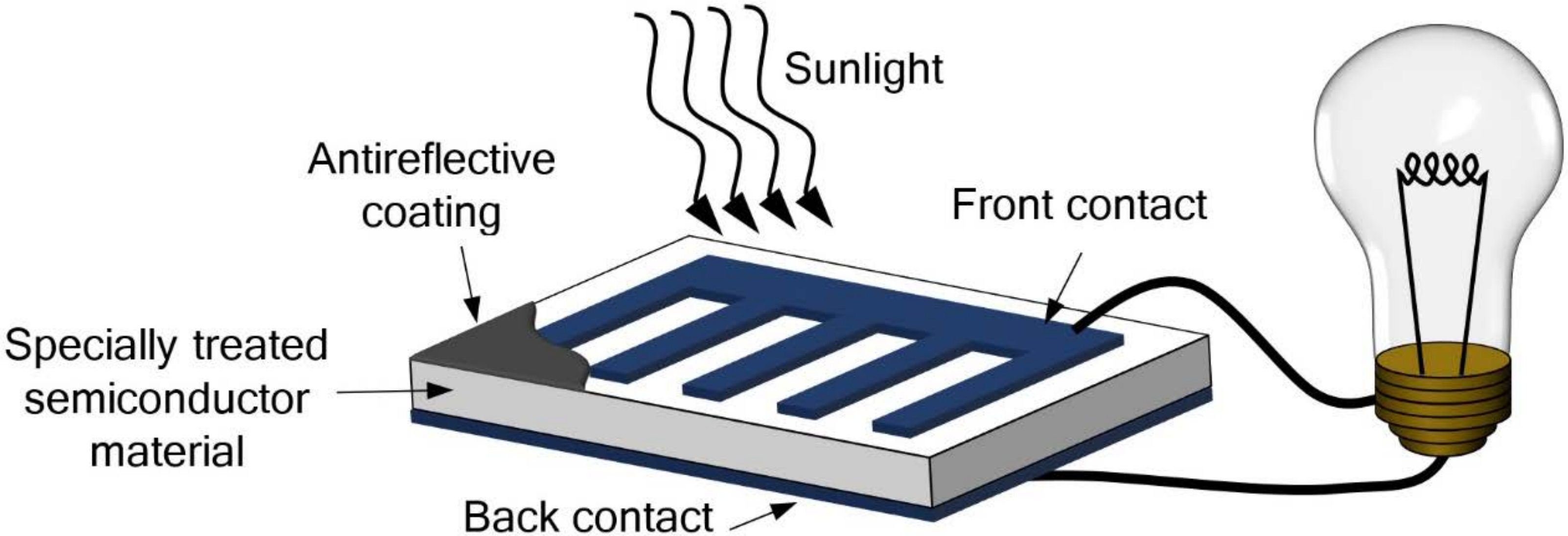
2. What questions would you ask an expert who is currently trying to solve problems like this one?

3. Who in our society will benefit from this problem being solved? How could this relate to everyday use?

Source(s):

4. What have you learned from the Supporting Science Investigations that you can apply to this challenge?

How Does Solar Power Work?



When sunlight hits a solar panel on a house, the energy knocks loose some electrons from the atoms in the material. The electrons flow into the circuits of the house.

Solar Concentrators

These solar concentrators are curved mirrors engineered to reflect sunlight rather than absorb it. They follow the path of the Sun throughout the day, changing position to best capture and utilize the sunlight.

PhotoVolt cells can generate grid-scale solar power at a lower cost per kilowatt-hour than most existing photovoltaic systems.

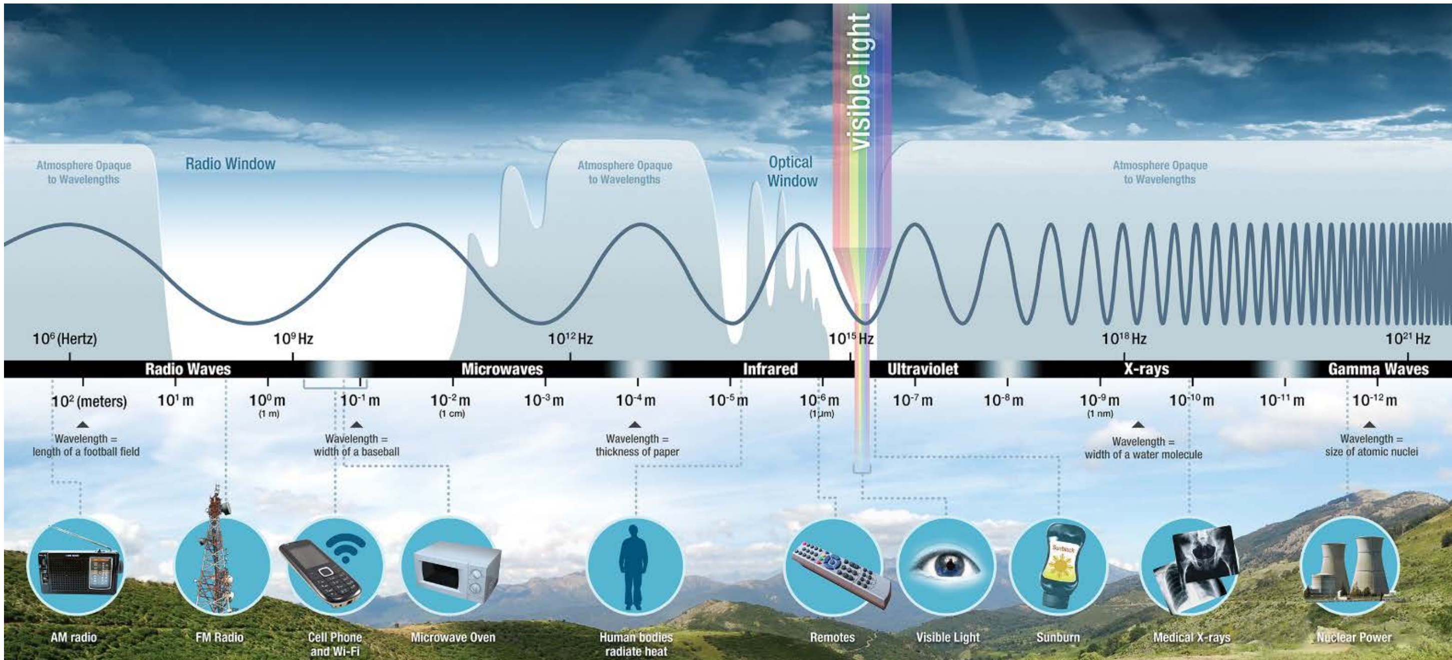
Solar Concentrators

Glenn Research Center's sapphire refractive secondary concentrator will be used with primary collector-concentrators to focus solar energy. The solar energy can be used in power conversion systems, thermal propulsion systems, and solar furnaces.

Mars Exploration Rovers

NASA's Mars Exploration Rovers were designed to take panoramic images of the Martian landscape. Scientist look at those images and select promising geological targets that may reveal the role of water in Mars' past. The rovers are solar powered.

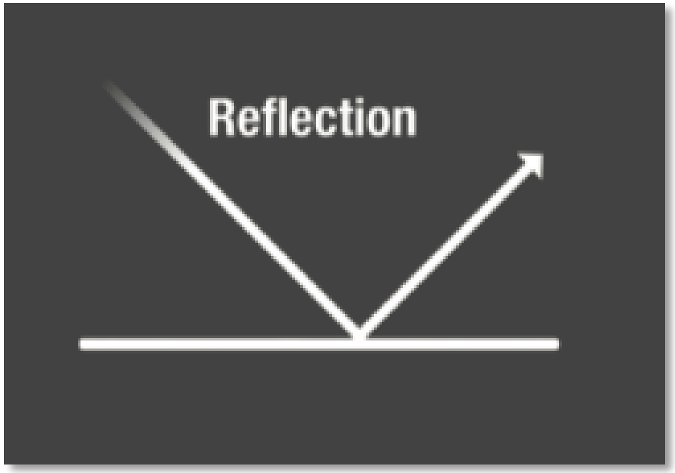
Electromagnetic Radiation and Waves

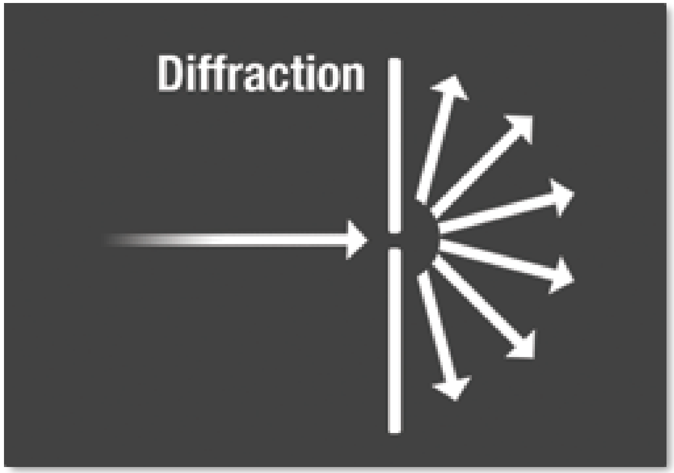


- **Radio waves and microwaves**: Low-frequency waves easily blocked by buildings and other objects
- **Infrared waves**: Invisible to the naked eye, but we feel them in the form of heat
- **Visible light:** Red, orange, yellow, green, blue, indigo, and violet
- **Ultraviolet**: Invisible to the naked eye but potentially harmful to human skin and eyes
- **X-rays:** Visualize bones through skin and muscle
- **Gamma rays:** Used in PET scans and gamma knife surgeries

Investigating Light

Light typically moves in straight lines, although it can behave differently based on the matter it encounters.





Investigating Light

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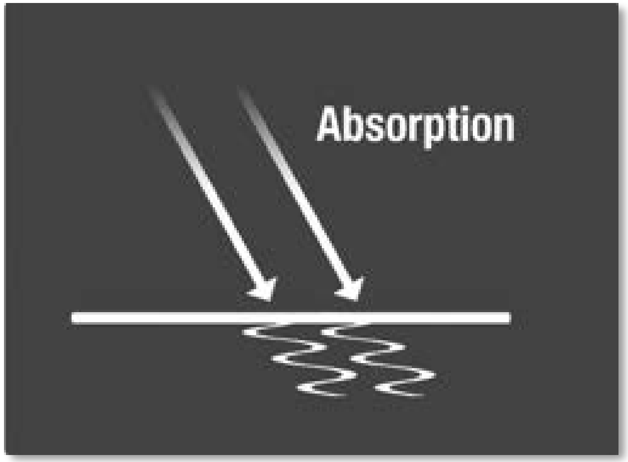

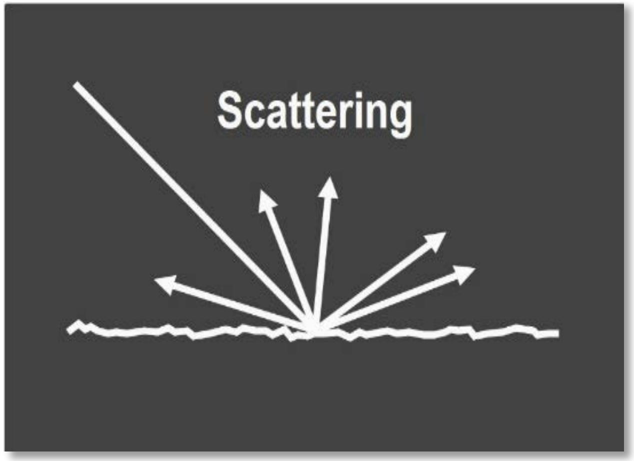

Investigating Light

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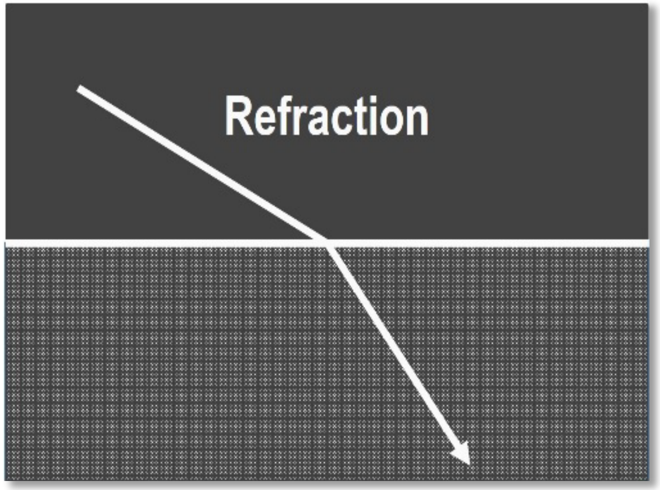
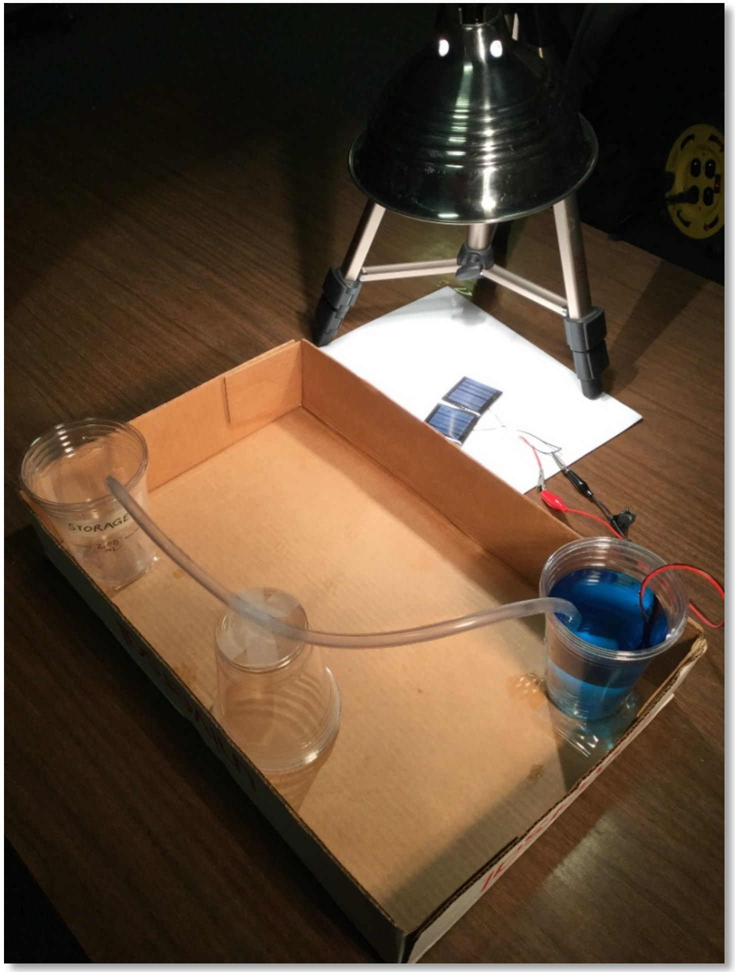


Research



The Engineering Design Process: Research

Page Number__________

Part 2: Research for Solar Cell and Motor

Work with your team to set up the lamp on the work station. The lamp must be 30 cm above the tabletop. Place a blank piece of white paper under the lamp of the challenge setup. Turn the lamp on. Is the light evenly spread across the paper? Describe and/or draw what you see.

Can you predict where the solar cell will receive the most light to power the motor? Put an X at this location on your drawing and label it.

Connect the solar cells to the motor. Connect the red clip to the red wire, making sure the bare wire is completely grabbed by the clip. Do the same for the black wire. Place the solar cells where you think they will receive the most light under the lamp. Turn the lamp on.

What observations can you make? Can you hear the motor running?

While the motor is running:
Have a volunteer from the team touch one of the metal clips attached to the motor the motor. What happens?

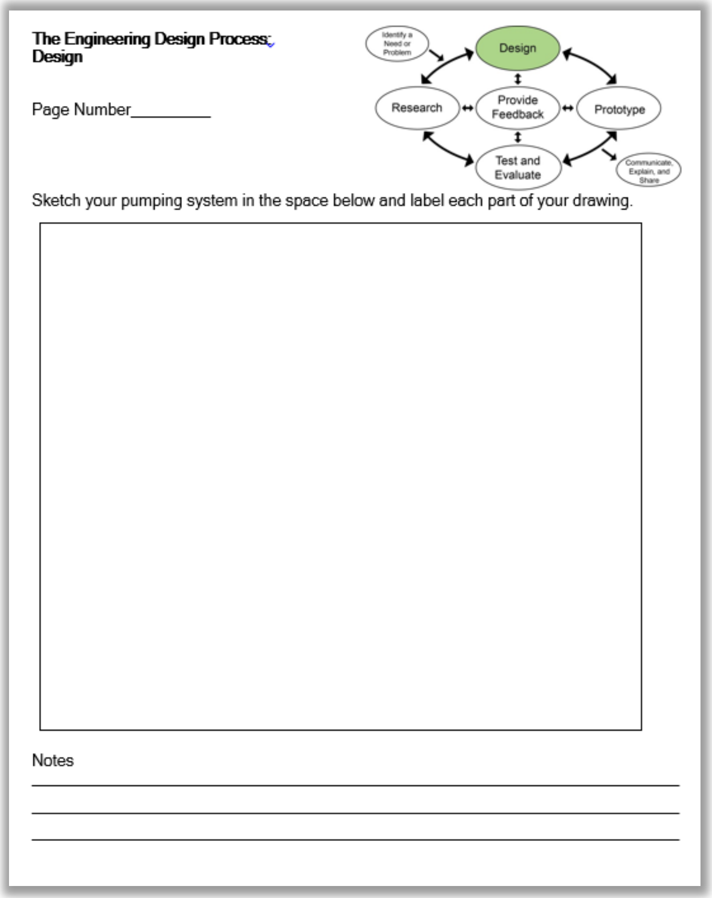
Have a volunteer touch the two clips together, metal to metal. What happens?

Have a volunteer put a hand between the light and the solar cells. What happens? What do you hear?

Have a volunteer pick up the solar cells just enough to place them at an angle to the light. What happens? What do you hear?

Design

- Use your research and scientific knowledge to brainstorm all the possible ways you can think of to improve the solar cell.
- Quickly sketch your design, using labels and arrows to identify parts.


The Engineering Design Process: Design

Page Number________

Sketch your pumping system in the space below and label each part of your drawing.

Notes

Design

- Share your ideas with your team.
- Discuss strengths and weaknesses from each design.
- Which design best solves the challenge? Are there parts from other designs that could improve that idea?

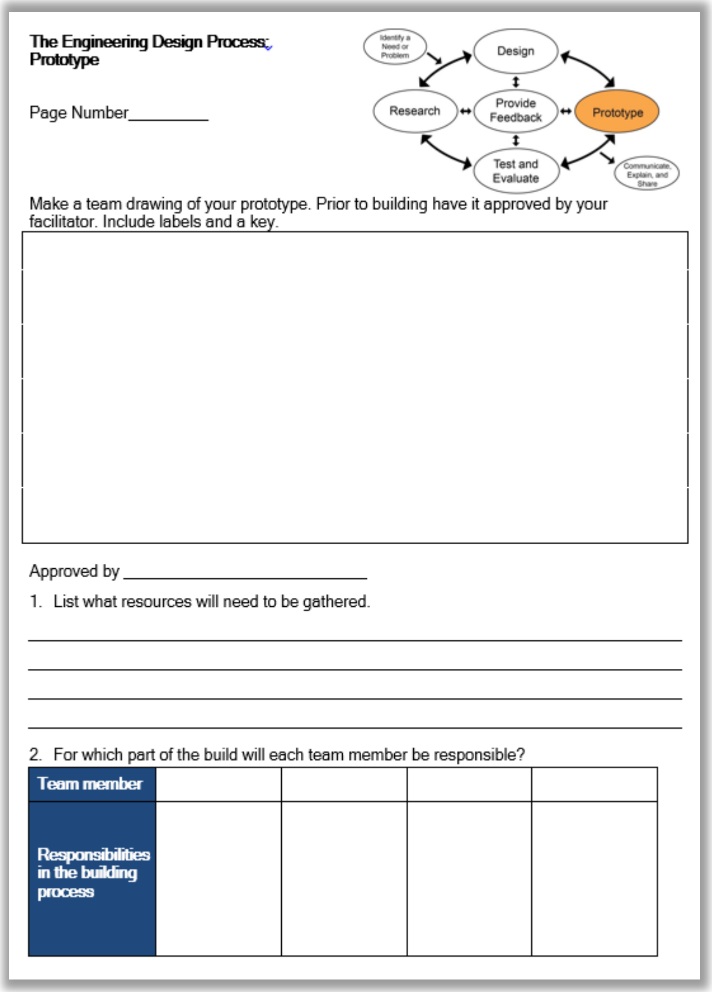
The Engineering Design Process:
Select the Best Possible Solution

Collaborate with your team to analyze each team member's final drawing using the table below. Based on a team discussion, determine which design elements will be used to solve the problem and what features will be included to create the team's prototype. The most promising solution should include elements from more than one design.

Designer Name	Does this design meet all problem criteria and constraints?	What are the strongest elements of this design?	What elements need to be improved?
1			
2			
3			
4			

Prototype

- Construct a model of the selected solution.
- What materials will be needed for each part of the assembly?
- Who will build each part?



The Engineering Design Process: Prototype

Identify a Need or Problem → Design → Prototype → Communicate, Explain, and Share; Research; Provide Feedback; Test and Evaluate

Page Number________

Make a team drawing of your prototype. Prior to building have it approved by your facilitator. Include labels and a key.

Approved by ____________________________

1. List what resources will need to be gathered.

2. For which part of the build will each team member be responsible?

Team member				
Responsibilities in the building process				

Safety Considerations

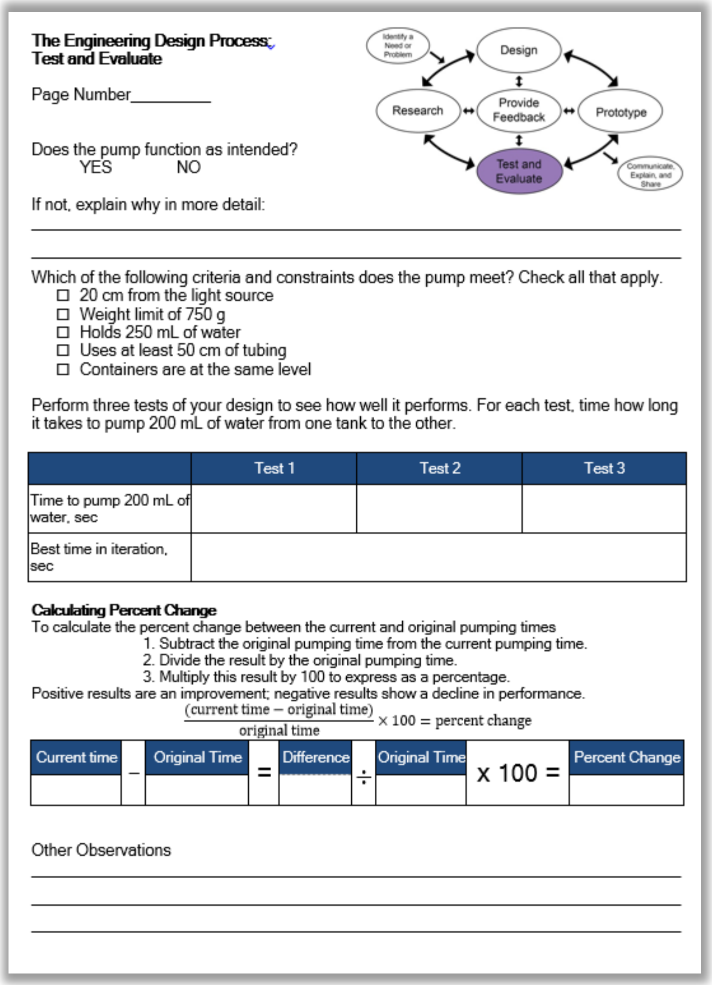
Safety is Priority #1.

- Make sure students understand the safety precautions necessary for all activities.
  - Light bulbs can be **very** hot to the touch. Avoid coming in contact with all light bulbs.
  - Use care when working with water around electricity. Clean up any spills immediately. Keep electrical wires away from water.
- Designs should be approved by a facilitator to prevent sharp or dangerous models.

A NASA researcher wearing personal protective equipment (PPE) appropriate for his work in this lab at Kennedy Space Center. PPE should be selected to match the potential risks of the work to be done.

Test and Evaluate

- Test your team's model.
  - Weigh your device prior to testing.
  - Test three times and record data.
  - Make modifications and test again.
  - Calculate percent change.
- Did the performance improve?



The Engineering Design Process: Test and Evaluate

Page Number_________

Does the pump function as intended?
YES NO

If not, explain why in more detail:

____

____

Which of the following criteria and constraints does the pump meet? Check all that apply.

- ☐ 20 cm from the light source
- ☐ Weight limit of 750 g
- ☐ Holds 250 mL of water
- ☐ Uses at least 50 cm of tubing
- ☐ Containers are at the same level

Perform three tests of your design to see how well it performs. For each test, time how long it takes to pump 200 mL of water from one tank to the other.

	Test 1	Test 2	Test 3
Time to pump 200 mL of water, sec			
Best time in iteration, sec			

Calculating Percent Change

To calculate the percent change between the current and original pumping times

1. Subtract the original pumping time from the current pumping time.
2. Divide the result by the original pumping time.
3. Multiply this result by 100 to express as a percentage.

Positive results are an improvement; negative results show a decline in performance.

$$\frac{(\text{current time} - \text{original time})}{\text{original time}} \times 100 = \text{percent change}$$

Current time	–	Original Time	=	Difference	÷	Original Time	x 100 =	Percent Change

Other Observations

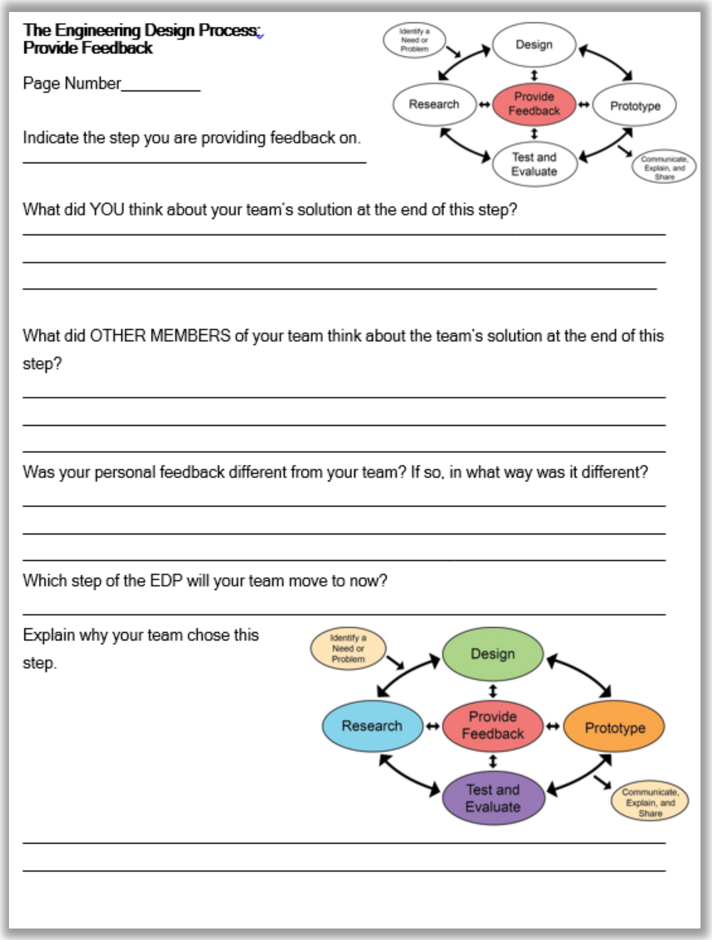
____

____

____

Provide Feedback

- Use this sheet to collaborate with your team as you progress through the challenge.
  - What worked?
  - What needs improvement?



The Engineering Design Process: Provide Feedback

Page Number________

Indicate the step you are providing feedback on.

____

What did YOU think about your team's solution at the end of this step?

____

What did OTHER MEMBERS of your team think about the team's solution at the end of this step?

____

Was your personal feedback different from your team? If so, in what way was it different?

____

Which step of the EDP will your team move to now?

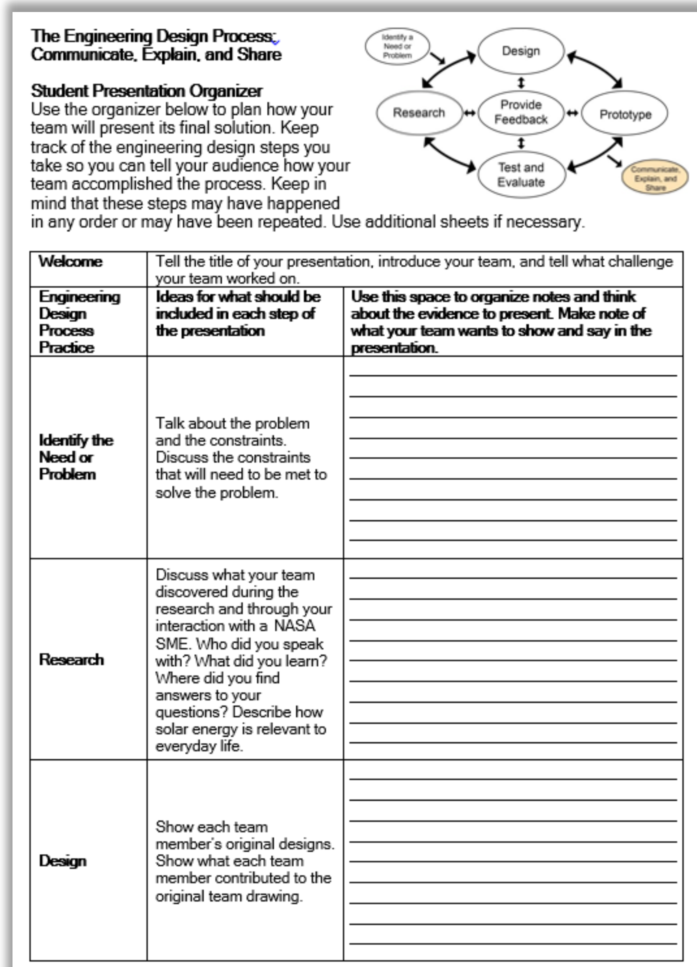
____

Explain why your team chose this step.

____

Communicate, Explain, and Share

- Record and share what your team learned about your design based on testing.
  - What worked?
  - What needs improvement?
- Talk with other teams to get ideas.



The Engineering Design Process: Communicate, Explain, and Share

Student Presentation Organizer

Use the organizer below to plan how your team will present its final solution. Keep track of the engineering design steps you take so you can tell your audience how your team accomplished the process. Keep in mind that these steps may have happened in any order or may have been repeated. Use additional sheets if necessary.

Welcome	Tell the title of your presentation, introduce your team, and tell what challenge your team worked on.	
Engineering Design Process Practice	**Ideas for what should be included in each step of the presentation**	**Use this space to organize notes and think about the evidence to present. Make note of what your team wants to show and say in the presentation.**
Identify the Need or Problem	Talk about the problem and the constraints. Discuss the constraints that will need to be met to solve the problem.	
Research	Discuss what your team discovered during the research and through your interaction with a NASA SME. Who did you speak with? What did you learn? Where did you find answers to your questions? Describe how solar energy is relevant to everyday life.	
Design	Show each team member's original designs. Show what each team member contributed to the original team drawing.	

Communicate, Explain, and Share

- Record and share what your team learned about your design based on testing.
  - What worked?
  - What needs improvement?
- Talk with other teams to get ideas.

Prototype	Show materials used and how you put the prototype together.	
Test and Evaluate	Talk about how your team tested the design and discuss the results. Using the data, discuss the strengths and weaknesses of your team prototype.	Summary Data Sheet (see below)
Provide Feedback	Describe how your team members communicated with each other to improve the solution. Also describe how you discussed options with people outside your group.	
Communicate, Explain, and Share	Talk about your data. Was your team able to solve the problem or not? What improvements did your team make to reach your final solution? Discuss any further action your team would take to improve this solution.	

Summary Data Sheet

Iteration #	Best Time	Percent Change
Original Test		
1		
2		
3		
4		

Debriefing Questions

1. Why did your team use this approach to solve the problem?
2. How did your research help you decide that this was the best solution?
3. What changes did you make to your design during your iterations of redesign?
4. How could you further improve on your design?
5. What were the greatest challenges for your team throughout this process?

Debriefing Questions

6. What strategies did your team use that proved effective in overcoming challenges?
7. How did you use the EDP to help with your design?
8. What concerns must be considered in constructing a quality pumping system?
9. What specific problems did you need to address in designing the pumping system?
10. If you were an astronaut heading to Mars, would you trust your team's pumping system during an extended stay on the planet? Why or why not?