Junior Solar Sprint: Introduction & Overview

If you are unfamiliar with the Junior Solar Sprint, before beginning watch the video and read the rules. The Junior Solar Sprint video can be found here: **https://vimeo.com/fsec/jss2001**
and the rules for the competition can be found here:
http://www.fsec.ucf.edu/en/education/k-12/energywhiz_olympics/jss/rules.htm

Background Information For Educators

If you are unfamiliar with the Junior Solar Sprint, you may want to preview the video and read the rules before class.

The competition challenges students to design, build and race model cars powered entirely by solar energy. The students are challenged to use scientific know-how, creative thinking, experimentation and teamwork to design and build their solar-powered electric vehicle.

The Junior Solar Sprint competition was started by the US Department of Energy in 1991 to expose students to photovoltaics and its potential for their future. Several states hold Junior Solar Spring competitions, including Florida, Colorado, Texas, Virginia, and New York. In Florida, the Junior Solar Sprint is held in several regional events (Expos) in the spring with the culminating event at the Florida Solar Energy center in May. Each year at the Energy Whiz event at FSEC over 60 teams from throughout Florida and other surrounding states compete in race and design competitions. Check the FSEC website **http://www.fsec.ucf.edu/go/energywhiz** for the current year's dates and places.

The goal of this engineering challenge is for the team to design and build a race-worthy, solar-powered vehicle that can rapidly transport a ping-pong ball down a 20 meter track.

Materials Needed for Building the JSS Cars

- solar panel and motor (from Solar Made or Pitsco kit)
- multimeter
- wheels – found, recycled or purchased
- gears – found, recycled or purchased
- various materials for car body and chassis such as balsa wood, styrofoam, foam core, aluminum, plastic, heavy paper, and recycled containers
- rods for axles
- plastic and metal tubing for bearings and bushings
- various glues such as hot glue, wood glue, and contact cement
- various tools such as soldering iron and solder, needle nose pliers, screwdriver, razor knife, scissors, wire cutters, small adjustable wrench, electric drill & bits
- rulers
- small vice or clamps
- wire

- alligator clips
- electrical tape
- velcro
- safety glasses

Materials Needed for Specific Investigations

For The Photovoltaic Panel:
- protrator
- aluminum foil
- wires with alligator clips

For The Chassis
- heavy paper, cardstock
- small weights or uniformly weighted objects (such as pennies)
- dowels

For Wheels, Axles and Bearings:
- plank that can be lifted at one end
- soup or juice cans
- lid that fits over top of cans–not tight
- marbles
- plasticine clay
- coins (15 per team)

For Drive Train & Transmission
- board with two nails hammered through it just far enough apart to stretch the rubber bands between them
- large spool and small spool to put on nails
- wide rubber bands
- gear table and gears with several different sizes of gears (such as Lego, K'nex or other educational gear sets) Or:
    - non-corrugated cardboard
    - glue stick
    - T-pins or other large pins
    - 6" x 8" piece of foamboard

For The Body
- miniature or toy car
- 6 x 8" piece of foamcore or thin plywood
- masking tape
- ramp
- empty soda can
- (2) dowels, 10" long, ½" in diameter or greater
- 6" strips of lightweight string or yarn
- box fan
- cardboard box with a face dimension close to that of the fan
- cardboard tubes (paper towel size)

1 – Junior Solar Sprint: Let's Get Started!

This module serves as an introduction to Junior Solar Sprint, and to help the students think 'outside the box' for materials and construction ideas. Team members should freely discuss ideas for building–at this point nothing is 'wrong'. Even though you know the challenges of building something like a 1-wheel vehicle, save those concrete design discoveries for a later time. That being said, students should think within the parameters of the rules (i.e. size constraints, no radio controlled steering, etc).

If the team members are unfamiliar with the Junior Solar Sprint competition, show the video to get them excited, then turn them loose. It can be useful to provide large sheets of paper for the students to sketch out design ideas and thoughts. Remember, if your teams are competing in a sanctioned Junior Solar Sprint event, a log book of the team's work will be required. This is a good time to have them start collecting their sketches!

Tips For Success

- Working in teams the members can share their strengths, and also hone their teamwork skills
- Good sources of recycled parts are: bottles, syrofoam trays, and boxes for bodys; CDs, and old toy parts for wheels; parts recycled from broken printers, VHS machines and other electronics for gears.
- Weight is the number one concern. Because of their weight, some items are not good for JSS cars, such as: Legos, most 'toy' R/C car parts, and wood other than balsa.
- Too large is not good either. JSS cars are usually small and do not come close to the maximum allowable size.
- JSS cars can have any number of wheels–3 and 4 wheels are the most common.

Florida Next Generation Science Standards

Fourth Grade: SC.4.N.1.1, SC.4.N.1.5 (Practice of Science), SC.4.P.10.1, SC.4.P.10.2 (Forms of Energy)

Fifth Grade: SC.5.N.1.1 (Practice of Science), SC.5.P.10.1, SC.5.P.10.2, SC.5.P.10.4 (Forms of Energy), SC.5.P.11.1 (Energy Transfer and Transformations), SC.5.P.13.1, SC.5.P.13.2, SC.5.P.13.3, SC.5.P.13.4 (Forces and Changes in Motion)

Sixth Grade: SC.6.N.1 (Practice of Science), SC.6.P.11 (Energy Transfer & Transformation)

Seventh Grade: SC.7.N.1 (Practice of Science), SC.7.P.11 (Energy Transfer & Transformation)

National Common Core Science Standards

Fourth Grade: PS3-1, PS3-2, PS3-4 (Energy), ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Fifth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Sixth, Seventh and Eighth Grades: PS2-3 (Motion and Stability), ETS1-1, ETS1-2, DTS1-3, ETS1-4 (Engineering Design)

Suggested Internet Sites

http://www.nrel.gov/education/jss_hfc.html

National Junior Solar Sprint web site sponsored by the National Renewable Energy Laboratory

http://www.fsec.ucf.edu/go/jss

Florida Solar Energy Center's Junior Solar Sprint web page.

http://fsec.zenfolio.com/ew

Photo gallery of past year's Energy Whiz JSS entries.

http://doolittle.icarus.com/jss/

Larry Doolittle of Lawrence Berkeley National Laboratory has written a program that simulates a Junior Solar Sprint race based on the variables of your car.

http://science.howstuffworks.com/178-how-solar-cars-work-video.htm

How Stuff works video, How Solar Cars Work. Interview with captain of the University of Michigan solar car race team, describing the race car, its parts and how they work.

http://tryengineering.org/play-games/solar-car-racing-game

Try Engineering, solar car race game. Pick the components of your solar race car and then race it on the track.

http://www.worldsolarchallenge.org/

World Solar Car Challenge, annual solar car race held in Australia.

http://americansolarchallenge.org/

American Solar Challenge, a college level competition to design, build and race solar-powered cars across America.

www.solarcarchallenge.org/

A long distance solar car race for high school students.

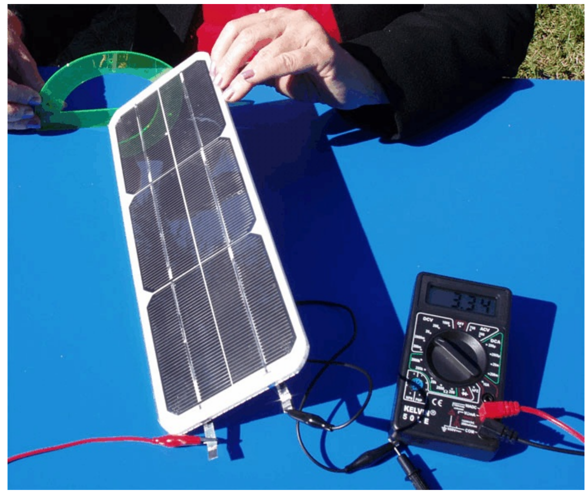
https://www.youtube.com/watch?v=OXcPFuAhvkk

Dragon Fly TV's episode on solar cars. Kids do experiments using a Junior Solar Sprint car.

Further Research

1. How can photovoltaics be utilized in full sized cars? Research full sized solar race cars. When and where is the next race going to be held?
2. How could solar be used to charge an electric car? Draw a diagram or find a photograph on the internet of an electric car that charges its batteries using photovoltaics.

2 – Junior Solar Sprint: The Photovoltaic Panel



In this module the team will learn what factors influence how much electricity their solar (photovoltaic) panel produces, and how to maximize its output. This will be important to them because the more electricity they can get to the motor, the more power will be available for their race car!

The results for the investigations will vary between seasons and time of day, but the teams should discover:

- that shading drastically affects the output of the cell–shading 1/3 of a cell will decrease the amount of power output by more than 1/3
- the best angle for the panel is with the face perpendicular to the sun at near the angle of incidence (Additional fun note: Your angle of incidence will equal your latitude on solar noon in the summer)
- the amperage output of the cells will increase as the cell cools. One of the easiest ways for the students to understand this is that the cells are made of the same type of materials as computer cells. (Additional fun note: Full-size solar race car teams often cool their panels down prior to a race by hosing them down with cool water!)

In the *Discussion & Design Decisions* section, there are questions that the team can use to help them formulate design ideas based on the information they learned about their panel during the activity.

Tips For Success

- Reflectors will increase the electrical output of the panel, but can shade the panel when the sun is low in the sky and are not effective in windy conditions.
- Photovoltaics produce the most electricity during the hours of peak sunshine, approximately 10:00 - 2:00 each day.
- Haze or shade will decrease the output of the panel, however the best cars will still be able to run in hazy conditions.
- To test the panels when sunlight is not available, use an overhead projector, xenon light or a halogen light. If you use a halogen bulb, care must be taken with the extreme heat from the bulb–it will damage the panel and can burn the skin.
- Velcro may be used to secure the panel to the chassis/body of the car, so that the panel can be used with several vehicles or for several years. Solder alligator clips on the leads from the panel so it can be attached to the motor easily.
- If students use rubber bands or tie-wraps to secure the panel to the car, it will shade part of the panel and decrease its output.

Background Information For Educators – Photovoltaics

Photovoltaics use light to produce electricity. Photovoltaic systems are quiet, clean, and non-polluting. Photovoltaic cells (called PV or solar cells) are made of silicon (sand). The silicon is heated to extreme temperatures. It is doped (mixed) with chemicals, usually boron and phosphorous. This sets up an unstable environment within the photovoltaic cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electrons follow the wire and power whatever load is attached--in this case a motor. This flow of electrons is called electricity. Photovoltaic systems are quiet, clean, and non-polluting.

The stated output rating for any size photovoltaic device is the amount of electricity in watts expected when sunlight and temperature are at Standard Test Conditions (STC). The STC for photovoltaics is irradiance (sunlight) at 1000 W/m^2, solar spectrum (air mass) at AM 1.5 (sea level with the sun directly overhead would be AM 1.0), and temperature of 25º C. When any of these three factors are different than the standard amounts, the electrical output of the photovoltaics will vary. Real world variables that affect the electrical output of photovoltaics are:

- **time of day** - As the Earth rotates and sun appears to move across the sky during the day, the amount of air mass that sunlight has to travel through varies. A graph of the intensity of sunlight throughout the hours of a clear day would be bell-shaped.
- **season of the year** - In the northern hemisphere, the sun is higher in the sky (less air mass) in the summer than in the winter. The difference in the angle of the sun between summer and winter is 47º, or a difference in air mass of approximately .75.
- **latitude** - because of the tilt of the Earth, the higher the latitude above 23½ º, the more atmosphere that sunlight must go through to reach the surface. Latitudes between 23½º N and 23½º S will have two days each year when the sun is directly overhead at noon–an airmass of 1.0 at sea level.
- **angle** - photovoltaic output is the highest when the cell/panel is perpendicular to the sunlight. To maximize the electric output of a photovoltaic cell/module/array throughout the year, it would need to track the sun on two axis to remain perpendicular to the sun throughout the day and seasons. In real world situations, most panels are mounted in one fixed direction (south facing–in the Northern Hemisphere) and to one fixed angle. As the sunlight moves away from the perpendicular during the day (east-west axis) or during the seasons (north-south) axis, the output of the array decreases.
- **temperature** - Heat can reduce a photovoltaic cell's electrical output. (Higher temperature increases the conductivity of the semiconductor, charges become balanced within the material, reducing the magnitude of the electric field, and inhibiting the charge separation, which lowers the voltage across the cell.) Higher temperatures can decrease the electrical output by 10% or more; conversely, cooling photovoltaics in warm climates can increase their output.
- **irradiance** - (measure of the power density of the sunlight that strikes the earth) - This is affected by weather phenomena such as clouds, but also particulate matter in the air. Latitude figures into the range that this value can take (air mass again) so that in some areas a clear sunny day at solar noon would have an irradiance level of 900 W/m^2, while others would have 1200 W/m^2
- **shadows** - as expected, any shadow on a photovoltaic cell decreases its output. In a single cell, the amount of shading is proportional to the decrease in output. However, in a panel

or module where cells are connected in series, shading can produce a significant voltage drop that can result in a decrease in electric output far greater than the percentage of the panel that is shaded.

- **reflection** - extra light reflected onto photovoltaics will increase their electric output. Snow banks, bodies of water or mirrors can increase the output of a panel or module. However, care must be taken not to increase the temperature of the cells, or these benefits will be negated.

Electricity

The Junior Solar Sprint panel has two leads (wire or metal) coming off of it–a positive and a negative. The motor can be attached in either direction; however, if your car runs backwards after attaching the panel, reverse the wires on the motor. After you determine which lead should be connected to the positive and which to the negative, mark the leads of the motor with sharpie or paint. Electrical terminology and associations to the Junior Solar Sprint project are:

- **amp (amperage)** is the unit of measure of the number of electrons flowing through a wire per unit of time (current). The amperage output of the Junior Solar Sprint panel at full sunlight is approximately 1 amp. A high enough amperage is necessary to power the motor; if the amperage output is too low (not enough sunlight), the motor will not spin.
- **angle of incidence** - the angle of the sun in relation to level ground. Varies according to location (latitude) and time of day. The best angle for sunlight to strike the photovoltaic panel is perpendicular (90º).
- **volt** - the unit of measure of the force of electricity in a circuit. The volt is not a unit of flow, it is analogous to pressure of water in a hose. The Junior Solar Sprint panel is a 3 volt panel.
- **watt** - the standard unit used to measure electricity, specifically the rate at which electrical energy is dissipated. It is calculated by multiplying the amperage times the voltage. The Junior Solar Sprint panel measures 3 watts in full sun, meaning that its output is basically equal to the output of two AA batteries.
- **resistance** - the measure of how much a material reduces the current going through it. To reduce the amount of resistance (current loss) in a Junior Solar Sprint car, make sure that all the wire connections are secure (soldier those that you can), and make sure that the wire isn't too thin or longer than it needs to be.

Florida Next Generation Science Standards

Fourth Grade: SC.4.N.1.1, SC.4.N.1.4, SC.4.N.1.5 (Practice of Science), SC.4.P.10.1 (Forms of Energy)

Fifth Grade: SC.5.N.1.1 (Practice of Science), SC.5.P.10.1 (Forms of Energy), SC.5.P.11.1 (Energy Transfer and Transformations)

Sixth Grade: SC.6.N.1.1, SC.6.N.1.4, SC.6.N.1.5 (Practice of Science)

Seventh Grade: SC.7.N.1.1 (Practice of Science), SC.7.P.10.1 (Forms of Energy), SC.7.P.11.2 (Energy Transfer & Transformations)

Eighth Grade: SC.8.N.1.1, SC.8.N.1.2, SC.8.N.1.6 (Practice of Science)

National Common Core Science Standards

Fourth Grade: PS3-2 (Energy), ETS1-1, ETS1-2, ETS1-3 (Engineering Design)
Fifth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)
Sixth, Seventh and Eighth Grades: PS2-3 (Motion and Stability), ETS1-1, ETS1-2, ETS1-3, ETS1-4 (Engineering Design)

Suggested Internet Sites

http://www.chuck-wright.com/SolarSprintPV/SolarSprintPV.html
Explains the basic physics of the photovoltaics and specifically the 3V (Junior Solar Sprint) panel used in this activity. Inclueds graphs of the panel current and output power in varying conditions

http://www.eia.gov/kids/energy.cfm?page=solar_home-basics
Department of Energy, Energy Kids photovoltaics page

http://energy.gov/eere/energybasics/articles/photovoltaic-technology-basics
Department of Energy photovoltaics page explains how photovoltaics work and includes a brief animation

http://energyquest.ca.gov/
California Energy Commission's interactive student page

http://www.engineeringtoolbox.com/electrical-formulas-d_455.html
Common electrical formulas.

http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm
Florida Solar Energy Center's photovoltaic fundamentals page explains the basics of photovoltaic cells including their manufacture, the components of systems, as well as the pros and cons of photovoltaic power. Site is suitable for teachers, mentors and advanced students.

Further Research

1. Photovoltaic mounting systems that track the sun during the day are not common. Research why this is currently the case. What would have to be different for tracking systems to become more common?
2. What is the current efficiency that is being reported in laboratory experiments with photovoltaics? Why would the efficiencies reported in these experiments be higher than the efficiencies that are common on photovoltaic systems installed on homes and businesses today?
3. The American Solar Energy Society (ASES) hosts a yearly solar 'tour' throughout the United States. Find out when the next tour is to be held in your state.

3 – Junior Solar Sprint: The Chassis

In this module, students will learn the properties that make a good chassis, learn the difference between stiffness and strength, investigate ways to strengthen weak materials and stiffen flexible materials.

In the *Discussion & Design Decisions* section, there are questions that the team can use to help them formulate design ideas based on the information they learned about material strength and flexibility.

Before beginning, make sure the teams understand the difference between chassis materials and body materials. For example, a plastic soda bottle may make an excellent body, but a lousy chassis, since it would be difficult to attach the axles, wheels, motors and gears to it!

Tips For Success

- Students should think lightweight.
- Students may design a chassis that allows the angle of the panel to be adjusted to match the angle of the sunlight for a specific location and time of day.
- Besides the motor and panel, the chassis will need to hold the battery clip(s), ping-pong ball holder, axles and eyelet. Most battery clips and ping-pong ball holders are located on the top and most eyelets and axles are on the bottom of the chassis. However, this is not a requirement; a car could instead have the eyelet on the front or on one side.
- All parts need to be glued securely to the chassis. Hot glue, 2 part epoxy and Gorilla glue can all be used successfully. Hot glue works well on the motor, but it can be challenging to get the motor in the perfect spot before it hardens. Also, students should not glue shut the motor's ventilation holes.
- The chassis and the glue holding the component parts should be strong enough to withstand some bumps and crashes. Students should design for worse care scenarios.
- An eyelet (see examples below) must be attached to the bottom of the car. This is the way the car will be steered on a line down the track. The eyelet must be designed so the car can be easily removable from the guide line, without disconnecting the guide line.

The rules state that the guide line is "1 cm (+/- .5cm) from the surface of the track". The variance of +/- .5cm is the difference between the ends which are higher, and the middle of the track which will sag slightly. A rectangular shaped eyelet has an advantage of having less friction when the guide wire is in the upper or lower position. The example on the right is a piece of a spine used for bound notebooks. It is extremely easy (and quick) to attach and disconnect from the wire.

- A switch needs to be put in the electrical circuit so that the power supply can be switched from the photovoltaic panel to the battery clip if the race needs to be switched to batteries because of weather. Only one source of power may be powering the motor at any given time. All connections should be secure–soldered if possible.

Florida Next Generation Science Standards

Fourth Grade: SC.4.N.1.1, SC.4.N.1.2, SC.4.N.1.4, SC.4.N.1.6 (Practice of Science), SC.4.P.8.1 (Properties of Matter)

Fifth Grade: SC.5.N.1.1 (Practice of Science)

Sixth Grade: SC.6.N.1.1, SC.6.N.1.4, SC.6.N.1.5 (Practice of Science), SC.6.N.3.4 (Theories, Laws, Hypothesis, Models), SC.6.P.13.1 (Forces & Changes in Motion)

Seventh Grade: SC.7.N.1.1 (Practice of Science)

Eighth Grade: SC.8.N.1.1, SC.8.N.1.2, SC.8.N.1.6 (Practice of Science), SC.8.N.3.1 (Role of Theories, Laws, Hypotheses, and Models)

National Common Core Science Standards

Fourth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

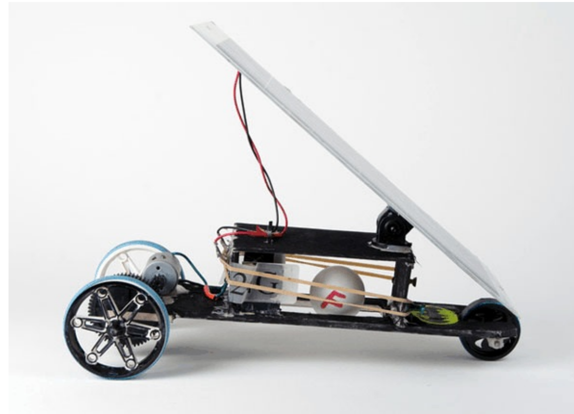
Fifth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Sixth, Seventh and Eighth Grades: ETS1-1, ETS1-2, ETS1-3, ETS1-4 (Engineering Design)

Further Research

1. What materials are currently being used in the chassis of our cars? Are there other materials that could be used in the future? Research materials being used in other applications such as bicycles and rockets.
2. What is a 'monocoque' construction? How has this been used in vehicles?

4 – Junior Solar Sprint: Wheels, Axles & Bearing



In this module, students will learn the reason for using bearings and bushings, and how to pick materials for wheels and axles. They will also investigate good friction (traction) and bad friction, and ways to minimize it.

In the *Discussion & Design Decisions* section, there are questions that the team can use to help them formulate design ideas to help them decide what materials to use for their wheels, axles and bearings, and whether or not they will use tires. The students shouldn't make a final decision on the size of their wheels yet–they will learn more about choosing the size of their wheels in the next activity.

Tips For Success

- Handmade wheels must be very accurately drilled with the hole in the exact center. This is not an easy task for a student, so whenever possible use disks that already have the center hole in them.
- The wheel is the last gear in the drive train and its size will have an effect on the top speed and the torque of the transmission.
- Make sure the axles are exactly perpendicular to the body of the car. The car should go straight forward on its own when placed on a flat surface and no guide line. If it doesn't, it will drag on the guide line going down the track, which will reduce its speed or stop its forward motion.
- The wheels should not rub against the side of the body or chassis. Use thrust bearing to hold the wheel off the side of the car. These can be made simply out of pieces of drinking straws.
- Axles and bearings should be made of smooth, slippery feeling, dissimilar materials.

Background Information For Educators

Bearing and bushing terminology and associations to the Junior Solar Sprint project:

- **bearing** – the interface between two parts. In your JSS vehicle we will be referring to the interface between the axle and the chassis. This can be as simple as a hole, or as complex as bushings or ball bearings.
- **ball bearing** – a type of bearing that uses small balls to reduce friction. These types of bearings can be used in JSS vehicles, although they are not necessary and would add extra weight to the vehicle.
- **thrust bearing** – in your JSS vehicle it is a device that keeps the axle from falling off the chassis. It can also keep the wheels from rubbing onto the side of the car. Pieces cut from drinking straws make excellent thrust bearings for JSS vehicles.

- **bushing** – a smooth sleeve that gives the axle a low friction surface. This is another place where pieces cut from drinking straws work very well.

Florida Next Generation Science Standards

Fourth Grade: SC.4.N.1.1, SC.4.N.1.2, SC.4.N.1.4 (Practice of Science), SC.4.P.8.1 (Properties of Matter)

Fifth Grade: SC.5.N.1.1 (Practice of Science), SC.5.P.13.1, SC.5.P.13.3, SC.5.P.13.4 (Forces and Changes in Motion)

Sixth Grade: SC.6.N.1.1, SC.6.N.1.4, SC.6.N.1.5 (Practice of Science), SC.6.N.3.4 (Theories, Laws, Hypothesis, Models), SC.6.P.12.1 (Motion of Objects), SC.6.P.13.1 (Forces & Changes in Motion)

Seventh Grade: SC.7.N.1.1 (Practice of Science), SC.7.P.11.2 (Energy Transfer & Transformations)

Eighth Grade: SC.8.N.1.1, SC.8.N.1.2, SC.8.N.1.6 (Practice of Science), SC.8.N.3.1 (Role of Theories, Laws, Hypotheses, and Models)

National Common Core Science Standards

Fourth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Fifth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Sixth, Seventh and Eighth Grades: ETS1-1, ETS1-2, ETS1-3, ETS1-4 (Engineering Design)

Suggested Internet Sites

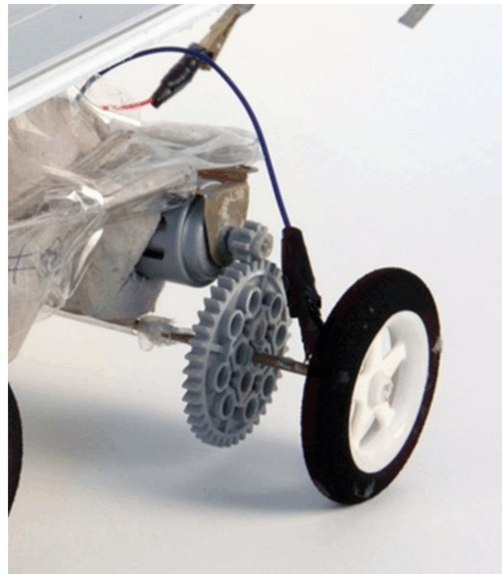
http://www.exploratorium.edu/snacks/downhill_race/index.html

Supplemental experiment/demonstration from the Exploratorium Teacher Institute demonstrating how the distribution of mass in a cylinder (wheel) affects how quickly an object accelerates.

http://www.societyofrobots.com/mechanics_dynamics.shtml

Humorous site discussing dynamics (acceleration, torque, wheel diameter, etc) in building motorized robots. The same basic principles apply to JSS cars.

5 – Junior Solar Sprint: Drive Train & Transmission



In this module the students will learn about different drive trains–direct drive, belt drive and gear drive. Students will investigate gear trains, discover how they work and how to calculate gear ratios. Students will also learn the difference between (and the importance of) torque and top speed and begin to design to maximize both.

In the *Discussion & Design Decisions* section, there are questions that the team can use to help them formulate design ideas based on the information they learned to decide what kind of transmission they want to use and begin to test their options.

Tips for Success

- Many students choose to use gears, but that is not the only way a JSS car can be powered. Successful cars have been made using belt drives; however, it is best to steer your students away from direct drive transmissions.
- The gears used on the car must have the same pitch to work properly. (Pitch refers to the size and angle of the teeth, not how many teeth the gear has).
- If the gears make a chattering noise when running, the gears are either not lined up correctly or are too loose and slipping. The connection between the gears must be made more solid. However, if the gears are too tight, they won't spin freely.
- If the car 'runs' great when held in the air but won't run when set on the ground, the car does not have enough torque to overcome the friction of the ground.
- A 4-to-1 gear ratio is a good place for students to start. Wheel size, car weight, wheel traction and number of gears will influence where the students will go from there.
- If the car runs backwards when the motor is connected, reverse the wires coming from the panel, then mark the connections.
- Since the JSS motor is a small hobby motor, it may need to be replaced after several years (or particularly hard) usage. The regulation motor and panel 'kits' for JSS are specifically paired and sold as a unit by the manufacturer (Pitsco or Solar Made). If the motor is changed out, it must be the same brand and size of motor that came with the panel you are using. Additionally, if you are using one panel for several different cars and moving it as you need it, make sure the additional motors that you purchase match the panel that will be powering them.
- Because of its weight, the position of the motor on the chassis can have an effect on the car's traction and its alignment. Additionally, if batteries are needed, their weight will have an influence on the car–a good design should take this possibility into account.

Background Information For Educators

Drive train terminology and associations to the Junior Solar Sprint project:

- **direct drive** – a transmission that has the motor connected directly to the axle of the driven wheel, as in a unicycle. These do not give a mechanical advantage, and do not work well in Junior Solar Sprint cars.
- **friction drive** – a transmission that uses the friction between the motor shaft and the drive wheel. In JSS vehicles, it is difficult to design this type of drive without slippage. Because of this, vehicles with friction drive are rarely seen in JSS cars.
- **pulley drive** – a transmission that uses a belt or chain between pulleys or wheels. Although it can be difficult to design a pulley drive so that the belt does not work its way off of the pulleys, this type of transmission is occasionally used successfully in JSS cars.
- **gear drive** – a transmission that uses a series of meshing gears (a gear train) to transfer power to the wheels. This type of transmission is the most common in JSS cars.

The gears in a gear train are:

- **driver gear** – the input motion and force is applied to this gear. It then transfers the power to the next gear in the sequence.
- **driven gear** – the output motion and force are transmitted by this gear. It receives its power from the prior gear in the sequence.
- **idler gear** – a gear in a gear train that is used to keep the driver and driven gears rotating in the same direction.

Gear ratios are the ratio of the rotation speed (number of turns) of the output shaft (driver gear) divided by the rotation speed of the input shaft (driven gear. This ratio is usually written as: ***gear ratio = rotations of a driver gear*** **:** ***rotations of a driven gear***. Individual gears are designated by their **pitch**--the number of teeth that can be put on 1 inch around a gear. Gears of the same pitch must be used together or they won't mesh properly.

In designing a vehicle, the **transmission ratio**, is the 'sweet spot' between speed and torque produced by a transmission to give the vehicle the desired power. Different applications and jobs will require differing transmission ratios to obtain the desired power. For example, a vehicle that carries a heavy load will require greater force (**torque**) to start from a stopped position.

Florida Next Generation Science Standards

Fourth Grade: SC.4.N.1.1 (Practice of Science), SC.4.P.10.1 (Forms of Energy), SC.4.P.12.1, SC.4.P.12.2. (Motion of Objects)

Fifth Grade: SC.5.N.1.1 (Practice of Science), SC.5.P.13.1, SC.5.P.13.2 (Forces and Changes in Motion)

Sixth Grade: SC.6.N.1.1, SC.6.N.1.4, SC.6.N.1.5 (Practice of Science), SC.6.N.3.4 (Theories, Laws, Hypothesis, Models), SC.6.P.13.1 (Forces & Changes in Motion)

Seventh Grade: SC.7.N.1.1 (Practice of Science), SC.7.P.11.2 (Energy Transfer & Transformations)

Eighth Grade: SC.8.N.1.1, SC.8.N.1.2, SC.8.N.1.6 (Practice of Science), SC.8.N.3.1 (Role of Theories, Laws, Hypotheses, and Models)

National Common Core Science Standards

Fourth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Fifth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Sixth, Seventh and Eighth Grades: ETS1-1, ETS1-2, ETS1-3, ETS1-4 (Engineering Design)

Suggested Internet Sites

http://www.nrel.gov/docs/gen/fy01/30827.pdf

National Renewable Energy Lab's Junior Solar Sprint page "Inside Tips on Parts and Construction". Pages 4 - 7 focus on drive trains and include the formulas needed to determine gear ratios, wheel speed in revolutions per second, optimal wheel circumference, and optimal drive pulley length.

http://www.nrel.gov/docs/gen/fy01/30830.pdf

National Renewable Energy Lab's Junior Solar Sprint page "Classroom Investigations". Page 4 includes an easy to fabricate transmission test box that is very useful for testing transmissions, axles and bearings before they are mounted on the car. Page 7 includes investigations that students can do with a multi-speed bicycle at home, including a racing investigation.

http://www.societyofrobots.com/mechanics_dynamics.shtml

Humorous site discussing dynamics (acceleration, torque, wheel diameter, etc) in building motorized robots. The same basic principles apply to JSS cars.

Further Research

1. What do the mass production electric vehicles currently use for a 'transmission'? How does it work?
2. How would you have to modify a Junior Solar Sprint car to run on the moon? Think of the change of gravity as well as the surface of the moon.

6 – Junior Solar Sprint: The Body

In this module, students will investigate aerodynamics and use a homemade wind tunnel to test different front end designs.

In the *Discussion & Design Decisions* section, there are questions that the team can use to help them formulate design ideas and plan what kind of body they want their vehicle to have.

The students JSS vehicles should now be taking shape. Encourage them to test, modify, test, modify, test, modify....and so on, until they think they have the fastest vehicle they can build. Then they can paint, decorate, add thematic items and personalize it.

Tips for Success

- The body for the JSS cars can be simple–paper, shirt cardboard, a plastic bottle, foamboard, etc. The students should try to think as lightweight as possible.
- A full body is not required for Junior Solar Sprint cars. They are required to have a space big enough for the decals on the side. That being said, there is an advantage to making the vehicle aerodynamic–at least to the point that head-on and cross winds on race day will not hinder the performance of the vehicle.

Florida Next Generation Science Standards

Fourth Grade: SC.4.N.1.1, SC.4.N.1.2 (Practice of Science), SC.4.P.10.4 (Forms of Energy)

Fifth Grade: SC.4.N.1.1 (Practice of Science), SC.5.P.13.1, SC.5.P.13.2 (Forces and Changes in Motion)

Sixth Grade: SC.6.N.1.1, SC.6.N.1.4, SC.6.N.1.5 (Practice of Science), SC.6.N.3.4 (Theories, Laws, Hypothesis, Models), SC.6.P.12.1 (Motion of Objects), SC.6.P.13.1 (Forces & Changes in Motion)

Seventh Grade: SC.7.N.1.1 (Practice of Science), SC.7.P.11.2 (Energy Transfer & Transformations)

Eighth Grade: SC.8.N.1.1, SC.8.N.1.2, SC.8.N.1.7 (Practice of Science), SC.8.N.3.1 (Role of Theories, Laws, Hypotheses, and Models)

National Common Core Science Standards

Fourth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Fifth Grade: ETS1-1, ETS1-2, ETS1-3 (Engineering Design)

Sixth, Seventh and Eighth Grades: ETS1-1, ETS1-2, ETS1-3, ETS1-4 (Engineering Design)

Suggested Internet Sites

http://www.uh.edu/engines/engines.htm

University of Houston's College of Engineering's *Engines of Our Ingenuity* series, #255 "Car Design" (**http://www.uh.edu/engines/epi255.htm**), and #1520 "Automobile Drag Coefficients" (**http://www.uh.edu/engines/epi1520.htm**). These are transcripts from John Lienhard's popular radio show. Audio versions are also available on the website.

Further Research

1. Research what devices race cars use to manipulate the airflow around the cars to add to the driver's control at top speeds.

Junior Solar Sprint: Instructions for Race Organizers

The information below is given for those who want to put on their own race or intramural event.

Track Specifications:

Lane Length:
20 meters

Lane Width:
60 centimeters

Number of Lanes:

- Depends upon the total number of entrants and the time available. Less than 25 teams can be run on one (two lane) track.
- Time trials are done during a set amount of time (½ hour to 1 hour depending on the number of vehicles entered). Allow 1 hour for each division's double elimination.

Track Surface:

- As smooth as possible, flat and level or slightly downhill in the direction of the race.
- Unshaded, fully exposed to the open sky all day.
- Oriented if possible, so that prevailing winds are behind the vehicles as crosswinds can be a problem.
- Energy Whiz Expos and the Energy Whiz event at the Florida Solar Energy Center use a heavy gauge PVC coated 'turbidity barrier' (used in the construction industry for containment barriers) for the track lanes.

Layout:

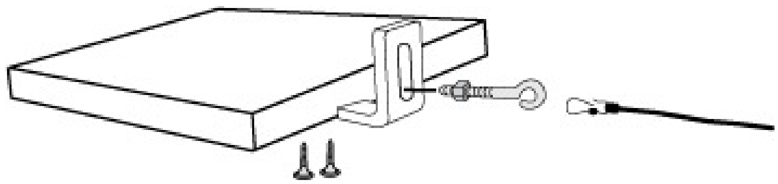
- Security roping should be placed around the perimeter of the track, as the guide lines are difficult to see.
- A second level of security roping should be used for team movement and to keep spectators off the track.
- A staging area near the start line and a run-off area beyond the finish line is necessary.
- A pit area is recommended for tune-ups between races. If possible, it should have a practice guide line.

Guide Lines:

- Monofilament fishing line, 60-lb test is adequate, braided line works best for hot sunny days.
- The line should be suspended about 1 cm (+/- .5 cm) off the ground.
- Lines must be kept taut. Check the line periodically during the event and pull taut as needed.

One way that the guide lines may be attached (see diagram following instructions):

- A 12" x 12" piece of 3/4" plywood may be used to anchor both ends of the guide wire.
- A threaded eye-bolt can be attached to a comer-reinforcing bracket to allow for height adjustment of the guide wire.
- Pre-measured guide wires can be attached to the eye bolts with fishing tackle clips.
- Once assembled, plywood should be anchored with 40lbs. of ballast (concrete blocks are easy) and moved apart to give the desired line tension.



Detail of guide wire ends

Timer:
- During time trials, one timing official is needed for each lane.
- During double elimination, the timer need not measure speed but must be able to determine the winner. (Note: Just like car or horse racing, the nose of the car crossing the finish line is the deciding event)

Communication:
- Efficient communication is needed between the starting line, the finish line, and the scoreboard. During time trials, it is helpful to have runners take the finish times from the timers to the scoreboard.
- A loudspeaker or bullhorn is helpful for public announcements and crowd control.

Intramural Racing:
- The purpose of the intramural race is to determine your class or school's entry to the regional race conducted by your Junior Solar Sprint host site.
- There are several options for determining your school's entry:
    - Teacher decision – It is not mandatory to conduct an intramural race.
    - By the clock – A school may set up one lane and race each vehicle against the clock. The vehicle with the best average time becomes the entry to the regional race. However, it is important that the vehicles run on a guide wire, as how well the car can run on a wire is a big factor in the car’s performance.
    - Lane races – Construct lanes and conduct a double elimination race.
    - Full-scale intramural race – The JSS is a great opportunity for publicity at many levels. Invite as many people as possible to the event including parents, scientists, teachers, students, and the media.