

Solar Car Obstacle Course Challenge



Quantum Energy and Sustainable Solar Technologies

QESST Solar Car Challenge 2019-2020 Hosting Guidelines

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Welcome:

Welcome to the exciting challenge of solar cars. Here you will find the opportunity to design and build a solar car that completes an obstacle course with three challenges to gain the most points and be crowned the best! Or at least have some fun along the way. Many of you are familiar with solar powered cars. These challenges will help you dive deeper into exactly what makes solar cars run and how to optimize them so they can complete the jobs we want them to do.

In this specification packet, you will find:

- Information about the three challenges in the obstacle course (*How do I get points and win?*)
- Requirements for your Engineering Design Notebook.
- Extra information about solar energy and car mechanics to help you get started

Day of Competition Expectations:

1. Teams must be comprised of 2-5 students. At least two are required to be present for testing at MESA Day.
2. Regional competitions will be run as workshops. They will have the same rules and guidelines as the state competition. However, the focus is on practicing in an authentic setting. NO awards will be given, but you are encouraged to scrimmage against other teams. QESST scholars will be available to help you with questions and ideas.
3. An engineering design notebook is REQUIRED. You will NOT be allowed to compete if your team checks in at the state competition without a notebook or it appears that you just began a notebook.
4. The events will be run as an open “carnival” competition. All three challenges in the solar car obstacle course will be open to compete for three hours. Your team may complete the challenges in any order you decide. You can complete up to three times in each challenge. Only your highest score will be counted.
5. You can make adjustments to your car in order to meet the specific requirements of each challenge. You do not have to change your car in between challenges, but it is allowed if you want. For instance, you can add attachments (such as a snowplow) that are only part of your car for certain tasks.

Vehicle Specifications:

1. The vehicle must be safe. For instance, there must be no sharp edges, projectiles, etc.
2. The vehicle cannot exceed the following dimensions: Length: 60cm, Width: 30cm
3. The sun's light is the ONLY energy source that may be used to power the vehicle. No rubber bands, etc. allowed. No extra motors or alternative energy storage devices (such as batteries) of any kind are permitted.
4. Solar concentrators, such as mirrors, are permitted, but must be firmly attached to the vehicle.
5. The body of the car must be three-dimensional. The solar cells cannot be used as the body of the car (e.g. teams may not bolt the axles and wheels to the solar cell directly).
6. The vehicle must be clearly labeled with school name.
7. ALL 4 solar panels and motor must be used.

Mandatory Materials:

- You may use all types of materials when designing your car. However, you MUST use the four solar panels and motor provided by QESST (See notes on page 9 for more information).

Overview of Obstacle Course Challenges:

You will be presented with a series of challenges for your car to complete: a sprint challenge, an alignment challenge, and an impact challenge. Each challenge is worth 30 points. Additionally, you will be required to have an engineering design notebook. The notebook will be worth 24 points. At the end of the competition the team with the most points (out of 114) is crowned the "Overall Obstacle Course Champion Car" winner.

Awards will be given for the following: (subject to change based on regional competitions)

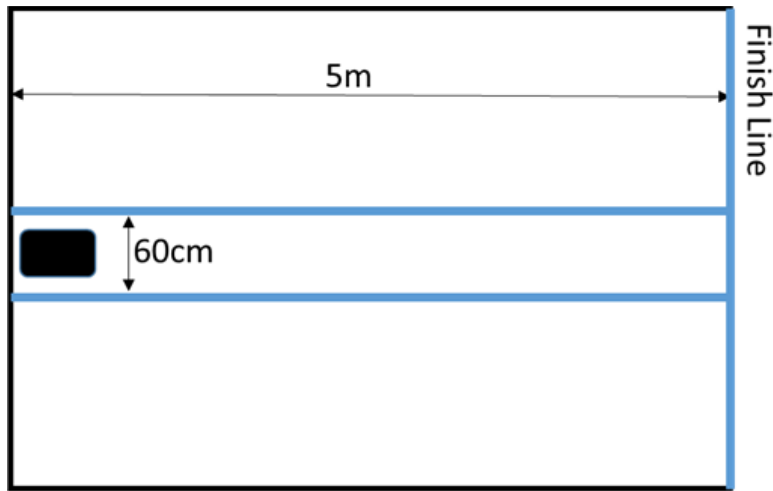
- Best Engineering Design Notebook
- Overall Obstacle Course Champion
- Fastest recorded time
- Best alignment
- Most cans knocked over during impact

Challenge # 1 - Sprint Challenge:

This challenge measures speed. Your car must move 5 meters in the shortest amount of time possible (this is a race against the clock!).

Important design criteria to consider that will help you achieve this goal: **(and added to your notebook)**

- Good gear ratio (transfer of power, within limitations of starting) *See appendix A: Mechanical Design*
- Solar cell placement and arrangement (more power means a faster car) *See Appendix B: Examples of Parallel and Series Circuits*
- Body and wheel design (needs to be sturdy enough to make it the distance without falling apart, but weight will also affect how fast your car will move)



Sprint Track Specifications (see the figures above)

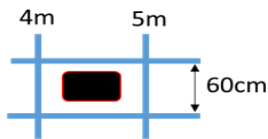
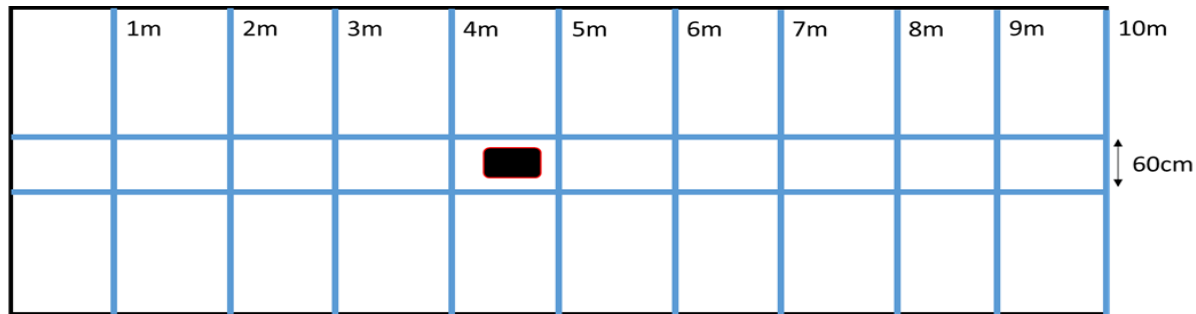
1. The length of the race course is 5 meters over flat terrain such as a sidewalk or similar surface.
2. Race lanes are 60 cm wide. It is recommended that your car stay within the lane, but it is not required for this challenge.
3. Lanes are on a hard surface (like concrete) and designated by blue painters tape.
4. Points are awarded based on the time recorded according to the chart below.
5. Time is measured from the word “go” spoken by the judges to when the first part of the car crosses the finish line.

Time	Points awarded
0-5 seconds	30 points
5-10 seconds	27 points
10-15 seconds	24 points
15-20 seconds	21 points
20-25 seconds	18 points
25-30 seconds	15 points
30-35 seconds	12 points
35-40 seconds	9 points
40-45 seconds	6 points
> 45 seconds	3 point
Does not reach 5 meters	0 points

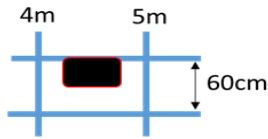
Challenge #2 - Alignment Challenge:

This challenge measures how well your car can travel in a straight line. Important design criteria to consider that will help you achieve this goal: **(and added to your Notebook)**

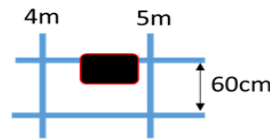
- How straight your car goes? (e.g. if it goes sideways it will have to travel farther and thus cross the blue line sooner)
- Is the weight distributed equally on both sides of your car?
- Are your wheels in line with each other?



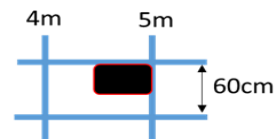
Car is within the lane



Car is outside the lane
and awarded 4 points



Car is outside the lane
And awarded 4 points



Car is outside the lane
And awarded 5 points

1. The length of the course is 10 meters over flat terrain.
2. Lanes are 60 cm wide.
3. Lanes are on concrete-like and designated by blue painters tape.
4. Points will be assessed for every meter traveled down the course inside the lane. As soon as any part of the car is over or comes in contact with the blue tape, this portion of the competition will stop and points will be awarded.
5. Tie breaker: If car has reached the maximum 10 meters, it can continue moving down the track. However, the race lane will become narrower until it becomes 30 cm. The same rules apply (e.g. the car must stay within the lines). The car that goes the furthest distance without going outside the lane will be considered the winner.

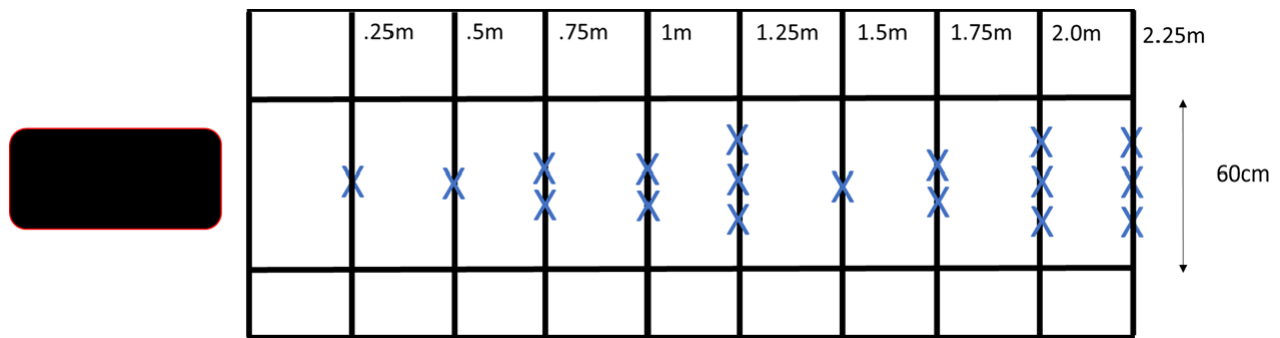
Alignment Challenge	
Distance car travels in a straight line	Points awarded
10 meters	30 points
9 meters	27 points
8 meters	24 points
7 meters	21 points
6 meters	18 points
5 meters	15 points
4 meters	12 points
3 meters	9 points
2 meters	6 points
1 meter	3 point
<1 meter	0 points

Challenge #3 - Impact Challenge:

This challenge measures your car's ability to remove obstacles from its path, while protecting the car from these obstacles. Specifically, empty soda cans will be placed in the way of the vehicle and the challenge is to remove as many of these cans from the path of travel as possible.

Important design criteria to consider that will help you achieve this goal: **(and added to your Notebook)**

- Torque (turning power) of the wheels (is it sufficient to push the soda cans out of the way?)
- Body and wheel design (needs to push cans out of the path and also keep cans from falling on the solar panels)



Track Specifications

1. Lanes will be 60 cm wide. Soda cans will be located every 0.25m down the lane, as shown in the figure above.
2. X's will be marked on the ground with blue painters tape, and the judges will place the cans there as shown.
3. Cans will be stacked as follows:
 - a. Cans will be stacked one-high for lines 1-5.
 - b. Cans will be stacked two-high for lines 6-8.
 - c. Cans will be stacked three-high for the final line.
 - i. For example, there are three cans located at 1.25m. There are six cans (three cans on top of three cans) at 2 m, and nine cans located at 2.25 m (three cans on top of three cans on top of three cans)
4. The front of the car will start at 0 m. The car will move forward and knock over as many cans as it can without help from team members. For example, team members cannot remove a soda can if it falls on the solar panels. The competition will continue until the car comes to a complete stop, passes 2.25m, or goes far enough off course that it will not come back. All cans knocked over will count towards points: i.e. if your car passes one set of cans without knocking them over, you can still gain points for cans knocked over further down the track. Each can that falls over or moves away from the X will count as 1 point. (Total possible points for this competition are 30)
5. Tie Breaker 1: The car that knocked down the most cans, traveled the furthest and knocked over the furthest can from the start line. (If you have knocked over all 30 cans and have a remaining ticket, additional cans will be set up. These cans will not count towards more points in the overall competition, but will help determine the individual winner of this challenge.)

Engineering Design Notebook:

Engineers document their project work in an engineering design notebook. The purpose is to record written ideas, sketches, work session summaries, research findings, testing results and interview information in chronological order.

1. Why are notebooks important?
 - a. An engineering notebook is a legal document used to prove ownership of ideas
 - b. Using a notebook will improve documentation, sketching, research, and communication skills
 - c. A notebook protects the groups' ideas if a member leaves the project
2. Your notebook should document at least 3 completed design cycles.
3. Grading of notebooks will be based on the MESA rubric.
4. The design notebook is worth 24 points. (See **APPENDIX C** for a student example)

Notes to MESA Coaches:

1. Teams will receive 3 different colored tickets to each challenge. There is no particular order that must compete. The teams will first check in with the lead judge to check vehicle specs (to ensure that no alternative energy sources have been added). They will then present their ticket to the event judge to compete.
2. As the competition comes to a close, teams will be given a 5 minute warning. If they are not in line during that time to compete, their ticket(s) will be forfeited. Students should be told that time is a constraint. QESST will be running several challenges at a time, so this should not be an issue.
3. QESST will provide 1 motor and 4 solar panels to 1 team at each school. If more than one team wishes to compete per school, schools may purchase the items below:
 - <http://www.pitsco.com/Motor-280>
 - <http://www.solarmade.com/store/product/mini-panel-4-1-0-400> (1.0V, 400 mA)

Judging and Evaluation:

DISPUTES:

- Teams can only dispute their own results and not dispute or complain about other team's designs/results.
- Should there be a dispute, the Lead Judge should briefly address the dispute with parties making the protest and the other judges at the time of the dispute.

JUDGES:

- Judges will be fair.
- Judges will discourage any interruptions to their duties, because distractions can cause a delay in the event.
- Judges will refer people to the committee chairmen, registration or other volunteers for questions and help.

Rubric for Engineering Design Notebooks (EDN).

EDN Goals	3	2	1	0
1. Explore				
☐ Described Design Objective ☐ Described Success Criteria ☐ Described Constraints ☐ Described Variables and Constants	All	Most	Some	None
☐ Described Prior Knowledge ☐ Described Brainstorming ☐ Described Exploration (testing materials, modelling, etc.)	All	Most	Some	None
☐ Has Research documented with at least 5 sources (website, book, video, article, interviews, etc.) ☐ Research is reliable (i.e. experts, researched websites, etc.)	All	Most	Some	None
2. Design				
☐ Describes materials used ☐ Documents data from previous trials ☐ Documents modifications	All	Most	Some	None
☐ Includes sketch/photo of initial prototype ☐ Includes sketch/photo of final prototype	All	Most	Some	None
3. Test				
☐ Has data in graphical form ☐ Has written description of data ☐ Multiple iterations	All	Most	Some	None
☐ Describes pros and cons of data results ☐ Discusses next steps ☐ Tests are well designed	All	Most	Some	None
4. EDN Organization				
☐ Has Table of Contents or clearly labelled sections ☐ Notebook is organized	All	Most	Some	None
4.2 Labeled. Clearly labeled with School and Team Members names.			Yes	No
Column Totals (for selected categories)				
Total (out of 25)				

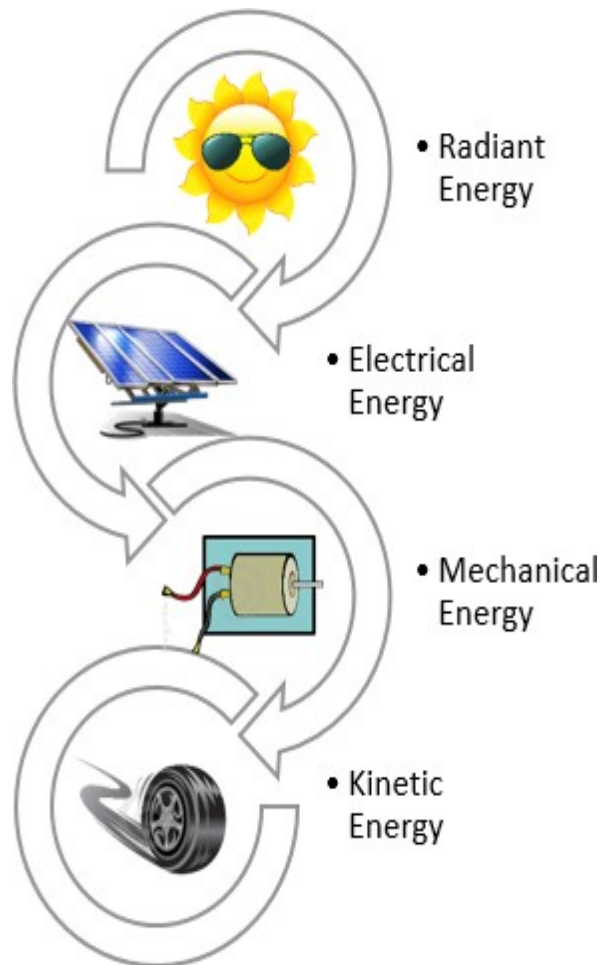
Comments/Suggestions:

APPENDIX A: Background Information to help you design your car:

Solar Cars:

A solar car is an automobile that is powered by the sun. Recently, solar power has seen a large interest in the news as a way to help us reduce our carbon footprint and still power the technology of the future. Here at QESST, we are interested in helping further this goal. That is why we are actively involved in research improving solar cell design and manufacturing. However, once a solar cell is assembled, there is still more to consider before we can use the power to run our device. Namely, how do we connect the solar cells to our devices, and how does this affect their performance? These are exciting questions, and we will discuss them more below. But, maybe we are getting a little ahead of ourselves. First we need to consider: just what is a solar car?

Like all cars, a solar car converts a form of energy into motion. In most automobiles today, gasoline provides the energy, and the engine and drivetrain converts that energy into motion. For solar cars, the sun's rays carry the energy. Solar energy is captured by the solar cells and converted into electrical energy. This, in turn, is converted into motion by the motor. Maximizing the energy captured by the solar panels and transferred to the wheels is crucial in designing a good solar car.



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These ideas are captured by two engineering fields: mechanical and electrical. The *mechanical design* will consider things such as gear ratios, wheel alignment, and weight of the vehicle in order to maximize the energy transferred from the engine to the wheels. The *electrical design* will consider the energy absorbed by the solar cell and converted into turning power (torque) in the motor. We will treat each one of these separately below

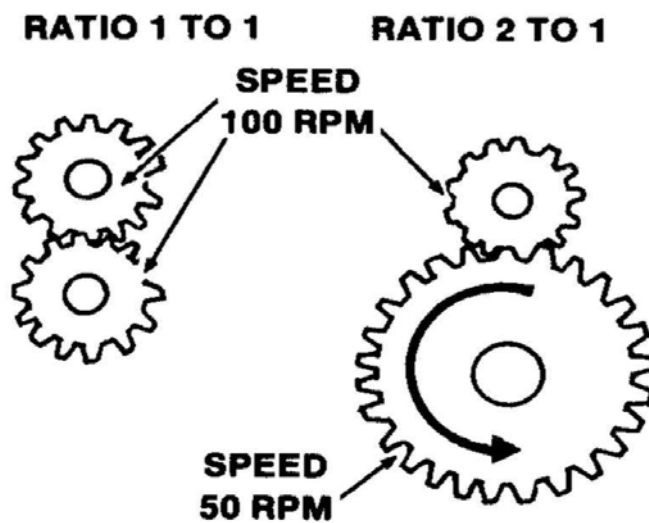
Mechanical Design (Maximizing your motion given a certain amount of power):

Each team is provided a motor for the solar car obstacle course challenges. Motors perform the important function of converting the incoming energy into rotational motion. Each motor comes with a specific power output and other specs. For this challenge this is a *design constraint*. (Remember to include design constraints in your **NOTEBOOK**).

The gear ratio controls the distribution of power to the wheels. A familiar example of this occurs while riding a bike. As you are riding a bike the power is limited (that is the power of your legs). Suddenly, when you go uphill the bike doesn't want to go as fast. You cannot just switch out your legs to get larger muscles so instead you gear down.

What does it mean to *gear down*? Gear down means controlling the number of turns of the pedal per turn of the wheel. If there are more turns of the pedals per turn of the wheel it requires less power. How does this work? A lower gear moves you a shorter distance for each spin of the pedals, which makes it easier to pedal (but slower).

For the solar car challenge it will be important to consider the gear ratio. This is because the power from the engine is limited and might be less than you want. However, with the proper gear ratio the car can move and (possibly) even do so fast.



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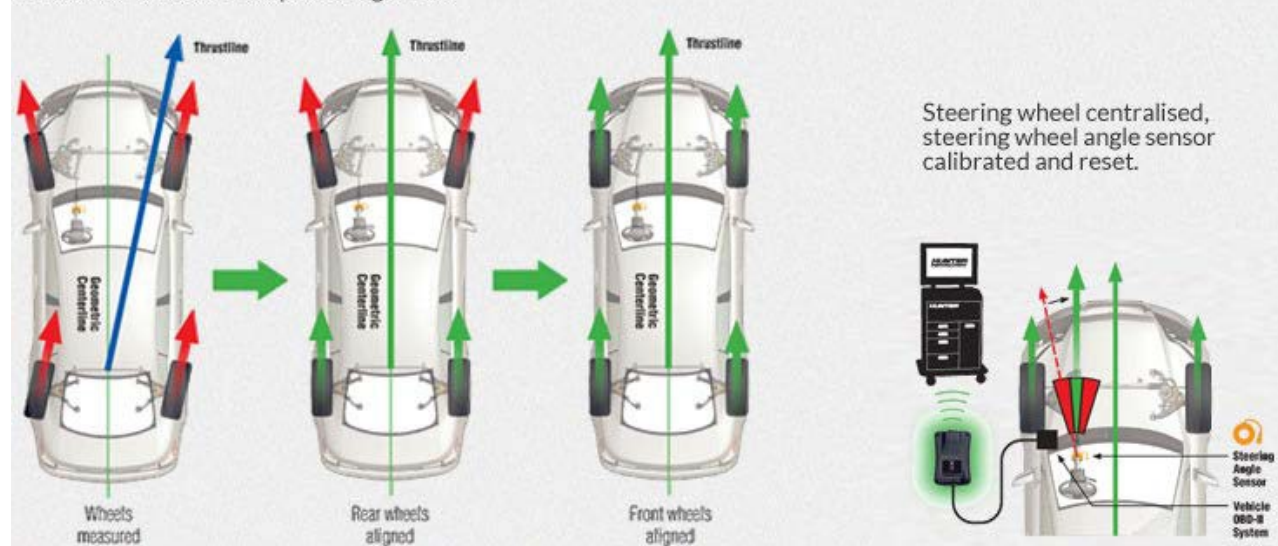
The wheels are another important design parameter. There are two important things to consider:

1. The friction of the wheels
2. The alignment

Low friction on the wheel's axle will help transfer the most power to move your car forward. The wheels need enough friction so that they can push the car forward. Choice of wheel material and bearing type is important. Your team should experiment with these variables (and log your experiments in your NOTEBOOK).

Once you maximize the rotation of each of the wheels, you need to synch them with each other. This process is called *alignment*. The idea of alignment is to make sure all the wheels are pointing in the same direction and not tilted in or out. Without good alignment it doesn't matter how you design your car, it will not move as desired. The image below shows good and bad alignment. It is also important to make sure that all the wheels are at the same height and not tilted in the other directions (for more information, google "*toe caster camber*").

Process for 4 Wheel Computer Alignment



<http://areamotorsport.co.uk/work/alignment-frsu/>

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Electrical Power:

Solar cars use sunlight to create energy. Each solar cell on your car converts light to electrical power using *photovoltaics*. Electrical power (P) is calculated by multiplying the current (I) by the voltage (V). We can write this as:

$$P=IV$$

Electrical Power (P) is the rate at which electrical energy is converted to another form, such as your car traveling down the track!

Current (I) is the amount of electrical charge.

Voltage (V) is the rate at which you can draw or use the current.

The more current and/or the more voltage you have, the greater the power.

Current and Solar Cells:

The more sunlight the solar cell collects, the more current the solar cell generates. The more current the solar cell generates, the more potential power you gain for your car.

A. What happens if we double the amount of light that the solar cell collects?

Answer: The current will double.

B. What happens if we double the area of the solar cell (or use two solar cells of equal size)?

Answer: The current will also double.

C. What happens if we half the amount of light?

Answer: We will get half the current.

D. What happens if we half the area of the solar cell?

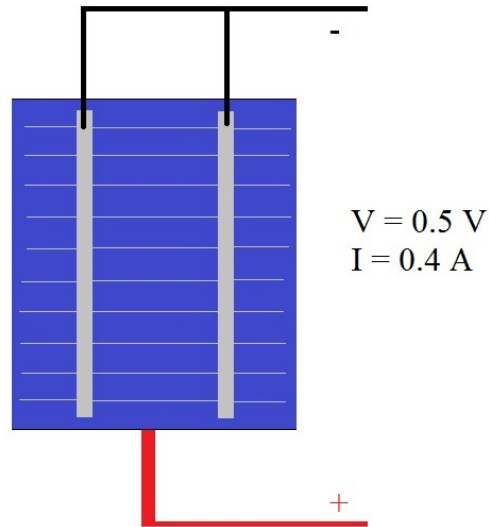
Answer: We will get half the current.

These are not the only factors that control the amount of current the solar cell generates, but they are some the main factors. The amount of current coming out of a cell is proportional to the amount of light it collects. Power requires both current and voltage. Unfortunately, there is a tradeoff. The more current a solar cell has to provide, the lower the voltage will be.

The next section will show you different examples of how to connect your solar cells in order to achieve the optimal power for your car.

How to Connect Your Solar Cells to Get the Optimal Current (I) and Voltage (V):

One solar cell looks something like this:



In this scenario, if we generate a small amount of current, let's say 0.1 A, the solar cell will run close to or above 0.5 V.

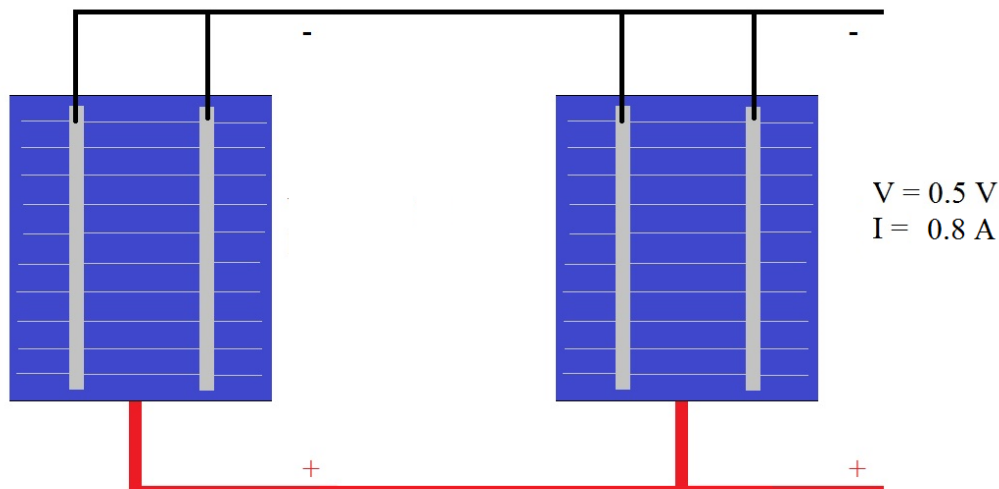
If we generate a large amount of current, close to 0.4 A, the solar cell will run closer to 0.3 or 0.4 V.

If we had multiple solar cells, how would we get more current?

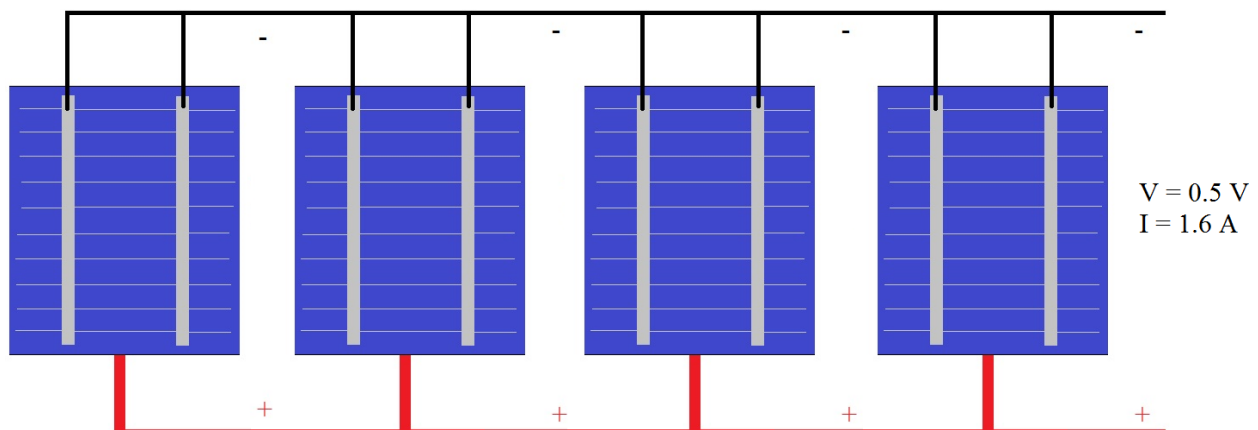
APPENDIX B: Examples of Parallel and Series Circuit

Parallel Connections:

If we take two similar or identical solar cells and connect the negative terminals together (negative to negative) and then connect the positive terminals together (positive to positive), we will create a solar cell that has twice the area (collects twice as much sunlight) and generates twice as much current. This is shown in the schematic below.



Now the new, larger solar cell can provide more current without the voltage dropping as much. If we had three or four solar cells and continued to connect them in parallel, we would continue to increase the current that the solar module would generate. Again, this is shown below:



This module (made up of four solar cells connected in parallel) is capable of producing four times the current of any one of the cells. **Parallel connected solar cells provide more current while operating their optimal voltage.**

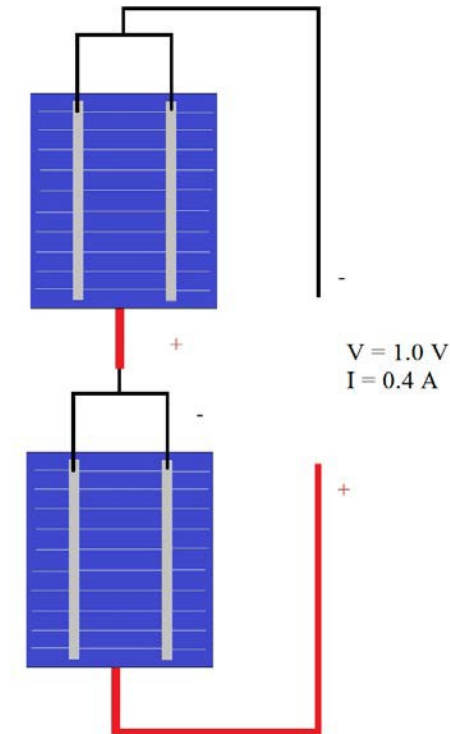
All we've done so far is increase the current of the system. Is there a way to increase the voltage?

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Yes there is! We can use **series connections**.

Series Connections:

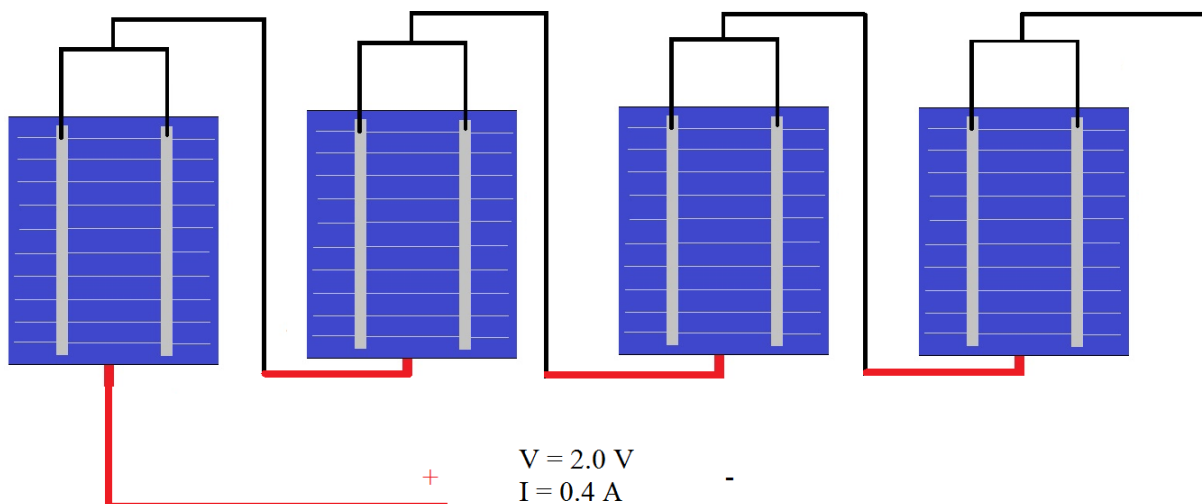
If we take two cells with the same current and connect one negative terminal to one positive terminal, then the remaining two connections will produce two times the voltage with the same current as before.



This new module is capable of producing more voltage than the single solar cell, but it does not have more current than the single solar cell.

What would happen if we connected three or four solar cells in series?

Answer: The voltage would increase proportionally.



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Can we increase the current **and** the voltage at the same time? Yes! We have to use a series-parallel configuration.

Series-Parallel Connections:

So far, we have dealt with identical solar cells, so we haven't had to match currents or match voltages. However, when you create series-parallel connections, it gets a little tricky.

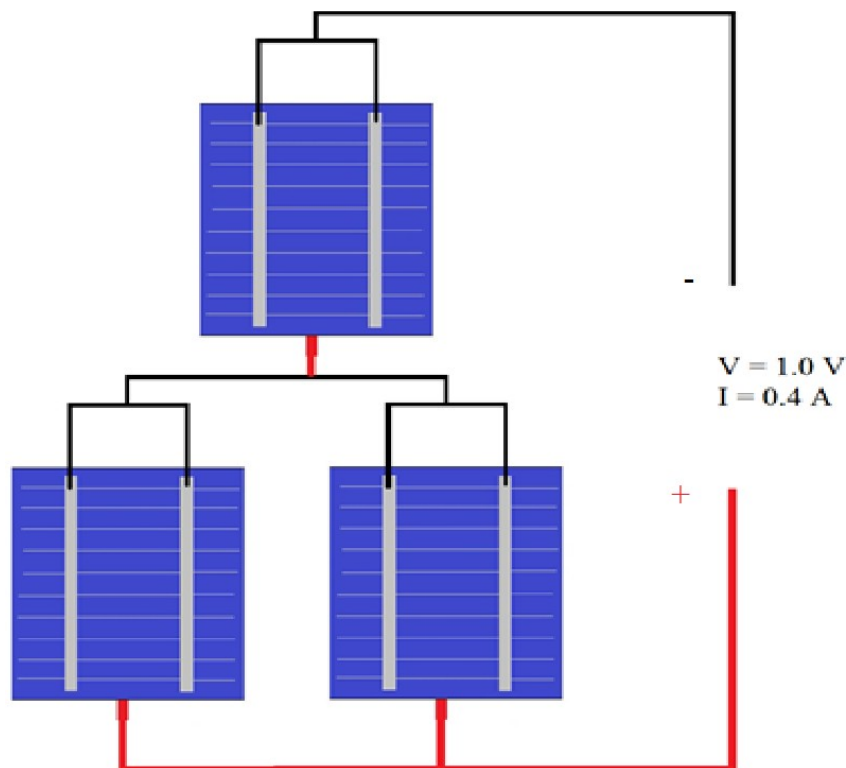
In a series connection, each solar cell has to produce the same amount of current. **If one produces a little less, then the new module will produce less.** This is called **current mismatch**.

In a parallel connection, each solar cell has to produce the same voltage. **If one produces a little less, then the new module will produce less.** This is called **voltage mismatch**.

Let's look at some configurations that have these problems.

Current Mismatch

This is when the current of the system is limited by one or more solar cells.

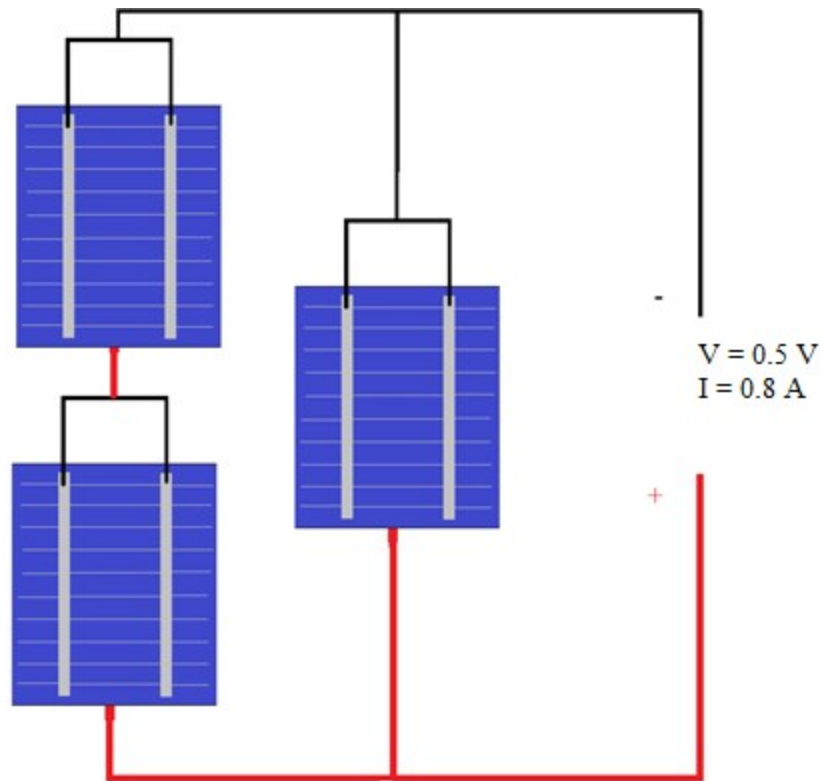


Here, the top cell only wants to produce 0.4 A of current, even though the bottom two cells are trying to produce 0.8 A. Ultimately, this makes a solar module that is limited to the least performing part of the circuit, the 0.4 A solar cell.

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Voltage Mismatch

This is when the voltage of the system is limited by one or more solar cells.

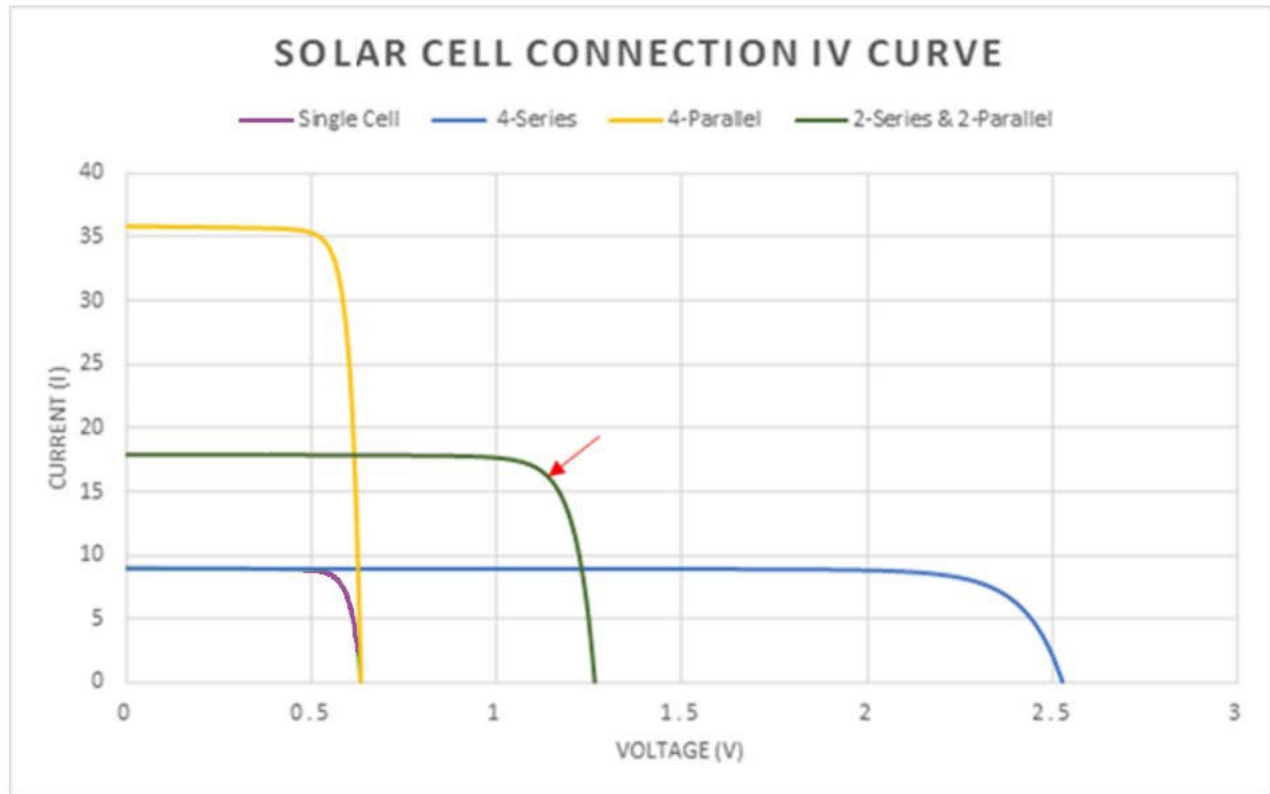


Here, the cells on the left are connected in series and want to produce 1.0 V, but the cell on the right only wants to produce 0.5 V. Ultimately this makes a solar module that is limited to the least performing part of the circuit, the 0.5 V of the solar cell.

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Cell Connection Summary

How will you connect your cells to get the optimal power? Remember: $P = IV$



The above graph represents how electrical performance is dependent upon the connections of your solar cells. The purple curve shows the electrical performance of a typical solar cell, with a small current (I) and small voltage (V). The blue curve shows that when 4 solar cells are connected in series the current will remain the same while the voltage increases. The yellow curve shows how current increases and voltage remains the same when you place all 4 cells in a parallel connection. The dark green curve shows how the current and voltage adds together when you place 2 series connected cells in parallel (series-parallel connections).

To get the maximum power you need the maximum product of current and voltage, not just one or the other, where does that happen on the graph? The red arrow shows the place with highest power given the solar cells available. However, this would be something that you could easily test and verify for yourself (**and record in your notebook.**) Which setup works best for you?

APPENDIX C: Example of Student Design Notebook

Today's Date 1

Problem Statement

- Build a solar car fitting specific requirements (see below) to compete in three challenges: a speed race, an alignment track, and a strength test; notebook also graded for points
 - Height: 30"
 - Width: 30"
 - Length: 60"
 - Other specs

Important Dates

Weekly meetings: Tuesdays, 3:00 PM

MESA Regionals

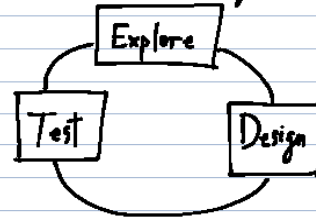
Other MESA-related events

Materials

Provided:

- 1) 4 small solar panels
 - 2) Motor
 - 3) Gears
- } Find specs

MESA Design Process



Team Members

Danny Simonet – SolidWorks, PSPICE, solar

Kathie Beckman – circuits, SolidWorks, PSPICE

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Today's Date 2

Today's Goals

- 1) Find all specs and dimensions of materials given
- 2) Tinker (free exploration) with solar panels and gears
 - a) What gears actually fit together? All? Some?
- 3) Take notes on information in packet and do research
 - a) Google?

Notes

From packet

Voltage: electric potential over an object, e.g. a battery (measured in volts, V)

Current: flow of electrons (measured in amps, A)

From pveducation.org:

Power = IV

Team Check

Ways we could improve as a team:

- Better time management
 - Create a calendar for the weeks
- Remember to build on each other's ideas more

Explore

2016 Hosting Guidelines

Appendix C

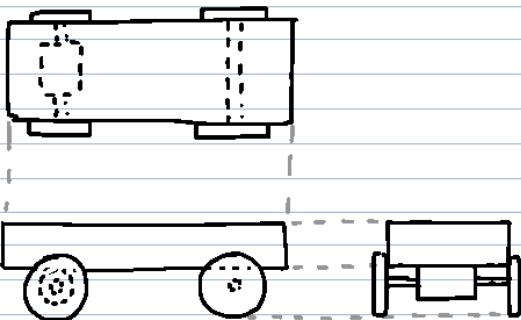
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Today's Date 3

Goals

- 1) Create a basic circuit to try to power the motor
 - a) Make various circuit designs to see how the motor is affected
- 2) Begin brainstorming a general body structure of the car for the panels
- 3) Ask about tips on making cars run

Design #1



Wheel radius: x inches

Axel radius: y inches

- Flat body to hold panels
- Cuts for gears to fit on axels
- Suggested made out of balsa wood
 - Lightweight

} Not shown in drawing

Design

Appendix C

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Today's Date 4

Data	Trial	Time	Comments
	1	22 sec	Not enough
	2	23 sec	sun?
	3	27 sec	

Test

Conclusion

- What went wrong?
 - Was not fast enough
- Solution
 - Create a completely new design

Notes

Talked to QESST graduate student Max Cotton and my uncle (mechanic) about cars

- Research gear ratio
 - What is torque? Power? How do they relate?
 - What is angular velocity? Max said we want to maximize this number for the fastest car
- Also think about different challenges - we don't need lots of speed (angular velocity) when pushing stuff
 - Why?
- Think about "Sketch Up" (computer program)

Explore

QESST Solar Car Challenge
2018 Hosting Guidelines

APPENDIX D: Helpful links to information about solar energy

Solar Energy Web Links

1. Conduct experiments related to designing solar cars <http://www.nrel.gov/docs/gen/fy01/30826.pdf>
2. Get ideas for designing solar cars <http://www.nrel.gov/docs/gen/fy01/30828.pdf>
3. Learn more about photovoltaics and powering DC motors. Plus, find ideas for solar science fair projects! <http://www.makeitsolar.com/solar-energy-information/07-solar-cells.htm>
4. Understand how a solar cell works <http://www.explainthatstuff.com/solarcells.html>
5. See a video explaining how a solar panel works <https://www.youtube.com/watch?v=xKxrkht7CpY>
6. Here is a lesson on solar concentrators_ https://www.teachengineering.org/lessons/view/cub_pveff_lesson04
7. See a video about why we do solar engineering research at QESST <http://pv.asu.edu/>
8. This is a challenging read, but good information about solar energy and photovoltaics_ <http://pveducation.org/pvcdrom>
9. There is a great interactive site for circuits and voltage that they can play with. https://phet.colorado.edu/sims/html/circuit-construction-kit-dc-virtual-lab/latest/circuit-construction-kit-dc-virtual-lab_en.html
10. AND of COURSE to learn more about what we do at QESST!! <https://qesst.asu.edu/>

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