

# Junior Solar Sprint

## Teacher and Mentor Guide

*Written by:*

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## Introduction

Thank you for participating in the Junior Solar Sprint (JSS) program. This program is quickly expanding and evolving! This year we are providing some new background information that we hope you and your students will find helpful. This Teacher and Mentor Guide includes a suggested lesson plan for you to work from. We encourage you to modify it to suit your own circumstances.

“An Introduction to Building a Model Solar Car” is a reference provided for students; teachers and mentors may find it useful either as background information or to generate ideas for their program. Keep in mind that one of the mentor’s roles is to provide teachers with technical support, so teachers should feel free to call mentors with any questions.

In designing this program we set the following goals:

- Present science concepts in a fun and exciting way.
- Give students a chance to interact with engineers and scientists.
- Stimulate creative thinking through a hands-on design project.
- Help students to experience the satisfaction of creating a working machine and the excitement of entering it in a competition.

In this guide, we have incorporated suggestions from last year’s teacher and mentor participants. The sections which follow are meant to be guidelines and suggestions. It is important to keep in mind that there is no single correct way to successfully complete this program. Remember that design is a creative process: professional engineers have variations in style and might not exactly follow the design procedure described in this document. If you have other ideas, which are not mentioned here, you should feel free to use them. We realize that mentors have different levels of time and flexibility and comfort with classroom teaching. Also, no two schools have exactly the same level of teacher expertise, student participation, or time scheduling flexibility.

## **The Role of Technical Mentor**

The role of a technical mentor is to provide teachers and classes with science and/or engineering expertise. How this occurs depends much on the individuals involved.

Examples of mentor contributions from 1993 Junior Solar Sprint include:

- Present JSS programs to the class.
- Bring students on a lab or workplace tour.
- Lead design and build sessions.
- Run Saturday or after school sessions.
- Provide constructive design feedback.
- Provide technical support for teachers and college-student volunteers.
- Build demonstrations.
- Assist students at area race.
- Discuss science and engineering professions.

Class time participation of the mentor ranges roughly from 5 to 20 hours. If the mentor is a student or has a very flexible work schedule, he or she may be able to spend even more time with the class. It is also common for mentors and teachers to have frequent telephone contact.

In addition to providing instruction and expertise for the JSS project, mentors share their professional science and engineering experiences with the class. This may or may not include tours of their lab or workplace.

Mentors have different levels of comfort with classroom teaching. Some may enjoy teaching class, while others may prefer to remain on the sidelines and answer questions.

It is suggested that teachers consider providing their mentors with a copy of the class's science and/or math (non-JSS) curriculum and schedule for the units covered during the JSS programs so the mentors have the opportunity to relate what they are presenting to the teacher's current lessons.

It is particularly useful for the mentor to come in to help the students evaluate one another's design, if a class period is set aside for this purpose. In this type of session, a design review, the mentor can ask and answer questions of the students and make suggestions for design enhancements.

## **Teaching Hands on Design: Comments and Suggestions**

**Working in Groups.** The recommended size for groups in this project is 2-4 students. We advocate that this project be completed by students working in groups rather than students working individually for several reasons. First, individual cooperation, like competition, involves skill and practice and is important in the professional engineering workplace. Second, working in a group is very often a strongly positive part of the project for students who have less confidence with hands-on work if group members help one another. Third, having the students share amongst themselves the search for and use of materials makes this portion of the project less costly and less intimidating for everyone.

We realize that in some classroom situations, setting up work teams is difficult. A common problem is that one student takes ownership of the project and the others have negligible contributions, making for resentment on all sides.

We do have some suggestions for avoiding this type of problem. Some teachers find that students unfamiliar with working in groups are more enthusiastic when working on a team that the students have selected. In other cases, it makes sense for teachers to designate groups themselves so that they can effectively balance student skills among groups. Another suggestion: encourage the groups to understand what is going on. For example, have the groups present their designs to the class, and require that each member of the group speak about some aspect of the design. Also, provide some incentives for the quiet people to speak up and the assertive people to listen. Both speaking and listening are important teamwork skills.

**Design Reviews as a Teaching Tool.** A particularly successful classroom activity, called the “design review” in the professional workplace, requires students to explain their designs to the entire class at certain designated points in the design process. Some examples are discussed in the curriculum section. This activity is helpful for everyone. The portion of the class listening to the presentation learns about other approaches to designing the car. The members of the group presenting have to understand their own project well enough to explain it. They receive useful feedback from their classmates, their teacher, and their mentor. Students gain valuable insight from constructively criticizing one another’s work. It is important, in the design review, to make sure that everyone gets a chance to give comments and receive suggestions.

**Answering Questions and Stimulating Thinking.** One of the goals of this project is to stimulate students to think and formulate their own questions. The next step in this process is to help students acquire the confidence to research their own answers, so that students do not make design selections because “This is what my teacher told me to do”. Students should be encouraged to ask questions because they are thinking, rather than to avoid thinking.

**Developing Individual Student Skills and Creativity.** We suggest thinking about ways to help individual students develop skills in areas which may not be their strengths. Encourage tentative

students to speak up and not be intimidated by assertive students. Encourage aggressive students to relax and listen to what others have to say. Since developing creativity is in itself a goal, give students room to be creative. Evaluate the project in multiple areas such as technical performance, aesthetics, and craftsmanship so that more students can be excited by at least one option. Encourage students who are not used to working with their hands to experiment and make mistakes. Encourage students who are used to working with their hands to be good teachers, patient and not overly helpful.

**Testing the Cars: Learning from Mistakes.** Students, like engineers, will learn from their mistakes! We expect things to go wrong the first (few) times. For this reason, engineers usually build one or more prototypes (test cars) to test out parts of their design before building the actual device.

Testing is an important part of the design process, and it often takes more time than anticipated. For students working on this project, it is useful to build one or more prototypes of components to help evaluate and test initial designs. Once a final version is built, it has to be tested as well.

**Recognition.**

It is important to give students positive feedback and recognition for their work. This can be done, for example, by holding races for the whole school to watch, or by having a school display of cars or drawings.

## **Leading the Program: Comments and Suggestions**

**Benefiting from Experienced Designers.** In some classrooms it makes sense to involve in the project parents who are scientists or engineers. These parents can advise in car-building sessions or arrange workplace tours for the class. Another possibility is to have students who participate in last year's program discuss their experiences with the class. They can demonstrate their car and explain design challenges they faced.

**Curriculum Areas Where JSS Can Be Used.** This program can be incorporated into many classroom curriculum areas, such as:

- Physics/Physical Science
- Transportation
- Alternative Energy
- Electricity
- Mechanics
- Earth Science

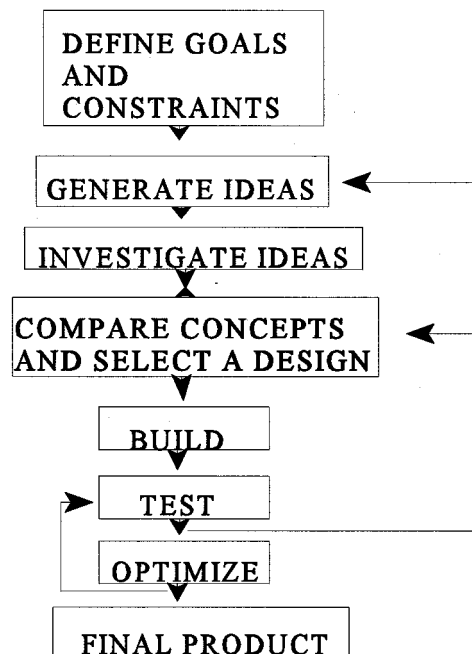
Incorporating the program into a pre-existing curriculum enable teachers to devote class time to the project while enhancing their existing curriculum.

**Working at Home vs. Working at School.** There are many scheduling alternatives: completing the program during class time, completing the program at school but after school, having Saturday working sessions, and having students take cars home to work on them. Each has its own advantages and disadvantages. We suggest having the students work at home only in programs where the students are likely to work in their groups at home. This alternative will be less ideal in schools and programs where the students working in group don't know each other or live far from one another. If the program is done primarily at school, it is important to reserve a space where students can store their materials safely.

## The Design Process

What is design? Design is the process of creating something new to perform a specific function. In this program, students will be given a specific mechanical design problem and asked to create a machine that solves it. To effectively channel creativity, professional design engineers impose a structure on the design process. The process used by many engineers is presented here for teachers and students to use in designing their solar vehicles.

The steps are as follows:



The process presented here may be used at any and all levels of model car design, from the design of individual components to the complete car as a system. The key principle in the process is to start all designs with many ideas, then investigate and evaluate several of them before locking into a design.

Part of the challenge in design is learning to combine good ideas from several people into a winning design. Students should be encouraged or required to use a notebook to record their ideas and sketches. Ideas not written down or sketched are quickly forgotten. In addition to providing a means to store and communicate ideas, putting thoughts down on paper often aids in idea generation and clarity.

## Define Goals and Constraints

To begin with, a designer needs to clearly define the problem: what is the **goal** of the design, and what **constraints** exist that will provide limits for the design.

Some possible **goals** for the design of the solar cars are:

- to make the race-winning model solar car
- to make a stylish model solar car
- to make a sturdy, robust solar car

Constraints are the limitations that are imposed upon the design by the designer or by the problem itself. In designing a model solar car some **constraints imposed by the designer** might be:

- Materials will cost less than \$20 and be easy to find
- The car must be constructed in 8 weeks

In addition, there are **constraints imposed by the rules**, such as:

- The car must be powered only by the solar panel and motor provided in the kit
- The car must be within the specified size limits
- The solar panel cannot be a structural member of the car

Defining the goals and constraints helps focus the designer's time and effort on the most important areas.

## Generate Ideas

Design relies on generating ideas. **Brainstorming** is an effective idea-generating technique that is usually done in groups. The goals of a "brainstorming session" is to generate as many ideas as possible in the given time. Groups often include individuals with varied backgrounds to get as many perspectives on a problem as possible. The duration of brainstorming sessions varies with the quantity and complexity of the issues to be discussed, but for a student group such as this a session lasting from 15 to 30 minutes is recommended. Students can begin with brainstorming ideas for car components.

Some possible topics for a brainstorming session are:

- Types of transmissions
- Ways to attach a solar panel to the car
- Aerodynamic body shapes
- Materials for wheels, axles and bearings

To make these sessions productive, it is useful to set a few rules before hand. One of the most important is "There is no such thing as a dumb idea". Participants are encouraged to contribute ideas they consider silly since these ideas may trigger more practical ones in their own or another participant's thinking. Another useful rule is "No one may interrupt the person who is speaking". To ensure that everyone gets a chance to contribute ideas, the leader may consider breaking the

class into smaller groups and sharing the results of the individual sessions. Students should sketch their ideas as much as possible, or otherwise record them clearly.

For an effective session there should be both a **leader** and a **scribe** (the mentor or teacher can serve as one or both). The leader's role is to keep the discussion from getting off-track and maintain order in the group. The scribe's job is to record all ideas that are generated. He or she is permitted to stop the session to ask for clarification of an idea (or for a participant to draw a concept) and should compile the notes for future reference.

Students can also generate ideas outside of brainstorming sessions. A skillful designer combines new ideas with existing ones, or combines existing ideas in innovative ways. To stimulate the generation of ideas and to increase the awareness of existing technologies, related mechanical devices (such as toys and small appliances) should be examined by the students. How did other designers solve problems similar to those in model solar car design (wheels, bearings, transmissions, chassis, etc.)? What parts can be used or where can similar parts be found? Reference book such as "The Way Things Work" by David Macaulay or users's manuals for various appliances may be consulted for ideas. Trips to hardware stores, hobby shops, crafts stores, etc. To look at various tools and gadgets are also good ways to get ideas. A good designer sees to it that he or she has a wide variety of ideas to choose from.

## **Investigate Ideas**

Once the ideas have been tossed around, students will be wondering how to choose between all of these concepts. They should be encouraged to formulate questions and experiments that will help to answer them. There is a natural tendency to go for the ideas that one likes best, or has a "gut" feeling for. These concepts may indeed be the ones that work out best, but unless they are tested against other concepts, the designer can never be sure that all ideas were investigated fully and the best design was selected.

There are many ways to investigate ideas, such as research and consulting with "experts", but the most direct and convincing way is to try it out for oneself. This is the essence of hands-on design. Often the design is broken into smaller problems which are investigating individually. In the case of a model solar car, the "smaller problems" are the individual mechanical components (wheels, transmissions, etc.). Some possible investigations are:

- What are good ways to build wheel axles and bearings?
- What is the effect of weight on a vehicle?
- How can a simple transmission be built from low-cost parts?
- What car body shapes have the lowest aerodynamic drag?

The investigations called for here are likely to be simple experiments where students get a feel for the mechanical concept behind their question. A complex investigation may be broken up and assigned to different groups or individuals; their results can later be shared with the entire class. A student investigating materials and methods for building a car chassis, for example, may take simple pieces of each material and watch how they react to various loads or forces. Another

example may be to build various transmissions on a simple chassis (not necessarily the one they intend to use in their final car) and compare their relative performance and ease of construction. As part of this process, students should identify design variable, that is, attributes which can be varied to affect performance. Some of those **design variables** are:

- transmission ratio
- wheel diameter
- vehicle shape
- material selection

The goal of these investigations is to gain an understanding of all the individual parts of a vehicle. The groups will probably have a few concepts for each component; they will be narrowed down in the next phase.

### **Compare Concepts and Select Design**

Designers are comparing concepts or doing “trade-offs” of alternative component designs throughout the design process. They weigh the various ideas against the design criteria and see which one(s) comes out best. Much of the time the designer does this in his or her head. However it is often helpful, especially when working with a group or a complex problem, to write down the pros and cons of each idea. Some examples of **pros and cons** for a particular transmission design (a gear drive in this case) are:

Pros	Cons
+ reliable	- harder to build and align properly
+ high efficiency	- harder to find meshing gears
+ won't slip	- harder to modify ratio

In addition to presenting all relevant information in a single place, the record of ideas also allows the designer to go back later and choose another design if the first one selected does not work out.

Once designs of individual components have been evaluated and one or two leaders identified, students can begin to integrate them into a complete car design. The design for the complete car will be a combination of the students' most workable components. The deciding factor in the choice between two or more workable options for a particular component may be its compatibility with the rest of the car's design. If concepts generated thus far are not sufficient, it may be necessary to refer to brainstorming notes and/or generate more ideas.

### **Build**

Building usually takes more time than you think, especially if the students are not familiar with the materials. The teacher and mentor should ensure that there is adequate time and supervision for build sessions. Thorough prototyping of components will also help final vehicle construction go smoothly. Parts built for experimentation may also be used in the final car design.

## Test

A long hallway or track and guide wires are useful for vehicle testing. Since solar power may not always be available for testing the vehicle, alternative power sources will be required. Teachers or mentors may need to help students mount batteries to their vehicles (note that car performance with batteries is unlikely to match that with the solar panel due to the internal resistance of the panel). A ramp may also be set up for “roll down” tests (motor must be disconnected from transmission) to test rolling resistance and aerodynamic drag.

The testing phase is an appropriate time for the class to discuss performance measures. Some **performance measures** for the complete car include:

- time to go 20 meters
- rolling resistance and aerodynamic drag
- total vehicle weight
- acceleration
- top speed

Intermediate contests based on one or more of these attributes may be held to identify leading designs. The winners can be decided on the basis of relative performance of multiple cars.

## Optimize

Optimization occurs after the car has been assembled and tested. This is the process of fine-tuning the design for top performance. The winning car in this contest is likely to have **optimized the design variables**, that is, chosen the best ones for the given task. This is not always straightforward. Experienced designers know that this process involved trade-offs, because optimizing one variable may prevent you optimizing another. For example, a frame that is both stiff and light may be desired, but stiffer frames may be heavier. Another classic example is the transmission ratio: a car with high top speed takes a long time to accelerate. Taking the time to optimize the car will often improve the performance dramatically.

## Suggested Syllabus

### Notes:

This is an eight week syllabus. Teachers and mentors are free to modify the content or schedule as they see fit.

Since we do not know when mentors will be able to attend classroom sessions, we have designed this curriculum with possible mentor roles at every point in the curriculum. This role may be filled when necessary by a teacher or other science resource.

### Philosophy:

In this syllabus for Junior Solar Sprint, students are encouraged to attack the overall design problem in a piece wise fashion, that is, to experiment with the various components individually.

Once students have a greater understanding of the working or various parts of the vehicle, assembling these components into a functional car becomes a simpler task. These investigations make up approximately the first half of the course. In the second half, students build, test and optimize the complete vehicle using the knowledge, and possibly some of the prototype components, from the first half of the course.

### **Week 1: JSS Program Introduction and Basics of Vehicle Design**

Mentor Visit:

- Show video and flyer
- Discuss Hands-on design and Design process
  - Relate to professional engineering
  - Relate to work and/or hobbies
- JSS Schedule
  - School Race approx. date
  - Area Race approx. date

Discuss Vehicle Design

- Define Goals and Constraints
  - Kit materials
  - Race rules
  - Vehicle specifications
- Discuss vehicle components
  - Chassis
  - Body
  - Motor
  - Wheels
  - Bearings
  - Transmissions
  - Energy source
- Brainstorm ideas for components/whole vehicle

Teacher Guidance:

- Form teams of 2-4 students
- Continue brainstorming in class

Student Work:

- **Brainstorm overall car concepts and sketch them**
  - How might your model solar car look?
- How do motors make things move?
  - Find examples of machines, toys, vehicles, etc. with mechanical components
- Come up with lists of questions that need answers before selecting a design

### **Week 2: Wheels, Axles, Bearings, and Chassis: Principles, Prototypes and Experiments**

Mentor Visit: **Design Review**

- Teams present car concepts and the questions that need answers before selecting design
- Class discussion of how to answer these questions, what experiments to conduct, performance measures
- Demonstrate/discuss physical principles:
  - Friction: losses in sliding parts
  - Inertia and acceleration
  - Stiffness and strength to weight ratio

#### Teacher Guidance

- Continue discussion of physical principles
- Lead class experiments
  - Inertia and acceleration
  - Methods of mounting wheels
  - Coasting test for friction and wheel alignment
- Assist students in obtaining building materials and tools
- See that all team members are contributing

#### Student Work:

- Conduct experiment to answer design questions
  - Build a prototype chassis and mount prototype wheels, axles and bearings
  - **Build something that rolls**
- Come up with additional lists of questions to be answered before a design can be selected
- Continue sketching concepts

### **Week 3: Motors, Transmissions and Gear Ratios: Principles, Prototypes and Experiments**

#### Mentor Visit:

- Class discussion of experimental results
- Demonstrate/discuss physical principles:
  - Transmission (gear) ratio
  - Motors
  - Torque and Force
  - Calculate distance travels per motor revolution (taking Into account gear ratio and wheel size)
- Continue class discussion of how to answer additional questions, what experiments to conduct, performance measures

#### Teacher Guidance:

- Continue discussion of physical principles
- Lead class experiments
  - Construct different transmission types and ratios
  - Study the effect of wheel diameter on transmission ratios
- Start planning for School Race

#### Student Work:

- Continue experiments to answer design questions
  - Experiment with various transmission types
  - Experiment with various wheel diameters
  - Mount motor and transmission on test chassis
  - **Build something that moves under its own power**

**Week 4: Motors, Electricity and Solar Panels: Principles and Experiments  
Aerodynamics: Principles and Experiments**

Mentor Visit:

- Class discussion of experimental results
- Discuss physical principles of:
  - Electric Motors
  - Electricity
  - Photovoltaics (Solar panels)
  - Aerodynamics and car body shape
- Continue class discussion of how to answer questions, what experiments to conduct, performance measures

Teacher Guidance:

- Continue discussion of physical principles
- Lead class experiments:
  - Measure solar panel output (voltage, current)
  - Demonstrate motor output (speed-torque relationship)
  - Study effects of voltage/current input on motor output
  - Measure air drag on different body shapes
- See that all team members are contributing

Student Work:

- Continue experiments to answer design questions
- Choose design for:
  - Chassis
  - Body/shell
  - Solar panel mount
  - **Build something that moves under solar power**
- Sketch final car designs to choose from

**Week 5: Select Overall Vehicle Design and Plan/Begin Construction**

Mentor Visit:

- Teams present car design to class and receive comments/suggestions
- Generate design criteria for vehicles:
  - Lightweight
  - Sturdy
  - Good acceleration
  - High top speed
  - Aerodynamic

- Low friction
- Steers straight
- Can accommodate guide wire
- Easy to build
- Aesthetics
- etc.
- Help each group select one design to build
  - List pros and cons
  - Combine best features from various concepts

Teacher Guidance:

- Assist students in selecting designs to build
- Help teams split up building tasks
  - Obtain materials
  - Build car components

Student Work:

- **Review concepts and select one design to be built**
  - Combine features from various designs
- Plan how to build it
  - Discuss building materials and methods
  - Split up building tasks
- Consider aesthetics
- Begin building

#### **Week 6: Construction of Vehicles**

Mentor Visit:

- Check progress of cars
- Find out problem areas and give design advice
- Remind teams to make provision for guide wire eyelet
- Review race rules

Teacher Guidance:

- Assist students to building vehicles and using tools
- Review physical principles with students as needed
- See that all team members are contributing

Student Work:

- **Build Vehicle**
  - Wheels
  - Mount wheels and axles on chassis
  - Build transmission and connect to motor

#### **Week 7: Complete Construction of Vehicles and Begin Testing**

Mentor Visit:

- Check progress of cars
- Find out problem areas and give design advice
- Check that vehicles are “legal”

- Will the designs work?  
- If a design cannot be successfully built, go back to list of concepts from Brainstorm session and select another

Teacher Guidance:

- Assist students in building vehicles and using tools
- Review physical principles with students as needed
- See that all team members are contributing
- Prepare for School Race

Student Work:

- **Finish building vehicles**
  - Complete chassis
  - Body
  - Solar panel mount
  - Aesthetics

## **Week 8: Optimize Vehicles**

Mentor Visit: **Design Review**

- Teams present vehicles to class and receive comments/suggestions
- Plan optimization experiments
  - Review design criteria for vehicles
  - Discuss performance measures

Teacher Guidance:

- Assist students in building vehicles and using tools
- Set up test track for optimization experiments
- See that all team members are contributing
- Check that vehicles are “legal”
- Prepare for School Race

Student Work:

### **Test vehicle**

- Decide whether or not to use existing design
- Begin optimization experiments
- Rework components as necessary to optimize vehicle
- Complete vehicles, add decorations and decals

### **Pre-Race**

Mentor Visit:

- See that all cars are working
- Assist teacher in making preparations for school race

Teacher Guidance:

- Assist students in building vehicles and using tools
- Set up test track for optimization experiments
- Finalize preparations for School Race

Student Work:

- Complete optimization experiments

- Rework components as necessary to optimize vehicle
- Complete vehicle

## **Project Tools and Materials**

Some of the materials and tools needed for the project are provided in the kits. Others are the responsibility of the schools and/or students. The lists which follow are not required lists; they are suggestions. Feel free to be creative and come up with other ideas.

### **Items Included in the Kit**

Solar Panel  
Motor

### **Items Available on NREL's Home Page:** <http://www.nrel.gov>

*Click on Global and Local Partnerships, click on education programs and click on Junior Solar Sprint*

“Introduction to Building a Model Solar Car”  
Junior Solar Sprint software (WINDOWS and MAC)  
Junior Solar Sprint software instructions  
“Junior Solar Sprint Classroom Investigations”  
“So... You Want to Build a Model Solar Car”  
“Junior Solar Sprint Teacher and Mentor Guide”  
“Junior Solar Sprint” Order form  
“Inside Tips on Parts and Construction”  
“Junior Solar Sprint Race Rules and Vehicle Specifications”

### **Suggested Materials**

Cardboard sheet  
Cardboard tubes  
Shaft material - 1/8 inch rods  
Foam core  
Styrofoam  
Wire hangers  
Straws  
Washers  
Stiff wire  
Solder tape (and matches)  
Wirenuts  
Electrical Wire  
Alligator Clips

### **Suggested Hand Tools**

Safety Glasses  
Scissors

Wire Cutters  
Pliers  
Tape -- masking, duct, electrical, fiberglass packing tape  
Hot glue  
Elmers glue  
Rulers  
Pencils  
Hacksaw  
Retractable Utility knife (or Exacto)  
File

## Safe Use of Hand Tools

Students will be working with hand tools while doing this project, so they should first familiarize themselves with their safe use. Below, we describe some commonly used hand tools and some dangerous situations that can result if they are not used properly.

Please be certain to go over this information with students, and enforce our suggested safety rules. Safety glasses are inexpensive, and available at any hardware store, or from your shop teacher. If possible, consult a shop/industrial arts teacher for more safety information, especially if students will be using tools that are not discussed here.

### Hot glue gun

Very useful for quickly fastening different materials together with a reasonably strong bond. Hot glue guns can cause **minor burns** if the gun nozzle or hot glue touches skin.

### Soldering Iron

Useful for making electrical connections. Soldering irons can cause minor burns if the soldering tip, or hot solder, touches skin.

**Wear safety glasses to protect against hot solder.**

### Electric hand drill

Hand drills are useful for placing holes in materials, and might be used in the fabrication of wheels, for example.

**Wear safety glasses.** If too much force is applied, drill bits can break, launching fragments into the air. Material removed by the drill bit can also become airborne. Students using hand drills should work a safe distance from students that are not wearing safety glasses.

**Clamp work securely.** A spinning drill bit can grab the work piece and yank it around if it is not properly clamped in place, resulting in hand injuries, especially if the work piece has sharp edges. A small vice or clamp is useful for this purpose.

**Note what is underneath the piece being drilled.** Be sure that drilling is done into a secure block of scrap wood or into a clear space.

### Hacksaw

Hacksaws are useful for cutting a variety of materials.

**Wear safety glasses.** Removed materials could become airborne.

**Keep hands away from the cutting zone.** The blade can jump and cause minor hand injuries.

**Clamp work securely.** This removes any inclination to hold the work piece near the

cutting zone, and allows better control of the tool.

#### Wire Clippers

These tools are useful for cutting wire and thin shafts. If both sides of the piece are not securely held, they may shoot out.

**Wear safety glasses, and:**

**Hold both sides of the part being cut, or orient the tool so that the section being clipped is aimed at the floor.**

#### Utility or “Exacto” knives

Useful for cutting cardboard, foam core, etc.

**Wear safety glasses.** It is possible that a blade could break and fly upwards.

**Cut away from yourself.** (i.e. don’t draw the blade towards your hand or any other part of your body)

**Store tools safely.** Avoid leaving exposed blades on table surfaces. Use a handle with a retractable blade if possible.

**Note what is underneath the material being cut.** Cut into scrap material to avoid scratching the surface below.