

Clark Public Utilities

Solar Car Challenge

Activity and Judging Guides



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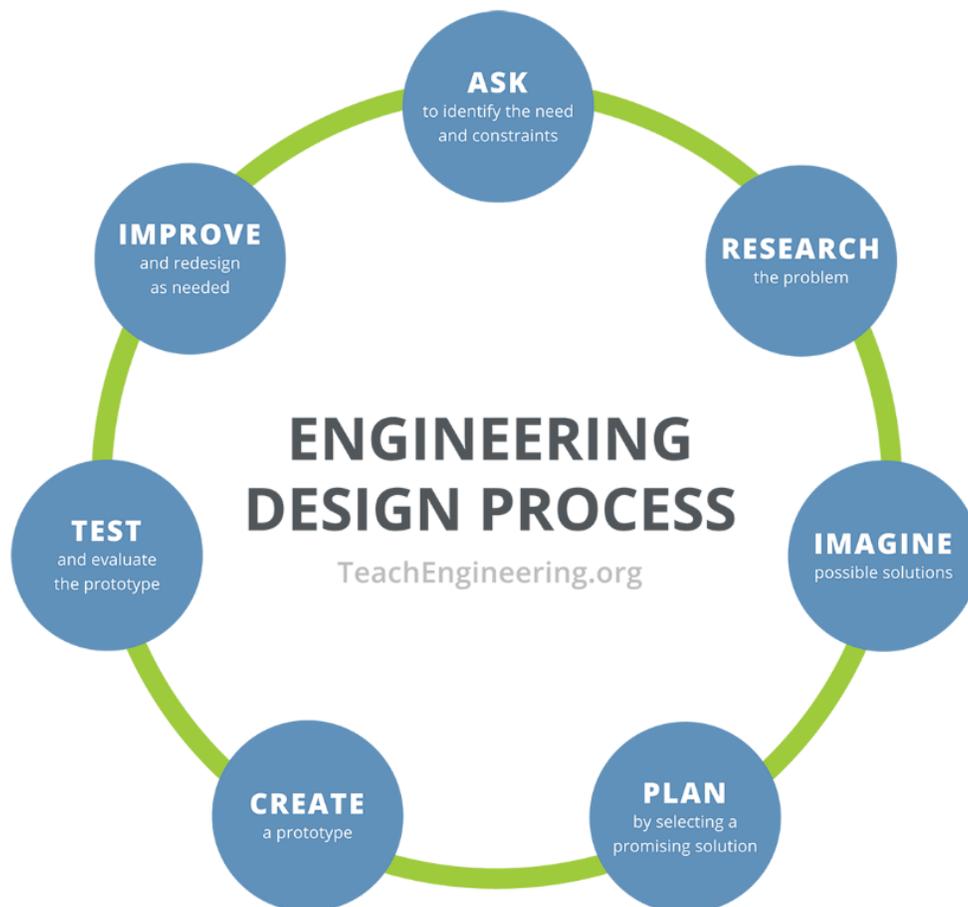
Teacher Guide

Overview

Welcome to the Clark Public Utilities Solar Car Challenge and thank you for taking the driver's seat with your students! This challenge is funded by Clark Public Utilities.

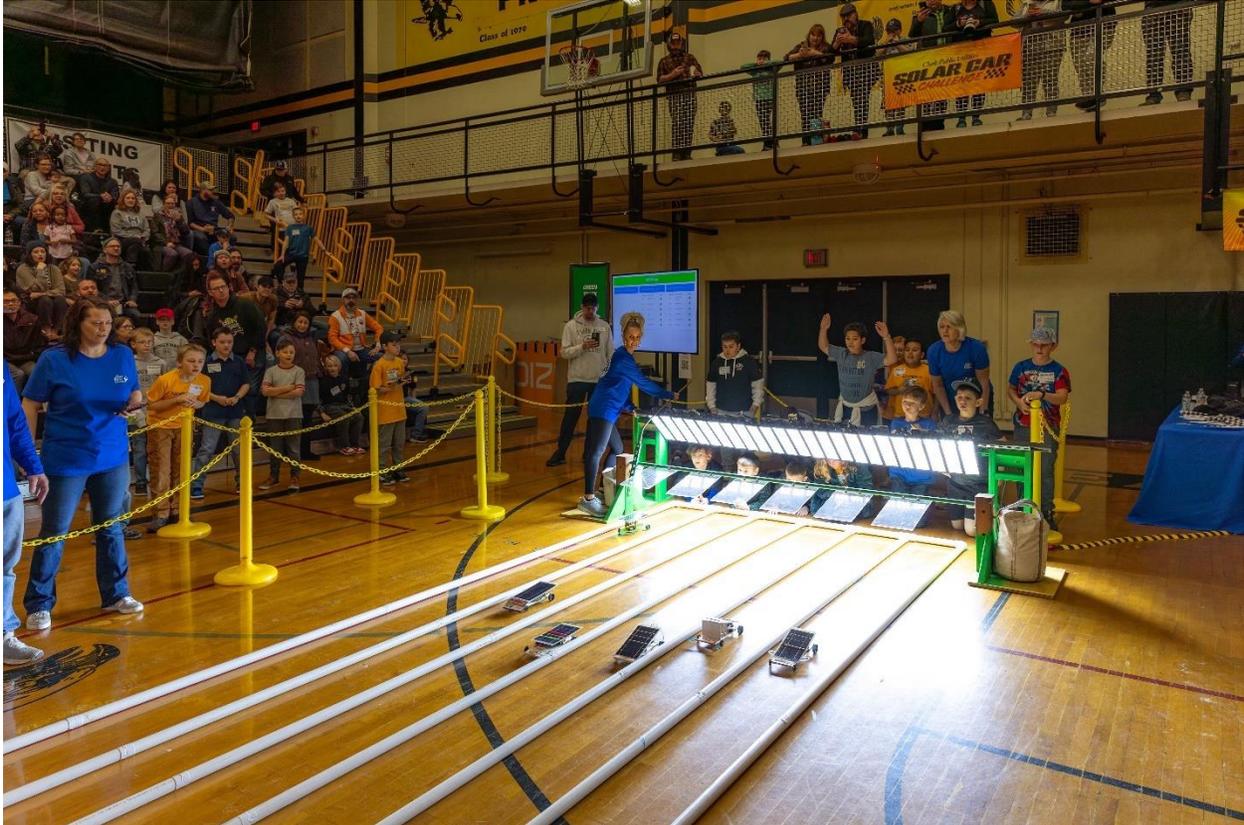
The classroom activities included in this curriculum are designed to facilitate Solar Car Challenge preparation and align with the engineering notebooks that teams produce and submit as part of the competition. Each activity has a simple lesson progression aligned with the materials provided and solar car kits.

Though the lessons are primarily geared towards elementary school students, the provided lessons and supplementary materials can be used as appropriate with your students at any grade level. Modules can be scaled up or down depending on class level and needs, and each activity is intended to align with NGSS Performance Expectations, grouped according to the Engineering Design Process model below.



Teach Engineering: <https://www.teachengineering.org/populartopics/designprocess>

The Clark Public Utilities Solar Car Challenge is based on other successful engineering challenges around the region. Here in Clark County, Washington the challenge has been modified to include “boost” lighting at the beginning of the race and batteries for supplemental power in cars to accommodate an indoor race format. This allows students to focus on the engineering process and increases the likelihood that cars will work on race day.



The Clark Public Utilities Solar Car Challenge will be held indoors at Hudson’s Bay High School on a Saturday in March each year. Dates will be announced on the PowerZone website in the Educator Resources Section.

Solar Car Challenge Scoring Breakdown

To emphasize the importance of the engineering design process as well as the races, the race day scoring has been designed to reflect the entire process of the Solar Car Challenge, from start to finish. This scoring will be explained in more detail on page 38.

Total Challenge Points	% Score
Race Trials (Team Heat Races, modified double elimination)	45%
Documentation of Engineering and Design Process (notebook and presentation)	30%
Team Interview	25%

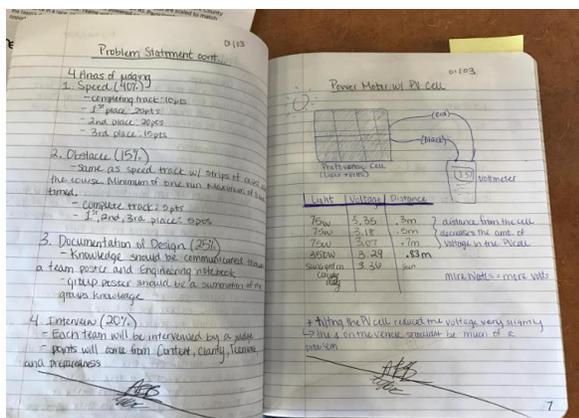
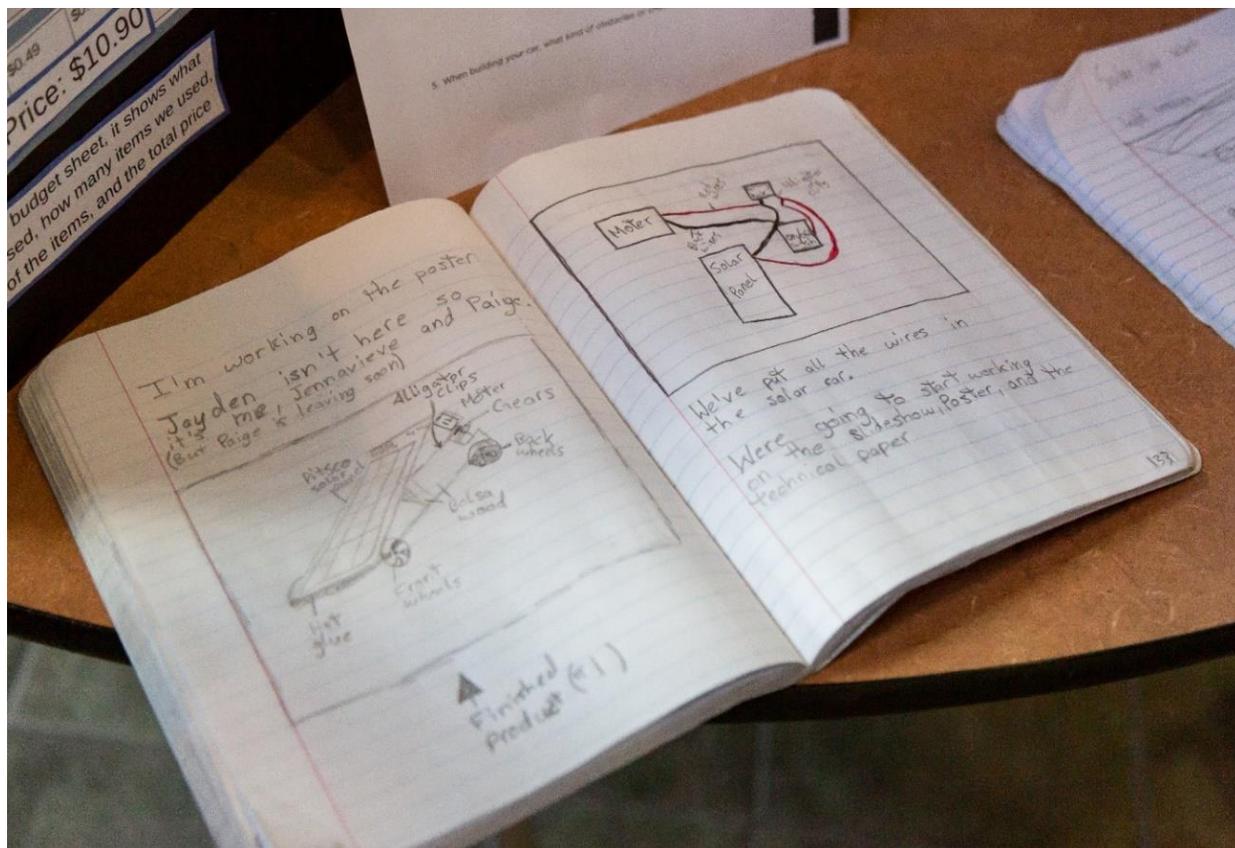
Best Practices for Engineering Notebooks

Students are required to submit individual "Engineering Notebooks," preferably a college-ruled composition book, to track their solar car project progress. This notebook serves as a personal development record, not just an academic tool, and should reflect their progress throughout the car design process. This isn't meant to be a traditional assignment that would be graded but can be used by teachers to formatively assess student progress. Success in the challenge also depends on maintaining good records, teamwork, and communication—skills essential for real-world engineering. Engineering notebooks and team interviews will make up 55% of a team's overall score.

Best practices for a well-organized engineering notebook:

- Date all entries
- Create new sections on the page if changing thought processes or working on a different piece of the design process.
- Keep entries clean and legible to help keep thoughts coherent.
- Mistakes happen and are important to the engineering process! Avoid erasing or making changes to previous thought processes. If students need to make changes, encourage them to add notes or explain how their previous ideas weren't correct.
- Color or writing style can highlight specific components of student's work that they want to emphasize. This works for dates, "a-ha!" moments, or specific things you want the judges to notice.

- Text, pictures, tables, and numerical data are all important and should be well balanced throughout the notebook. They can help to explain ideas in multiple ways.
- Make it yours! We want students to show their personality through their notebooks, as it reflects their understanding of the engineering design process.
- If students make an electronic notebook, please have them bring along a printed version to the event.



Examples of organized engineering notebooks

Engineering Challenge Specs (Materials Summary)

Track Notes

- Surface: Gym Floor
- Each Lane, bounded by ½” PVC pipe, is 12” wide
- 20 feet long

Lighting Notes

- The light reaches only the first 24 inches of track
- 23 72watt LEDs producing 330,000 lumens, 1,428 watts, placed at 45-degree angles
- 200-300W of irradiance at floor level

Car Requirement Summary

- 1 DC motor
- 1 Photo Voltaic module (2.76 V)
- 1 Switch (any type, team must create/provide)
- 2 AA batteries
- 1AA battery holder
- 1 LED (Middle School only)
- More details in Judging guide for each specific item

Team Kit Contents (Elementary School)

- 1 Photo Voltaic Module (Pitsco Ray Catcher Solar Module, 2.76 V, 1A)
- 1 small DC Motor (Pitsco Motor 280)
- 1 2-AA battery holder
- 2 rechargeable AA batteries
- 2 metal axles
- 4 rubber bands (2 thick, 2 thin)
- 8 gears (2mm hole)
- 8 gears (1/8” hole)
- 4 nylon spacers
- 4 wheels (2 large, 2 small)
- 2 balsa wood sheets
- 1 solar panel blank (cardstock)
- 12 pack mini alligator clip leads

- 2 small metal alligator clips
- 2 screw eyes

Team Kit Contents (Middle School)

- 1 Photo Voltaic Module (Pitsco Ray Catcher Solar Module, 2.76V, 1A)
- 1 small DC motor (Pitsco Motor 280)
- 1 2-AA battery holder
- 2 rechargeable AA batteries
- 2 metal axles
- 4 rubber bands (2 thick, 2 thin)
- 8 gears (2mm hole)
- 8 gears (1/8” hole)
- 4 nylon spacers
- 4 wheels (2 large, 2 small)
- 2 balsa wood sheets
- 1 solar panel blank (cardstock)
- 12 pack mini alligator clip leads
- 2 small metal alligator clips
- 2 screw eyes
- 3 red LEDs (specific to MS)

Suggested Tools and other Supplies

These items are not included in the kits but may be necessary to construct solar cars

- Glue gun and hot glue
- Hobby knife to cut balsa wood
- Sandpaper
- Needle Nosed pliers
- Rulers
- Clamps
- Soldering Iron and solder
- Material from which to construct a switch mechanism

Additional materials to add an original touch to cars for aesthetics or performance (in accordance with rules laid out in the Judging guide)

Supplemental Content Background

The resources below can supplement the lesson materials provided if you're interested in expanding the content

- Junior Solar Sprint's ["An Introduction to Building a Solar Car"](#)
- CE's Educator Library Activities:
 - ["Understanding Science and Engineering Through Solar Power"](#) by Mike Hellis (ES/MS)
 - Includes ["A Simple Circuit"](#) (ES)
 - ["How do Solar Panels Work?"](#) By Carol Patrick (ES)
 - ["Introduction to Energy"](#) by Craig Marais (MS)
 - ["Introduction to Circuits"](#) by Craig Marais (MS)
- [Solar Car Build Tutorial](#)
- Pitsco Education Resources (Solar Car Vendor) **
 - [Build a Solar Car Instruction Sheet](#) **
 - Video: [Building the Ray Catcher Solar Car](#)

** A note on the Pitsco Teacher's Guide: This is the official manual for building a successful solar car. We want you to use this so you're comfortable building a solar car and helping your students build a successful chassis. After the building of the chassis, the intention is to let the students practice the engineering and design process and find their own way through iterations of design improvement. More on this during topic 3 when we suggest starting the car build.

Support for Team Coaches (Teachers)

Please reach out to Amber Hall at Clark Public Utilities for support throughout the process:

Amber Hall

Education Engagement Specialist at Clark Public Utilities

- 360-992-3550
- ahall@clarkpud.com

One Tech Support Clinic will be held leading up to the Solar Car Challenge to provide guidance and hands-on expertise to support coaches and teams. The clinic will be held on a Saturday in February from 8am- Noon. The dates will be announced at the coach's clinic and on the PowerZone website, in the Educator Resources section. The clinic will be held at Clark Public Utilities: 1200 Fort Vancouver Way.

Activity Guide Overview

The following Coaches Activity and Judging Guide includes a suggested format for educators who might be new to the program and looking for instructional guidance. All activities and topic schedules are optional and are collected from recommendations by previous Solar Car Coaches, CE. Clean Energy. Bright Futures, and Clark Public Utilities. Please let us know if you have suggestions or lesson improvements that have worked for you and your students!

- **Topic 1: Challenge Introduction**
 - Setting up an Engineering notebook
 - Engineering Design Process
 - What is Solar Energy?

- **Topic 2: Review of Electricity Basics and Circuits**
 - What is Electricity?
 - Conductors and Insulators
 - Circuits
 - Series, parallel, and short circuits

- **Topic 3: Introduction to Solar Cars and Vehicle Mechanics**
 - Car parts and vocab
 - Car build begins
 - Wheels, Alignment, and Gear Ratios

- **Topic 4: Testing and Improvements**
 - Prototype testing and redesign

- **Topic 5: Presentations, Interviews, and Challenge Preparation**
 - Creating a presentation (Tri-Fold Poster, Google Slides, etc.)
 - Interview Prep
 - What to expect on race day!

Topic 1: Challenge Introduction

Objectives:

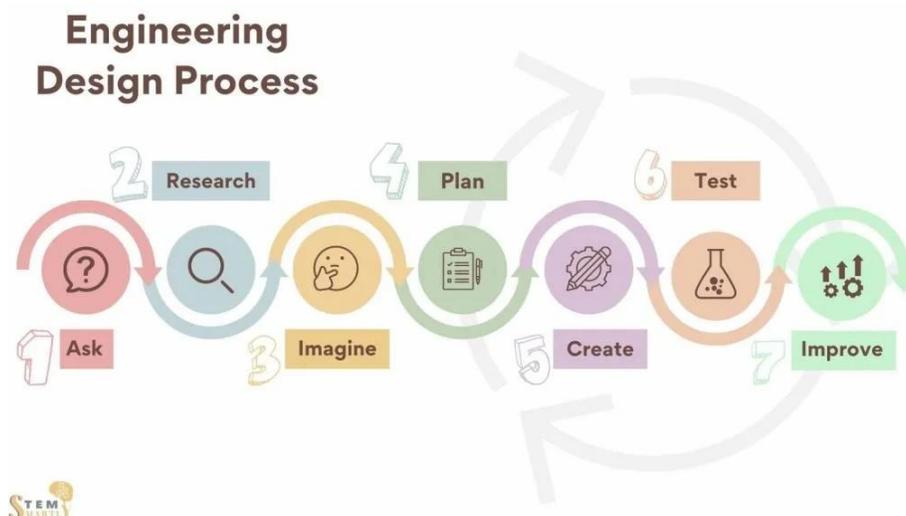
- Students will be introduced to the format of the Solar Car Challenge and practice setting up their engineering design notebook.
- Students will be able to describe the pros and cons of solar energy and how it's harnessed for electricity.

Materials Needed:

- Engineering design notebooks (preferably college ruled)
- Screen/Projector to introduce Solar Energy videos

Introduction:

- By participating in Clark Public Utilities' Solar Car Challenge, you and your team will get the chance to practice engineering skills and build your own solar car, which you will race against other students from Clark County!
- Introduce the engineering design process, engineering notebooks, and the importance of clear communication and data collection.
 - The engineering design process is meant to foster teamwork, imagination, and design to solve problems! That means we repeat the steps of the process and make improvements as we go to create the best version of the solar car that we can. Learning from mistakes is an important part of the design process.



Engineering Design Process: [Stem Smartly](#)

- Potential group brainstorm questions: Why is it important for engineers to improve on their ideas? What important information do engineers need to record? What might happen if engineers don't take good notes? What are you curious about the Solar Car Challenge? How can we learn from mistakes?

Solar Energy:

- Class Brainstorm- What is energy?
 - *Energy is the ability to do work.* There are multiple forms of energy, such as heat, light, motion, electrical, chemical, nuclear, and gravitational.
 - The biggest source of energy on earth is from the sun. The sun either directly or indirectly, through processes like photosynthesis, wind, and ocean currents, creates most of our energy resources on earth.
 - [Video: What is Solar Energy- SciToons](#)
- How do we harness solar energy?
 - Heat: we can use thermal energy from the sun to warm pools, homes, and buildings. Greenhouses are a great example of this!
 - Photovoltaic (PV) devices! Solar cells turn the energy from the sun's light into electricity.
 - [Optional Video: How do Solar Cells Work? - SciToons](#) (higher level ES/MS)
 - What are some of the strengths of solar power?
 - It's a renewable resource! No greenhouse gases are produced.
 - PV solar systems on buildings have minimal impacts on the environment.
 - Adding solar power to your house could reduce your electric bill.
 - What are some limitations of solar power?
 - Sunlight varies depending on the season, weather, time of day/year.
 - Large surface areas are needed to collect a useful amount of energy.

- Solar technology can be expensive.
- Space requirements for solar panels.
- Solar Vehicles: run exclusively on solar power!
 - [Solar-Powered cars race through Australian Outback-Reuters](#)

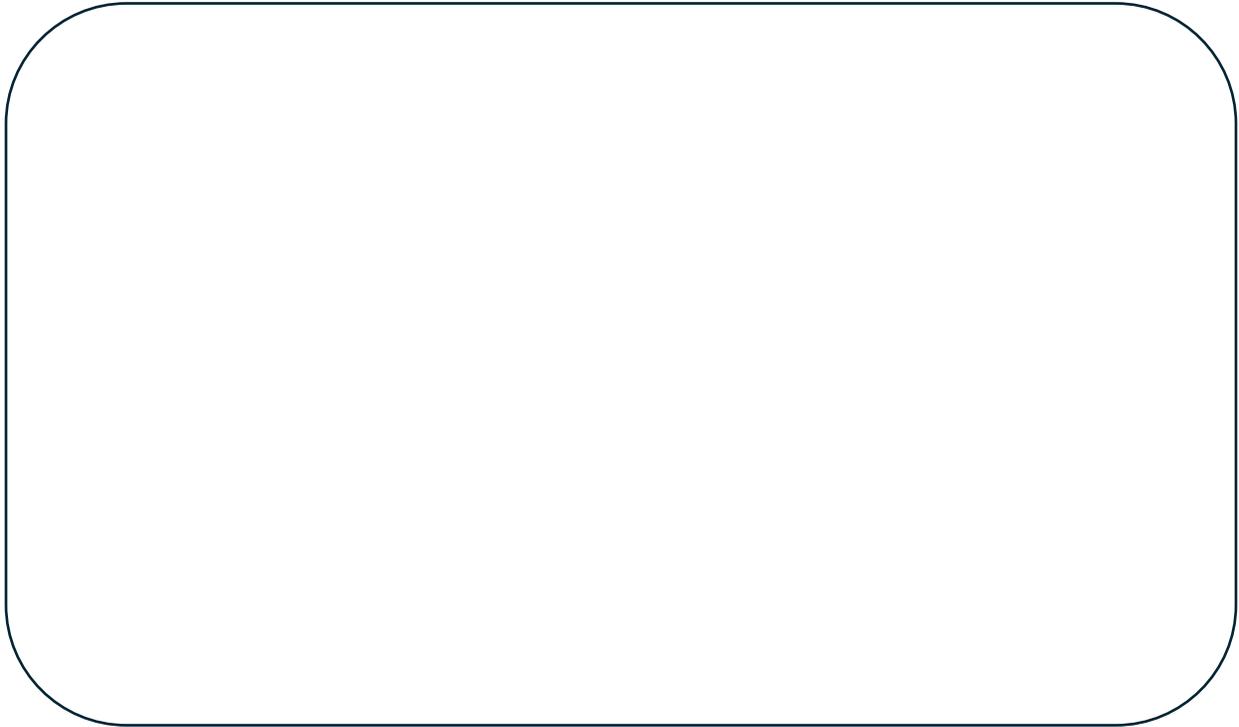
Let's think like Engineers!

- This is a great activity to start with in students' engineering notebooks!

Think Box #1: List 3 challenges you would expect in the design of a solar powered vehicle (car, plane, boat etc.), and how you think these challenges were overcome:

Challenges	Design Solutions

Design Box #1: Sketch up your very own solar vehicle! Use your imagination and be sure to label your drawing. How will your vehicle catch the most amount of the sun's rays?



Wrap Up Questions:

- Recap what students learned about solar power. What are its strengths and weaknesses?
- What are you excited to try on your solar vehicle?
- Challenge students to notice examples of solar power on their drives around their neighborhoods or riding the school bus. Where do you notice solar technology in your life?

Additional Resources:

- [Clark Public Utilities PowerZone-Solar Energy](#)
- [Britannica Solar Energy](#)
- [U.S. Energy Information: Energy Kids Website](#)
- [How Does Solar Energy Work: Octopus Energy \(Video\)](#)

Topic 2: Review of Electricity Basics and Circuits

Objectives:

- Students will understand that electricity is the flow of electrons and be able to explain the difference between static and current electricity.
- They will be able to explain the difference between a conductor and an insulator.
- They will understand simple circuits (in series and in parallel) and what causes a circuit to short.

Materials Needed:

- Engineering Notebooks
- Screen/Projector to introduce videos (optional)
- Circuit Creation Options
 - Simple Circuits: lightbulbs, battery, wires, tape (optional)
 - Snap Circuit Kit (optional alternative if your school has kits purchased)
 - Supplemental activity “Watts my name” on page 49.

Introduction:

- Discussion: ask students to explain what they think electricity is. Where do you use it in everyday life? What would life be like without it?
- Show a picture or a diagram of an atom (this is a Bohr model! Figure 1). Atoms are super small particles that make up everything in our universe. Atoms have 3 components. The center, or nucleus, is made up of protons (which have a positive charge) and neutrons (with a neutral or 0 charge). Flying around the outside, sort of like a solar system model, are the electrons (which have a negative charge).

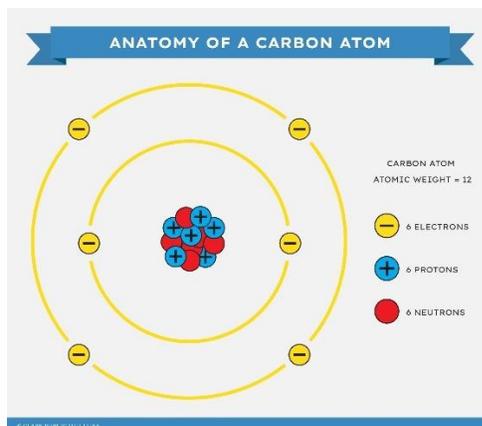
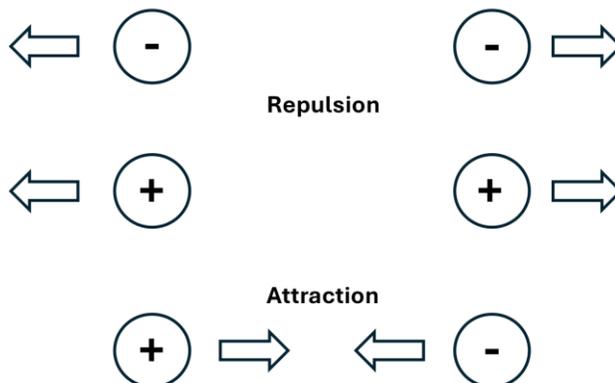


Figure 1: Bohr model of a carbon atom. Yellow electrons spin in set paths around the nucleus, which is made of protons and neutrons.

- Similarly to magnets, particles of the same charge don't like to be around each other, and they will repel each other. The flow of a charged particle is what electricity is!



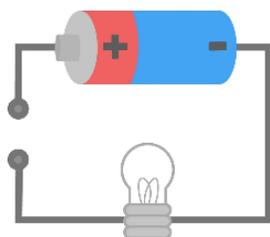
- Some atoms readily share their electrons. That means these materials allow electrons to flow easily. These materials are called **conductors** because they allow electrons to flow easily and move from atom to atom through a material. Metals such as aluminum, copper, silver, and bronze are good electrical conductors.
- Other materials hold on to their electrons tightly and don't allow them to move to other atoms. These materials are called **insulators**, as they don't allow electrons to pass through easily. Rubber, plastic, glass, and ceramic are examples of good insulators.
 - Optional Conductor/Insulator Activity:
 - Have the students draw this table in their notebooks and see how well they predict the conductivity of various items.

Item	Prediction (Conductor/Insulator)	Answer
Eraser		Insulator
Paper Clip		Conductor
Pencil		Conductor
Chalk		Insulator
Plastic		Insulator
Penny		Conductor
Acorn		Insulator
Glass		Insulator

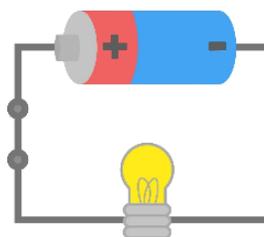
- There are 2 types of electricity, which both depend on the movement of electrons:
 - **Static Electricity:**
 - Where have you experienced static before? (slides, trampolines, walking across a carpet, rubbing a balloon on your hair, lightning!)
 - Static electricity is the buildup of electrons and there is an imbalance of negative and positive charges. It is not consistent enough to be used to charge appliances, as it's short-lasting.
 - **Current Electricity:**
 - Current is the *flow* of charged particles through a material. When electrons move quickly from atom to atom they create current electricity, like a flowing river has current. Conductive materials, like metals, are like highways for charged particles to travel.
 - When we interrupt the flow of charged particles with a light bulb, for example, that's when the electrons power the light bulb and we have light!

Circuits

- Our electric devices all have circuits in them so electrons can power them up so we can use them!
- Current electricity flows from the negative (-) side to the positive (+) side of a battery, as opposite charges attract and the negative particles want to travel to the positive side.
 - **Circuits** are circular paths that electrons travel.
 - If the pathway is incomplete, the electrons won't flow (open circuit)
 - If the pathway is complete, electrons will flow (closed circuit).



Open Circuit



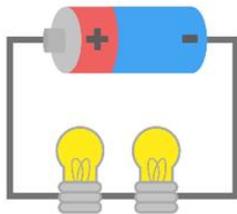
Closed Circuit

- All Circuits need:
 - Battery- the force that moves the electrons along the path.

- Path: conductors, like metal wires, make great pathways for the electrons to move on.
- Switch: determines if the path is open or closed.
- Light bulb: or another electronic device to turn on! In the case of our solar cars, this will also include a motor.
- Supplemental Video: [The Power of Circuits! SciShow Kids](#)

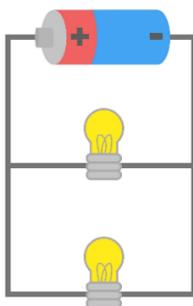
Build a Simple Circuit (also compatible with Snap Circuit Kits):

- Instruct students to draw a circuit in their engineering notebook and then work together to make their drawing a reality with the materials provided. (Circuit options included below with differing levels of cost.)
 - Traditional Wire Circuit: wire or alligator clips, battery holder, batteries, switch, 1.5-volt lightbulb, lightbulb holder (optional)
 - SnapCircuit Kit: [Link to Purchase](#)
 - Supplemental activity “Watts my name” on page 49.
- Walk around as students work and support.
 - Discussion or prompting questions:
 - What happens if you only use 1 battery? No batteries?
 - Why does the lightbulb turn on when the circuit is complete?
 - What happens if we break the circuit? Or remove a wire?
 - What flows around the circuit?
 - What pushes the electrons around the circuit?
 - How could we make the lightbulb shine brighter?
- **Series Circuit:**
 - Have the students add a second light bulb to their circuits. This would be a Series Circuit. Circuits with one pathway are called series circuits.
 - Discussion question: what would happen if the first lightbulb broke? Would the other one light up?
 - What are some weaknesses of series circuits?



Series Circuit

- **Parallel Circuits:** in contrast, parallel circuits have more than one pathway for the electrons (current) to travel. If one light bulb burns out, the second can still work because the electrons can flow through the second path instead.
 - Task your students with making a parallel circuit out of the provided materials. Test your circuit by removing one of the lightbulbs and seeing if the other still lights up.



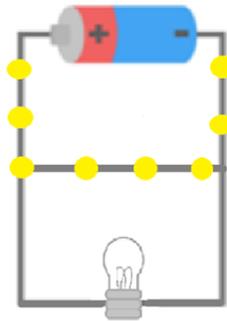
Parallel Circuit

- Supplementary Video: [Parallel and Series Circuits](#)

Short Circuits:

- Electrons can be a bit lazy, and when given the chance to take the shortest route they will! When working with circuits, we call this a short circuit- which is when the electrons skip the load (or lightbulb/electronic device we want to charge up) and return straight to the other terminal of the battery.
- This can happen when wires are incorrectly connected, or frayed, which can result in burning out the batteries or heating up.
 - Discussion: what do you think a short circuit can result in, in real life? (Damage, fires, sparks, ruined electronics).

- This is why we want to remove the batteries from our solar cars when we're not actively working on them. We don't want to create a short circuit!



Short Circuit

Wrap Up:

- Have students draw two circuits (with labels!). One in series and a second in parallel and have them describe how the electrons move through the circuit (negative to positive).
- Have the students list some other conductors or insulators they can think of from home/school.

Topic 3: Introduction to Solar Cars and Vehicle Mechanics

Objectives:

- Students will be able to identify the different parts of their solar car and work with their teams to design their initial model.
- Students will begin building their cars.
- Students will learn more about gearing and what gears make a car move quickly.

Materials Needed:

- Engineering Notebooks
- Solar Car Supplies
- Hobby knife or cutting tool, glue guns, sandpaper, rulers, and pencils
- Non-permanent building materials- tape, rubber bands.
- Gear Exploration Activity
 - Gears, Cardboard, paint/paint pen, thumb tacks/pins/paper clip

Note for Teachers:

- This is when we propose beginning the car build. The “*Ray Catcher Sprint Deluxe User Guide*” is a great manual for **your** use. We suggest that coaches build their own solar car prior to guiding your students, so you’re comfortable with the process and can provide scaffolding for the students as they work through the process.
- While the guide isn’t meant to be for student use, we do recommend teaching to it until the “Wheels, Gears, and Axles” section, as the chassis set up is important to the success of the car. Helping students create a reliable base for their vehicle sets them up for success later in the process.
- After they have a reliable chassis, they can experiment with their teammates to optimize the other car components such as alignment, wheel placement, gear ratios, and wheel type.
- We’ll introduce these topics with some discussion/brainstorm time and then following student work time.
- Remind students to take notes as they go! Every step of the build process should be noted in their engineering notebooks.

Introduction:

- Do a class or notebook brainstorm of the parts of a solar car and their purpose
 - **Chassis (Body/Frame):** to protect and support the motor.
 - **Wheels and Bearings:** wheels make the car move and support the chassis, while the bearings allow the wheels to spin easily
 - **Power source:** the solar panel and battery pack are needed to charge the motor!
 - **Gears:** how to transfer the motor’s energy to the wheels
 - **Wires:** needed to complete our circuit and get the electricity to the motor

- Optional: share your completed solar car and allow the students to observe it and identify the different car components and their purpose.

- Have students review the provided materials and have individuals sketch their initial designs in their engineering notebooks.
 - Encourage them to include a circuit diagram, labels, and other initial ideas or instructions of *how* to construct this idea.

Student work time-Chassis:

- Teams should begin the car build process by making the chassis of their car. Extra adult support for supervising cutting portions is encouraged. You can use the “*Ray Catcher Sprint Deluxe User Guide*” to support this portion of the build.

- After the students have a chassis created, the table below could help encourage reflections on the beginning of the car build:
 - The table could help students brainstorm materials for their design and *why* they’re choosing that material. How would it help your design? (make it faster, lighter, have more traction, etc.)

Car Part	Material	Modifications	How would this help improve your design?
Chassis			
Wheels/Bearings			
Power Source			
Gears			
Wires			

- Optional discussion questions: what constraints, or problems, do you predict your initial design might have?

Review Competition Materials Constraints:

- Before students begin designing and redesigning their cars, it's important that they are aware of the build constraints. Any outside materials, not included in the Solar Car Kit, must be less than \$10 in value.
- Receipts for purchased materials should be included in the engineering notebook!

Wheels, Alignment, and Gear Ratios

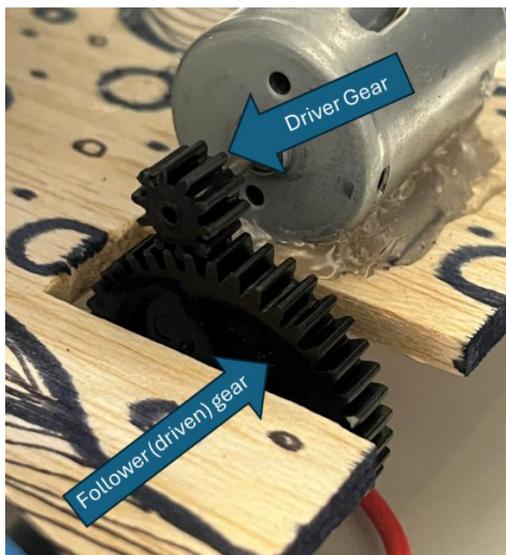
- Students can visualize these components with a complete Solar Car model (optional). It might help to scaffold conversation and allow them to visually reference the car components that you're discussing.
- Wheels are important to the success of your car! Discuss the pros and cons of the different types of wheels below:

- Mountain bike tires
 - Road bike tires
 - Roller Blades
 - Steamroller wheels
 - Tire with chains/tire without chains
- Potential discussion/journal questions:
 - What other materials could you use for wheels on your solar car? Why did you choose them?
 - How will you make sure your car has enough traction to roll?
 - Why might wheel weight be important?
 - How do you think weight distribution of the solar panel/batteries/motor might impact your wheel choice?
 - Wheels are attached to an axle, which is then spun by the motor- resulting in our car rolling forward. Axle alignment is necessary if you want your car to drive straight!
 - Do you think axles are glued to the body of the solar car? Why not?
 - What do you think we can use to allow those axles to spin freely?
 - Would friction be a barrier here? What material might cause a lot of friction? What material might have less friction?
 - **Student Work Time- Wheels, Axles, and Alignment**
 - Assist students in the initial wheel and axle build. Ensure that students are NOT using hot glue at this portion of the build. We want them to be able to improve, modify, and be creative with their car. Tape is a great option for a temporary adhesive. Hot glue will be used after they've finalized their design.
 - Students need to be able to remove their axles so they can add their gears in the next step of the build.
 - **Gears** are considered a simple machine that are crucial in our everyday life! Where are some places where you notice gears? (bike, car, unicycle, clocks, can openers, power tools, industrial machinery, garage openers, fishing reels, windup toys, elevators...)
 - Gear Introduction Videos (optional)
 - [Gears and the Principle of Gear Systems \(Knowledge Platform\)](#)
 - [Simple Machines-Gears \(Next Generation Science\)](#)
 - [Bianca Gets in Gear \(Cyberchase\)](#)

- [O Wow Moment: What's a Gear to Do? \(Children's Museum of Houston\)](#)

- **Student Work Time: Gear Ratios Activity**

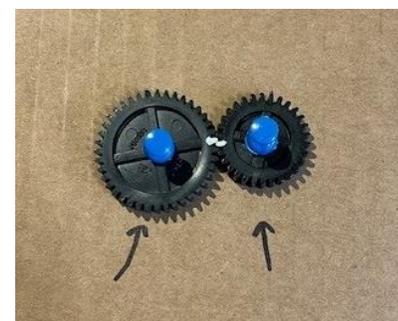
- Students will explore gear ratios using a simple set up with cardboard, thumb tacks, and paint. The concepts from the first video (Gears and Principles of Gear Systems) aligns well with this activity.
- Note all the different sizes of gears included in their solar car kit. We'll be talking about 2 different jobs for our gears.
 - **The Driver Gear:** the one connected to the motor or power source, where the effort is located
 - **The Follower Gear** (also called the driven gear): connected to the axle, which receives the rotational motion from the driver gear.



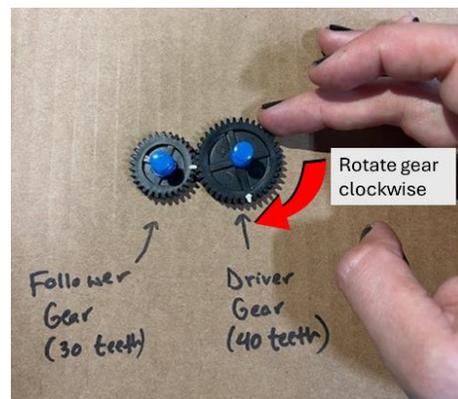
- Have students write their predictions about which gears will be the best combination for their final design in their engineering notebook.
- In their teams, students will be exploring different sizes of gears to determine the gear ratio. In their journals have students create tables to record the data they collect during the activity. This table is meant to try and explain gear ratios by a visual method by counting the number of turns per gear and mathematically. (this table can be printed out and students tape into their notebook, or drawn by hand)

Driver Gear (number of teeth)	Follower Gear (number of teeth)	Number of turns for driver gear	Number of turns for follower gear	Gear Ratio

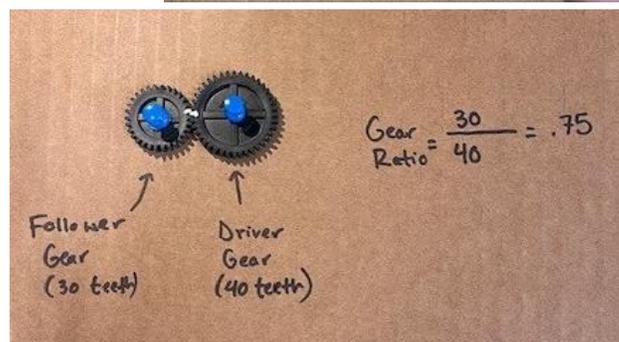
- Have students select 2 different sized gears and have them choose one to be their driver gear and one to be the follower gear. They'll do this process 3 times with different pairs of gears.
- Have them carefully paint one tooth on each gear. We use a paint notation, or tape, to visualize the gear ratio. It also helps to make counting the teeth easier which they should do next and add to their table.
- Students will then line up their gear pairs on the cardboard and pin down the gears, so the teeth are interlocked, and the painted teeth are aligned. Sometimes the gear is too small for a thumbtack, so a paper clip or pin works too! It should spin relatively easily.
- It also helps to have students label their gears on the cardboard so they can stay organized. The gear that they will be turning is the driver gear and the gear that is turned by the driver gear is the follower gear.



- Before mathematically calculating the gear ratio, have the students explore with the gears. By spinning the driver gear students can count how many rotations each gear makes before the white lines meet again. This is a visual representation of gear ratio, which they can use the formula to calculate next.

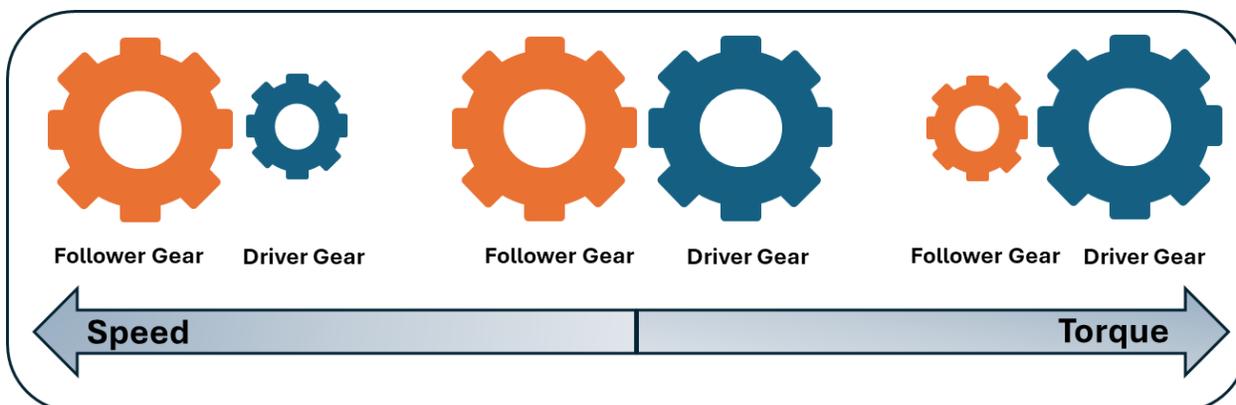


- Gear ratios can be calculated by dividing the number of teeth on the follower gear by the number of teeth on the driver gear.



- **Gear ratio** = $\frac{\text{\# of teeth on the follower gear}}{\text{\# of teeth on the driver gear}}$

- If the driver gear is larger than the follower gear, the car slows down, but has more torque. **Torque** is the force needed to twist an object. With a larger gear, more power from the motor is needed to rotate the gear to reach the same speed.
- If the driver gear is smaller than the follower gear, the car is faster but has less torque. See image below!
 - **Advanced Exploration:** power=(torque)x(speed). Torque and speed are inversely related. Increasing one will decrease the other.
- It is also important to note that the effectiveness of gear ratios depends on car design! The fastest gear ratio might not be the right solution for every car design. Gear selection might play a role in the continued redesign of their car.



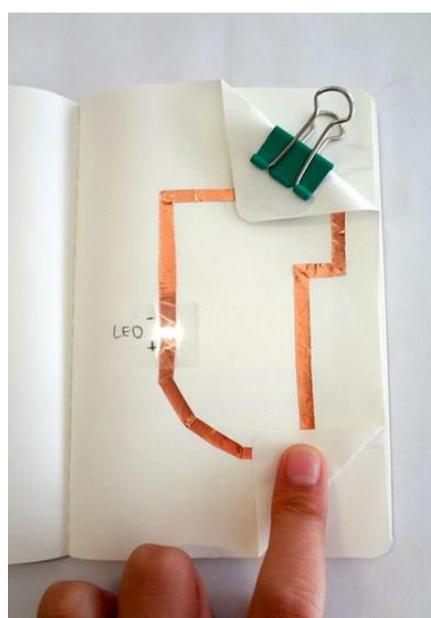
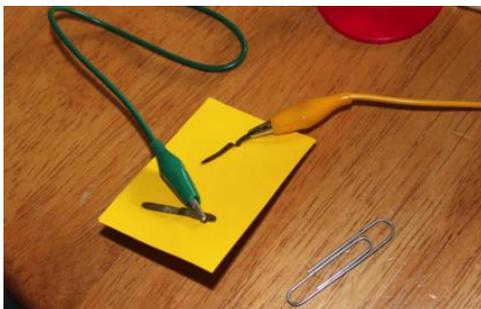
Speed and Torque are influenced by the size of the gears doing the work. They are inversely related.

Gears Wrap Up Reflection Questions:

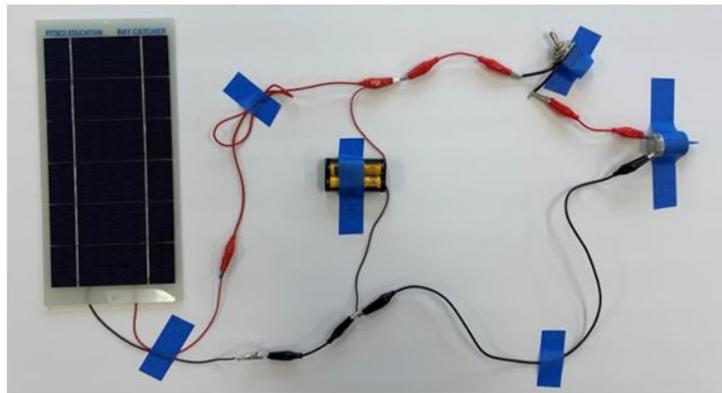
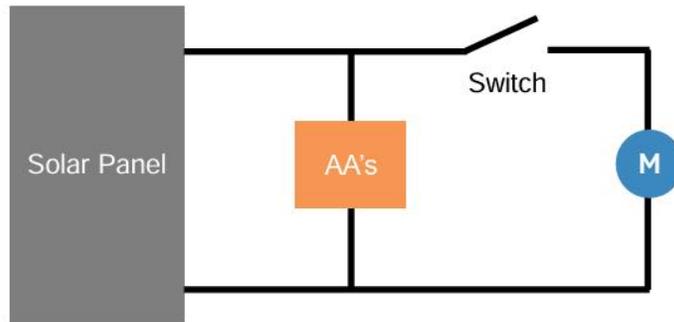
- What combination of gears resulted in a faster car?
- In what situations would you design a car with more speed?
- In what situations would you design a car with more torque?

Solar Car Circuits:

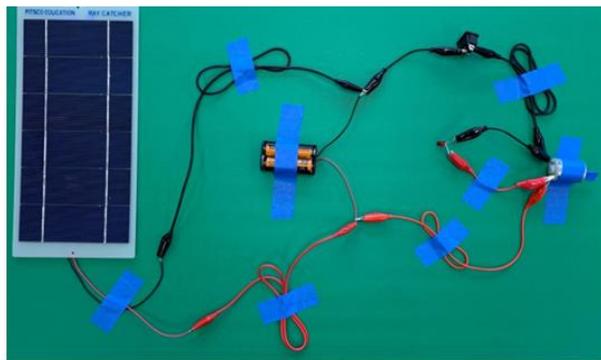
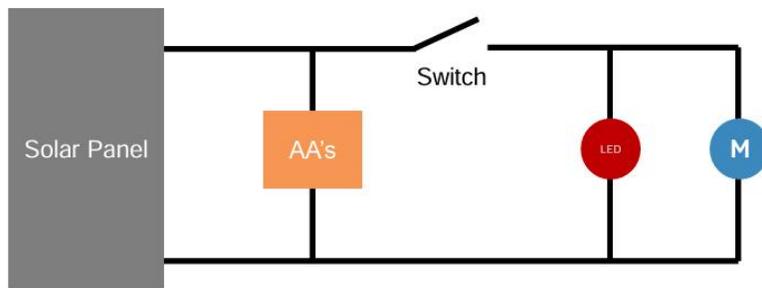
Elementary aged students are required to have a properly wired circuit that includes a switch (not included), the motor, 2AA batteries, and the solar panel. Middle schoolers have the same requirements but also must include a LED light in their circuit. Switches are not included in the solar kit and allow for students to flex their engineering brains to come up with a safe option. Some photo examples are included below for teacher reference.



Elementary School Circuit Schematic



Middle School Circuit Schematic



Finish the Initial Car Build:

- Allow students to finish their initial car build so it is functional for testing.
- Nothing should be permanently adhered to the car this point (tape is great!), as we want to encourage students to continue to improve upon their initial prototype after racing it a few times. The Pitsco user guide can help to scaffold the final steps of the car build.

Topic 4: Testing and Improvements

Objectives:

- Teams will test their initial prototype and identify improvements to their cars.
- Students will record their observations in their engineering notebooks and make appropriate changes to their prototypes.

Notes for Teachers:

- The official Solar Car Challenge will be conducted on the gym floor of Hudson’s Bay High School, so we recommend your practice sessions to be held on a similar surface to match race day conditions.
- Additionally- cars might be fragile at this point, so encourage teams to have one student “release” their car and a second student to “catch” their car.

Introduction:

- Prior to testing cars, have students reflect on the current state of their vehicle. The table below could be added to the engineering notebook to help structure this reflection.
 - What problems or difficulties do you envision you might discover when testing your car?
 - What observations and data do you want to collect during test runs?

Data	Observations
Anticipated Challenges?	

Test One: Make it to the other side

- The first goal will be for their initial prototype to reach the end of the track.
- Any changes students make to their initial designs should be detailed in their notebooks along with reasoning behind the change. See table for example:

Adjustments	Reasoning
What did you change about your design that was initially planned by your group?	Why did you make these changes? What impact do you hope they will have?

Test Two, Three, Four...: Observations on Previous Redesigns

- This iterative process is meant to reinforce the engineering design process. Students can adjust variables on their cars until they are happy with its performance.
- Ensure students are detailing all their changes and updates in their engineering notebooks!
- Potential changes students can make to their cars:
 - Wheels (sizes, materials...)
 - Wheel grip
 - Gear ratios
 - Bumpers
 - Chassis (length, width, shape)
 - Solar panel placement
 - Wiring optimization
 - Aerodynamics

Checking In:

- Students can continue the above process countless times to determine the best iterations of their designs. If students are struggling to make process, setting them up with “next steps” for their design might help structure their work time.
- A Claim-Evidence-Reasoning table might help brainstorm ways to keep working on their car:

Claim

What aspects of your car's design are successful? What aspects can be improved?

Evidence

What evidence can you point to from testing to support the above claims?

Reasoning

What background content knowledge do you have that supports this? What have you learned about how solar cars work?

Wrapping Up the Car Redesigns:

- Once teams are happy with their car's performance, ensure all components are securely fastened for competition day. Hot glue is great for this!

- Reflection Questions:
 - How did your team work together to improve your solar car?
 - What surprised you most about the process?
 - What was the biggest redesign change that your team made?

Topic 5: Presentations, Interviews, and Challenge Preparation

Objectives:

- Teams will be familiar with judging rubrics and will identify a presentation topic.

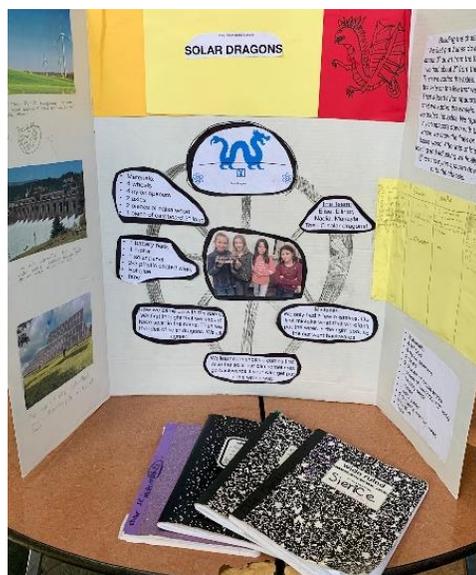
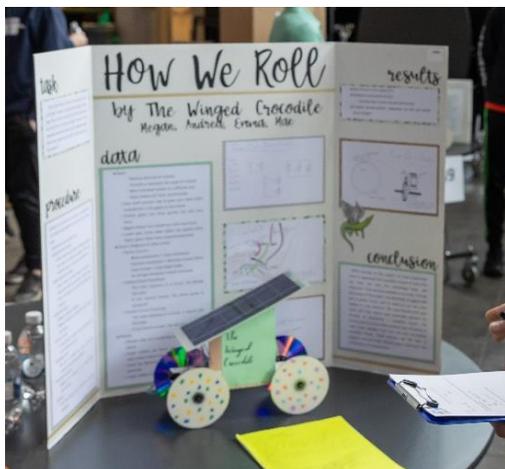
Reminder:

- 45% of team score depends on the Solar Car races and 55% of the overall score depends on their engineering notebook, presentation, and interview with a utility professional.

Presentation:

- As testing and redesign wraps up, students need to prepare a presentation for the competition. This could be a poster presentation or an online presentation, such as Google Slides.
- If students choose to make an online presentation, it should be around 10 slides and to be shareable without Wi-Fi.
- Potential Topic ideas:
 - How solar panels work
 - Solar vehicles
 - Renewable energy
 - Pros/Cons of Solar energy
 - Engineering Design Process
 - Car Technology
 - Use your teacher judgement! We are open to a variety of topics as long as they're related to the challenge. This is a great chance for your artistically and visually creative students to shine!





- As students begin to brainstorm presentation topic ideas, be sure they are familiar with the judging rubric so they can make sure they hit all the topics that judges will be looking for on race day.
- We encourage sketches, tables, data, or other useful information that students included in their engineering notebooks to be reflected on their presentations.

Interviews:

- Teams will be interviewed by Clark Public Utility employees as part of their overall score. All of the questions are available in the judging portion (pages 45-46) of this guide book, so students can prepare ahead of time!
- Interviews are usually under 10 minutes.

Challenge Preparation:

- As the race day approaches, ensure students have all components completed and travel-ready.
- It is also important to discuss with students that sometimes mechanical errors happen on race day. This is normal, and they will have access to Clark Public Utility engineers and tools to help get their cars running again.

Judging Guide

Challenge Details and Rules

Who can participate?

This challenge is designed for elementary and middle school students. Criteria for success are scaled to match grade level (see rubrics beginning page 41).

Students (with guidance from teachers/coaches) will design, build, and race hybrid solar battery-powered electric cars that include both a solar module and battery pack. Teams will be judged on their vehicle's performance in races (45%) and performance in a team interview with supporting engineering process documentation (55%). We recommend team sizes of 2-4 students per team for the most meaningful experience.



2019 Clark Public Utilities Solar Car Challenge Winners

Track Specifications

- Track Length: ~20'
- Track Width: ~12"
- Number of Lanes: 6

- Starting Gate: about 16” above the start line of the track.
- Track Surface: Lanes= ½” PVC pipe, track surface=gym floor
- Lighting: (22) 68 watt LED lights 32” above the track (center, left, and right)
- LED lights produce 330,000 lumens, 1428 watts, set at a 45-degree angle.
- If schools are interested in building their own test track (not a requirement!), the gate specs are available on this [document](#).



2024 Clark Public Utilities Solar Car Challenge Track (track subject to change)



Students' innovative designs!

Overview

Qualifying Checklist

Each car will be examined on the day of the challenge to ensure it meets vehicle specifications outlined for the challenge.

Race (45% weighted score)

The format of the speed trial will be a double elimination, meaning each team will race at least twice. A bracket system will be developed to track team movement throughout the challenge. This bracket will be visible to teams, coaches, and parents at the competition and through scanning QR codes on race day.

Documentation of Engineering Design Process and Team Interview (55% weighted score)

Team Poster

Each team must provide comprehensive documentation that reflects the engineering and design process. Knowledge should be demonstrated through a culminating team presentation (poster or digital) with supporting evidence from individual engineering notebooks. *A rubric will be used to assign points for the following steps in the engineering and design process:*

Ask, Research, Imagine/Plan, Create, Test and Evaluate, and Improve

The purpose of the engineering notebook is to document each individual team member's process and notes. The Team poster is the summation of the group's collaborative effort and should be a comprehensive snapshot of a topic related to the Solar Car Challenge.

Team Interview

Each team will be interviewed by a utility employee and may be asked questions related to the engineering design process or renewable energy. Questions are available on page _____. Translators are available. *A rubric will be used to assign points for the following categories:*

- Content
- Clarity
- Teamwork
- Preparedness/Research

Materials List and Specs

Required Materials	Prohibited Materials/Practices
<ul style="list-style-type: none"> • Provided motor • Provided Pitsco Ray Catcher (2.76 V) Solar Module • Switch (any that is safe-not provided) • Battery Holder • 2 AA Batteries • 1 red LED (*MS Only) 	<ul style="list-style-type: none"> • Any vehicle deemed unsafe by any judge (note-utilities are experts in electrical safety!!) • Additional power sources beyond what is included (and required) • Modifying power sources • Tampering with motor (re-wound or disassembled) • Additional purchased materials beyond \$10 (receipts for purchased materials must be included in documentation in notebook) • The solar panel cannot be used as the body of the vehicle. • The solar panel cannot be altered (drilled, sanded, or cut)
In the Kit-ES	In the Kit-MS
<ul style="list-style-type: none"> • 1 Photo Voltaic Module (Pitsco Ray Catcher Solar Module, 2.76 V, 1A) • 1 small DC Motor (Pitsco Motor 280) • 1 2-AA battery holder • 2 rechargeable AA batteries • 2 metal axles • 4 rubber bands (2 thick, 2 thin) • 8 gears (2mm hole) • 8 gears (1/8" hole) • 4 nylon spacers • 4 wheels (2 large, 2 small) • 2 balsa wood sheets • 1 solar panel blank (cardstock) • 12 pack mini alligator clip leads • 2 small metal alligator clips • 2 screw eyes 	<ul style="list-style-type: none"> • 1 Photo Voltaic Module (Pitsco Ray Catcher Solar Module, 2.76 V, 1A) • 1 small DC Motor (Pitsco Motor 280) • 1 2-AA battery holder • 2 rechargeable AA batteries • 2 metal axles • 4 rubber bands (2 thick, 2 thin) • 8 gears (2mm hole) • 8 gears (1/8" hole) • 4 nylon spacers • 4 wheels (2 large, 2 small) • 2 balsa wood sheets • 1 solar panel blank (cardstock) • 12 pack mini alligator clip leads • 2 small metal alligator clips • 2 screw eyes • 3 red LEDs *

Vehicle Specifications for Qualification

- Vehicle size: maximum length of 38 cm, width of 30 cm, and height of 30 cm.
- The solar panel cannot be used as the body of the vehicle
- The solar panel cannot be altered (e.g. drilled, sanded, or cut)
- Vehicles must be powered by 2AA batteries provided on the day of the challenge. The batteries must be connected to a working switch that can be turned off. The solar panel is not required to be connected to the on/off switch.
- There must be an available 5cm square of free space for team number sticker.
- Middle school teams must include a minimum of 1 red LED in their design that lights up when the vehicle is running.

Score Breakdown:

Total Challenge Points	% Score	Point Structure
Race Trials (Team Heat Races, modified double elimination)	45%	1 st place: 5 points 2 nd place: 3 points 3 rd place: 1 point DQ* or DNC**: 0 points
Documentation of Engineering and Design Process	30%	Poster and Engineering Notebook 500 maximum points
Team Interview	25%	Content, clarity, teamwork, preparedness/research, final product 400 maximum points

*DQ- disqualified

**DNC- did not complete race/length of the track

Ways to Win

The scores will be weighted by each team’s race performance, design, and interview. The following tables indicate the categories in which teams can win an award.



Racing Competition

Division	Awards
Elementary School	1 st , 2 nd , 3 rd
Middle School	1 st , 2 nd , 3 rd

Judge’s Choice

Division	Awards
Elementary School	1 st , 2 nd , 3 rd
Middle School	1 st , 2 nd , 3 rd

Interview and Engineering Design

Documentation

Division	Awards
Elementary School	1 st , 2 nd , 3 rd
Middle School	1 st , 2 nd , 3 rd

Track Officials Choice

Division	Awards
Elementary School	1 st , 2 nd , 3 rd
Middle School	1 st , 2 nd , 3 rd

JUDGING GUIDE: QUALIFICATIONS

Qualification Checklist: Elementary School

Before racing at the main event, cars must pass inspection.

Sizing

- 38 cm or less in length
- 30 cm or less in width
- 30 cm or less in height

Circuitry

- Circuits have solar panel and battery packs wired on separate parallel branches (see spec sheet).
- No additional power sources aside from 2AA battery pack and 2.76V Pitsco Ray Catcher solar module.
- Switch integrated into circuit (see spec sheet) either in series with battery or in series with motor. (**not in series with panel**)

Materials

- Motors from original team kit used (Pitsco Motor 280)
- Solar panel is not used as a chassis.
- Outside (found or created) materials are less than \$10 in value. This will need to be determined through questioning and volunteer discretion.

Additional

- No damage done to solar panel rendering it unable to be reused
- Visible 5cm square for registration sticker.

Team Number: _____

Team Name: _____

School: _____

Qualification Judge: _____

JUDGING GUIDE: QUALIFICATIONS

Qualification Checklist: Middle School

Before racing at the main event, cars must pass inspection.

Sizing

- 38 cm or less in length
- 30 cm or less in width
- 30 cm or less in height

Circuitry

- Circuits have solar panel and battery packs wired on separate parallel branches (see spec sheet).
- No additional power sources aside from 2AA battery pack and 2.76V Pitsco Ray Catcher solar module.
- Switch integrated into circuit (see spec sheet) either in series with battery or in series with motor. (**not in series with panel**)
- One LED in circuit.

Materials

- Motors from original team kit used (Pitsco Motor 280)
- Solar panel is not used as a chassis.
- Outside (found or created) materials are less than \$10 in value. This will need to be determined through questioning and volunteer discretion.

Additional

- No damage done to solar panel rendering it unable to be reused
- Visible 5cm square for registration sticker.

Team Number: _____

Team Name: _____

School: _____

Qualification Judge: _____

JUDGING GUIDE: RUBRICS/SCORING

Rubric Example: Elementary School

Elementary Scoring Sheet: Car Design and Engineering Notebook		
School:	Team Name:	Team Number:

Please assign teams a score between 1 and 100 for each of the following five criteria:

Ask: Research the Problem			Score
1 Students did not conduct research	50 Students conducted research about car materials.	100 Students conducted research about car materials and content. Students used research to address questions	
Imagine/Plan: Develop Possible Solutions			Score
1 Students selected a plan for prototype design at the outset of their design process	50 Students selected a car design and listed components.	100 Students selected a car design and listed components. Students explored wheel size, gear ratios, friction, etc.	
Create: Build a Prototype			Score
1 Students built a prototype	50 Students build a prototype with pictures included.	100 Students build a prototype, with pictures and detailed notes about adjustments made.	
Test, Evaluate, and Improve			Score
1 Students tested their prototype, but did not redesign	50 Students tested their prototype, listed results and developed a second design	100 Students tested their prototype, listed results, made a second design, and retested, taking careful notes.	
Final Design: Innovation			Score
1 Vehicle is not decorated, and students did not provide supporting documentation.	50 Vehicle is somewhat innovative in nature, but the team did not support with documentation.	100 Student creativity and innovation is clearly present in vehicle material testing or selection. Vehicle uses recycled materials and includes careful documentation.	

Judge's Choice Nominee?	<input type="radio"/> Yes	<input type="radio"/> No
Notes:		
Judge Name:		

JUDGING GUIDE: RUBRICS/SCORING

Rubric Example: Elementary School

Elementary Scoring Sheet: Presentation and Interview		
School:	Team Name:	Team Number:

Please assign teams a score between 1 and 100 for each of the following five criteria:

Content			Score
1	50	100	
Students demonstrated little knowledge of presentation topic or engineering process.	Students demonstrated knowledge of presentation topic and engineering process.	Students mastered presentation topic and engineering content as they relate to renewable energy.	
Clarity			Score
1	50	100	
Students selected presentation topic related to the challenge.	Students answered questions about the process and their presentation with evidence and reasoning.	Students answered questions with comprehensive understanding and communicated ideas with real world applications.	
Teamwork			Score
1	50	100	
One student answered all the questions.	More than one student answered all the questions.	Many team members answered questions and worked collaboratively.	
Research/Preparedness			Score
1	50	100	
Students shared their approach to the challenge, but with little detail.	Students demonstrated familiarity with components and asked initial questions before beginning the design process.	Students demonstrated familiarity with components, asked questions, and supported their decision making with research throughout the process.	

Judge's Choice Nominee?	<input type="radio"/> Yes	<input type="radio"/> No
Notes:		
Judge Name:		

JUDGING GUIDE: RUBRICS/SCORING

Rubric Example: Middle School

Elementary Scoring Sheet: Car Design and Engineering Notebook		
School:	Team Name:	Team Number:

Please assign teams a score between 1 and 100 for each of the following five criteria:

Ask: Research the Problem			Score
1 Students did not conduct research	50 Students conducted research about car materials.	100 Students conducted research about car materials and content. Students used research to address questions	
Imagine/Plan: Develop Possible Solutions			Score
1 Students selected a plan for prototype design at the outset of their design process	50 Students selected a car design and listed components.	100 Students selected a car design and listed components. Students explored wheel size, gear ratios, friction, etc.	
Create: Build a Prototype			Score
1 Students built a prototype	50 Students build a prototype with pictures included.	100 Students build a prototype, with pictures and detailed notes about adjustments made.	
Test, Evaluate, and Improve			Score
1 Students tested their prototype, but did not redesign	50 Students tested their prototype, listed results and developed a second design	100 Students tested their prototype, listed results, made a second design, and retested, taking careful notes.	
Final Design: Innovation			Score
1 Vehicle is not decorated, and students did not provide supporting documentation.	50 Vehicle is somewhat innovative in nature, but the team did not support with documentation.	100 Student creativity and innovation is clearly present in vehicle material testing or selection. Vehicle uses recycled materials and includes careful documentation.	

Judge's Choice Nominee?	<input type="radio"/> Yes	<input type="radio"/> No
Notes:		
Judge Name:		

JUDGING GUIDE: RUBRICS/SCORING

Rubric Example: Middle School

Elementary Scoring Sheet: Presentation and Interview		
School:	Team Name:	Team Number:

Please assign teams a score between 1 and 100 for each of the following five criteria:

Content			Score
1	50	100	
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Clarity			Score
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Teamwork			Score
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One student answered all the questions.	More than one student answered all the questions.	Many team members answered questions and worked collaboratively.	
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Students shared their approach to the challenge, but with little detail.	Students demonstrated familiarity with components and asked initial questions before beginning the design process.	Students demonstrated familiarity with components, asked questions, and supported their decision making with research throughout the process.	

Judge's Choice Nominee? <input type="radio"/> Yes <input type="radio"/> No
Notes:
Judge Name:

JUDGING GUIDE: INTERVIEW QUESTIONS

Interview Example: Elementary School

Team Name	Team ID
1.	(Briefly introduce yourself) Icebreaker: Why is renewable energy important to you? What are you most excited about at the competition today?
2.	What kind of research did you and your team do to prepare for the challenge?
3.	How did you choose the components for your solar car vehicle?
4.	What additional materials did you use to make your car? Why did you choose these?
5.	Did you have any issues with friction? How did you overcome these issues?
6.	When building your car, what kind of obstacles did you face?
7.	What trade-offs did you make when designing your car and selecting components?
8.	Describe any redesigns you made. Did they lead to performance gains?
9.	What is the topic you chose for your presentation? Why was this topic interesting to you?
10.	How did your team divide up tasks? Would you say you worked well together?

JUDGING GUIDE: INTERVIEW QUESTIONS

Interview Example: Middle School

Team Name	Team ID
1.	(Briefly introduce yourself) Icebreaker: Why is renewable energy important to you? What are you most excited about at the competition today?
2.	What kind of research did you and your team do to prepare for the challenge?
3.	How did you choose the components for your solar car vehicle?
4.	What additional materials did you use to make your car? Why did you choose these?
5.	Did you have any issues with friction? How did you overcome these issues?
6.	When building your car, what kind of obstacles did you face?
7.	What trade-offs did you make when designing your car and selecting components?
8.	Describe any redesigns you made. Did they lead to performance gains?
9.	What is the topic you chose for your presentation? Why was this topic interesting to you?
10.	How did your team divide up tasks? Would you say you worked well together?

NGSS Performance Expectations

Note: the following performance expectations are to serve as suggested targets for alignment. This activity guide is designed to allow teachers from different grade levels and subject areas to make modifications to more strongly align the activities to the appropriate standards for your age students.

Elementary

3-5-ETS1-1.	Define a simple design problem reflecting a need or want that includes specified criteria for success and constraints on material, time, or cost.
3-5-ETS1-2.	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3.	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
3-PS2-2.	Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
3-PS2-3	Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.
4-PS3-1.	Use evidence to construct an explanation relating the speed of an object to the energy of that object.
4-PS3-2.	Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
4-PS3-4.	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
5-ESS3-1.	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
4-ESS3-2.	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

Middle School

MS-PS2-2.	Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
MS-PS2-3.	Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
MS-PS3-5.	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
MS-ETS1-1.	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2.	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3.	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4.	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Supplemental Activities:

Watt's My Name?

Consider this: Before sticking tape and lighting up names like it's Times Square, pause and ponder: What are your students learning beneath the sparkle? This name tag is more than just crafty bling; it's a mini science lab stuck to their shirt! Intro to Circuits? Yep! Polarity? You bet! Cause and effect? Absolutely! And when it doesn't light up? Boom! Troubleshooting, persistence, and engineering thinking kick in. You're not just guiding a craft; you're wiring curiosity and preparing them for Clark Public Utilities Solar Car Challenge, where we make it fun, by making it electric!

1. Gather Materials

1. Cardboard, cardstock, gift tags or other durable paper-based material
2. Adhesive name tag pins, safety pins or clothespins
3. Hot glue if using safety pins or clothespins
4. Conductive Tape (Maker Tape for Paper Circuits)
5. 5 mm LED
6. 3V Lithium Coin Batteries
 - Consider safe disposal and storage when using this product
7. Scissors
8. Markers or Colored Pencils
9. Stickers or other decorations (optional)



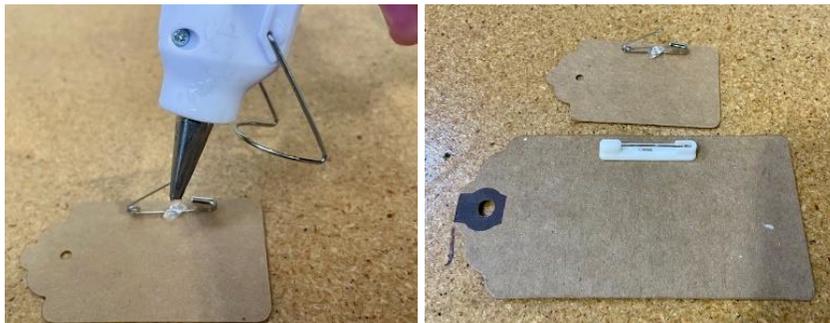
2. Name It

1. Cut paper materials into the name tag shape or use precut option
2. Write your name with markers or colored pencils
3. Add stickers or other decorations



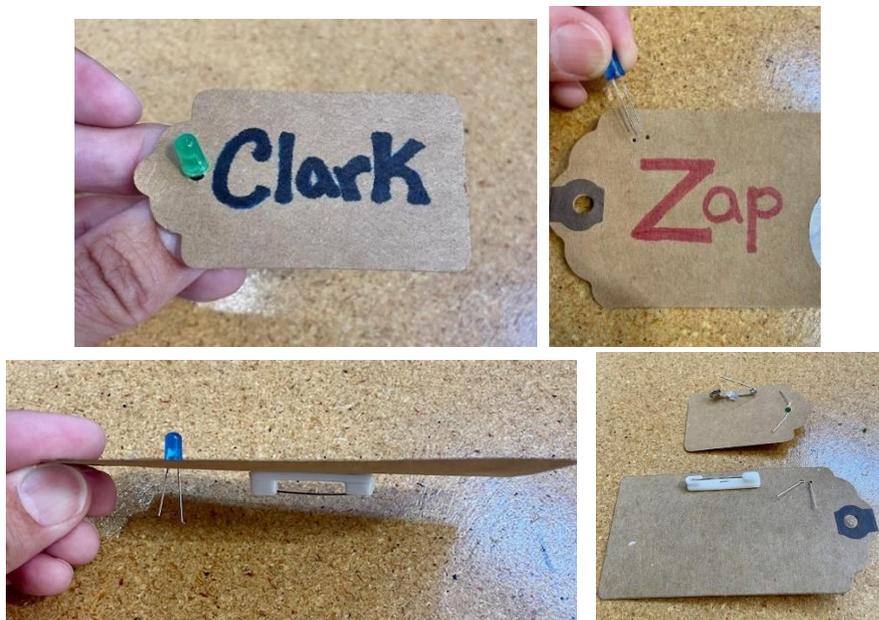
3. Pin It

1. Attach the peel and stick pin to the back of the name tag – near the top
2. Leave room for the circuit tape and battery
3. If using other fastener attach with hot glue. Contain glue to a small space in the middle of the pin



4. Light It

1. If using gift tags, like our example, use the string hole to insert the LED
2. Or – make two small holes next to each other with a safety pin or tack
3. LED orientation is important – insert the longer leg (positive +) into the **right** hole
4. Bend the legs of the LED down so they lay flat



5. Wire It

1. Using Makers Tape, measure, cut and peel a strip of conductive tape.
2. Connect the tape over the shorter leg (negative -) of the LED, extending towards one of the corners of the name tag
3. Curl a small loop of makers tape where the battery will sit
 - Careful, do not make this loop too big or the battery will short
4. Place the battery on top of the tape loop, with the positive (+) side facing up
5. Measure, cut, and peel a strip of tape, placing it over the longer LED leg (positive +) connecting this to the top (positive +) side of the battery
6. Add another piece of tape over the battery to secure it and complete the circuit



6. Test It

- Does the LED light up? If not...
 - Are the positive and negative legs on the correct sides of the battery?
 - Is there good contact between the positive leg, tape and battery?
 - Is there good contact between the negative leg and tape?
 - Is the circuit long and winding or short and efficient?



7. Wear It

- Does the LED light up? If yes...
 - Pin it on your shirt and “Amp Up Your Name!”

8. Think About It

- Polarity Matters: Direction of Electron Flow
 - What to observe:**
 - LEDs are polarized components, and they only work if the positive and negative ends are connected correctly.
 - Think about:**
 - Why does the LED only light up in one direction?

A: Because LEDs only allow electricity to flow in one direction – from the positive leg to the negative leg.
 - What does this tell me about how current flows in a circuit?

A: Current moves in a specific direction, from the positive side of the battery, through the components, and back to the negative side.
- The Circuit Must Be Closed
 - What to observe:**

- The light only turns on when there is a complete path from the battery, through the LED, and back.
- **Think about:**
 - What happens if one leg of the LED isn't connected with tape?

A: The LED won't light up because the circuit is open, electricity can't flow all the way through.

- How is the path of electricity like water flowing through a pipe?

A: Just like water needs a full pipe to flow, electricity needs a complete loop to move through the circuit.

3. Conductive Materials Enable Flow

- **What to observe:**
 - The conductive tape acts like wire, letting electrons travel between the components.
- **Think about:**
 - What makes some materials, like metal, good conductors?

A: Metals have free electrons that allow electricity to move through them easily.

- What would happen if I used regular tape instead?

A: Regular tape wouldn't work, it is not conductive, so electricity can't pass through it.

4. Energy Transformation

- **What to observe:**
 - The electrical energy from the battery is transformed into light energy by the LED.
- **Think about:**
 - Where does the energy come from, and what does the LED do with it?
 - Why doesn't the battery last forever?

5. Component Function

- **What to observe:**
 - The battery provides a power source (voltage).
 - The LED emits light when electrons move through it.
 - The tape connects everything like invisible wiring.

- **Think about:**
 - What does each part of the circuit do, and why do I need all of them?

A: Battery: Provides power, LED: Lights up using that power, Tape: Connects the parts so electricity can flow. You need all three to make the circuit work.

6. Short Circuits & Safety

- **What to observe:**
 - If the tape touches both sides of the battery without an LED in between, it creates a short circuit, which drains the battery or generates heat.
- **Think about:**
 - What happens if I connect both terminals of the battery directly?

A: It creates a short circuit, which can make the battery hot or drain very fast – and nothing useful happens.

- Why do circuits need to be designed carefully?

A: To make sure electricity flows the right way and doesn't damage anything or waste power.

7. Hands-On Troubleshooting

- **What to observe:**
 - If the LED doesn't light up, it's likely due to a break in the circuit, reversed polarity, or poor contact with the battery.
- **Think about:**
 - How can I test and fix my circuit like an engineer would?

A: Check each part step by step and make sure the LED is in the right direction, the tape touches both legs, and the battery is connected properly.

- What steps can I take to find out what's wrong?

A: Flip the LED if it doesn't light, press down on the tape connections, make sure the battery isn't dead, and check that the tape isn't peeling or broken.