

DAY	TIME	WHAT	HOW
1	Morning	<ul style="list-style-type: none"> ▪ Introductions ▪ Ice Breaker + Engineering Profiles ▪ Think Like an Engineer Activity ▪ Honor Code and Classroom Contract ▪ Pre-Test ▪ Technology as a Solution Discussion ▪ Guided Introduction to the Engineering Design Process 	<p><u>Introductions:</u> Instructor and TA introduce themselves to the class</p> <p><u>Engineering Profiles:</u> In pairs, students fill out profiles of each other including name, school, age, where they are from, likes, dislikes, favorite food, why they took engineering. TA walks around and takes head shots (to be printed later) to attach to the profile. Students introduce the person of whom they created a profile to the class. Hang these profiles around the classroom.</p> <p><u>Think Like an Engineer Activity:</u> Find six schematics and create six stations around the room. Student rotate between stations in groups of three looking at the schematics. They should record answers to the following questions:</p> <ul style="list-style-type: none"> • What is it? • How does it work? • What is it used for? • Have you ever seen one? <p>Even if students can not determine what it is, they should think creatively to come up with an answer. Review schematics when students have visited all stations.</p> <p><u>Honor Code and Classroom Contract:</u> Review honor code provided by CTY. Ask students to add additional items to create a classroom contract.</p> <p><u>Pre-Test:</u> Administer pre/post test. Provide blank instrument and results to academic dean.</p> <p><u>Technology as a Solution Discussion:</u> Students read page 3-4 in their text (<i>Engineering Design: An Introduction</i>) as a base for a brief discussion about what is technology and how it is used in engineering.</p> <p><u>Guided Introduction to the Engineering Design Process:</u> Using the Mail-A-Chip project, student are presented with a guided examination of the engineering design process as it is explained in Chapter 2. Students complete one phase of the engineering design process at a time. This is an introductory exercise in which students will see the design process clearly, and not be overwhelmed by the complexity of the project.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Engineering Design Process (cont.) 	<p><u>Engineering Design Process (cont.):</u> Continue the guided introduction to the engineering process. It should be completed on day one.</p>
	Evening	<ul style="list-style-type: none"> ▪ Engineering Design Process (cont. if needed) ▪ Final Design Document ▪ Text Problems ▪ Case Studies 	<p><u>Engineering Design Process (cont. if necessary):</u> Finish the process and project if extra time is needed.</p> <p><u>Final Design Document:</u> Students write a final analysis of their following sample guidelines on p. 52, or from guidance from instructor.</p> <p><u>Text Problems:</u> Problem 5 on p. 60 in the “Bring It Home” section, and/or Problem (1) on p. 61 in the “Extra Mile” section.</p> <p><u>Case Studies:</u> Students who need additional material are encouraged to read the case studies on p. 54 (Anytime Chair) or on p. 56 (Laser Designer).</p>

2	Morning	<ul style="list-style-type: none"> ▪ Fields of Engineering ▪ Introduce Bridge Design Project ▪ Brainstorming ▪ Identify the Problem ▪ Problem Analysis and Solution Searching Techniques: Why/Why Diagrams, Duncker Diagrams, and Kepner-Tregoe Decision Analysis 	<p><u>Fields of Engineering:</u> This course focuses primarily on structures (bridge design), mechanics and electronics (solar powered vehicle), and aerospace (airfoil), but students must be introduced to many other fields of engineering. The text <i>Engineering Your Future: Project-Based Approach</i> provides a nice overview (Chapter 5: Engineering Disciplines) of about 20 fields of engineering that can be used for a single activity, or used daily to introduce a new field (this choice is left up to the instructor).</p> <p><u>Introduce Bridge Design Project:</u> The bridge design project should be presented in a real-life situation. It must be given a place, a time, and have real economic and environmental consequences. Constraints must be included, such as the maximum weight the bridge must be able to hold during rush hour, environmentally friendly materials that must be used, etc. See attached documentation for an example design challenge.</p> <p><u>Brainstorming:</u> Students should be placed in groups for the project and allowed to brainstorm about the challenge, the problem, and a possible solution.</p> <p><u>Identify the Problem:</u> There are several techniques for identifying the problem, causes of the problem, or ideas for a solution. Several of these techniques are outlined in <i>Engineering by Design</i>, by Voland (page numbers provided below). It can be useful to teach students these methods to enhance their ability to think more systematically about an engineering design project.</p> <p><u>Problem Analysis and Solution Searching Techniques: Why/Why Diagrams, Duncker Diagrams, and Kepner-Tregoe Decision Analysis:</u></p> <p>Why/Why Diagrams, p. 95 (Volland) – These will show students a method for determining the source of the problem.</p> <p>Duncker Diagrams, p. 97 (Volland) – These will help students go from the present state of the problem to a solution by identifying general, functional, and specific solutions.</p> <p>Kepner-Tregoe Decision Analysis, p. 101, p. 411 (Volland) – The more advanced of the three methods, it assigns quantitative values to each constraint allowing a numerical value to help determine the most effective solution.</p> <p>Students should be able to use the well developed real-life bridge design problem to create detailed problem analysis charts.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Materials and Testing 	<p><u>Materials and Testing:</u> Students will have to do research on the type of materials available to build their bridges. Instructors can provide students with several types of material, including balsa wood sticks, toothpicks, coffee stirrers, popsicle sticks, etc. Each of these materials should have a different cost (students may or may not know the budget yet).</p> <p>In this afternoon exercise, the students in groups must design three or four tests that have quantitative results to determine strength of the materials against different types of forces (tension, compression, shear, and torsion). See p. 299 - 304 (Karnitz et.al.) for examples of the types of forces students can test. Students should then run these tests with each of the materials, keeping notes to describe their tests and keeping data in tables. Conclusions can be drawn about</p>

			which materials will be better for each aspect of bridge construction.
	Evening	<ul style="list-style-type: none"> ▪ Case Studies ▪ Applying Materials and Testing 	<p><u>Case Studies:</u> Tacoma Narrows Bridge Disaster is an excellent case study for students. There are several dramatic video clips available (Voland p. 218). Many articles also exist that create some controversy over the reasons for the bridge's collapse. Some other excellent examples are Voland, p. 131, p. 223, p. 386. Unlike the Tacoma Narrows example, these bridge collapse examples do have casualties, so use discretion when presenting them to the students.</p> <p><u>Applying Materials and Testing:</u> p. 318 (Karnitz, et.al.) problem 5 instructs students to design a beam structure out of one ounce of wooden stirrers that spans a 30cm open space. How much weight can it hold until until there is a 1.0mm deflection? This activity is a good follow-up to the materials and testing activity, and gives them good practice for building.</p>
3	Morning	<ul style="list-style-type: none"> ▪ Topics in Physics Applied to Bridges ▪ Introduction to Technical Drawing ▪ Technical Drawing and Construction Group Activity 	<p><u>Topics in Physics Applied to Bridges:</u> The instructor can cover any physics topics that are relevant to bridges. Possible topics include:</p> <ol style="list-style-type: none"> 1. Forces (Static and Dynamic) 2. Vectors (as related to forces) 3. Equilibrium 4. Free body diagrams 5. Calculating unknown forces <p><u>Introduction to Technical Drawing:</u> Students will need to draw 1:1 schematic diagrams of their bridges before construction. Chapter 10, p. 253 introduces them to these skills. Introduce students to top, front, side and isometric views. Show them the importance of adding dimensions and scale to their drawings. Note: This course does NOT cover Chapter 4: Drawing and Documenting or Chapter 17: Graphics and Presentation in Karsnitz et. al.</p> <p><u>Technical Drawing and Construction Group Activity:</u> Working in groups, students are given simple 3D geometric shapes to create front, side, and top views with dimensions (groups cannot see each others shape, and each group has a different shape). As groups finish their schematics, they swap schematics with another group and try to build the other team's shapes out of cardboard and tape.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Team Assignments and Responsibilities ▪ Project Planning ▪ West Point Bridge Design Computer Simulations ▪ Proposals for Prototypes Due to Instructor/TA 	<p><u>Team Assignments and Responsibilities:</u> Students are placed in teams and given the list of responsibilities of each team member. Within their team, they decide what role each person will take.</p> <p><u>Project Planning:</u> Students are given almost all of this period to plan their project in their new rolls. Construction of the prototype begins tomorrow, and a proposal is due by the end of the period (or evening period if students need some extra time). Students write a written proposal based on their assessment of the problem, the constraints of the situation, and the available materials. They produce a clear budget sheet proposal. Students also create a 1:1 schematic diagram on graph paper of their proposed design.</p> <p><u>West Point Bridge Design Computer Simulations:</u> If computer access is available at your site, it may be helpful to use the West Point Bridge Designer for students to simulate their designs. It may be downloaded for free from:</p>

			<p>http://bridgecontest.usma.edu/download.htm</p> <p><u>Proposals for Prototypes Due to Instructor/TA:</u> Final proposals are due to the instructor/TA by the end of the period (or evening session). The instructor should begin reviewing them to return to students the following day.</p>
	Evening	<ul style="list-style-type: none"> ▪ Project Planning (cont.) ▪ West Point Bridge Design Computer Simulations (cont.) ▪ Reinforcement of Physics Topics 	<p><u>Project Planning (cont.):</u> Reserve time for project planning, if necessary.</p> <p><u>West Point Bridge Design Computer Simulations (cont.):</u> Reserve time for the West Point Bridge Design computer simulations, if necessary.</p> <p><u>Reinforcement of Physics Topics:</u> Practice problems are assigned to reinforce the physics topics that were taught in the morning session.</p>
4	Morning	<ul style="list-style-type: none"> ▪ Return Project Proposals to Students ▪ Bridge Construction ▪ Unexpected Challenges for Students ▪ Work for Student Down-Time 	<p><u>Return Project Proposals to Students:</u> Instructor/TA return project proposals to students with comments. Some groups will be expected to make modifications before beginning to implement their proposal. When the changes are approved by the instructor/TA, students can begin their projects by purchasing materials.</p> <p><u>Bridge Construction:</u> Student groups purchase materials from the instructor/TA and begin building their bridges. Instructor/TA will give a brief introduction about any safety issues and potential pitfalls. Students have the entire day to implement their proposals.</p> <p><u>Unexpected Challenges for Students:</u> If students carefully planned during the previous stages of the project, implementing their proposals should be relatively straight forward. This, however, does not model real-life situations. The instructor is encouraged throughout the day to add in unexpected challenges for the students. Examples are below:</p> <ul style="list-style-type: none"> • Weather conditions at the build site are hazardous. In real life, engineers would lose time, which is money. Students must forfeit a portion of their budget. Student with no money left must sell back materials. • New materials become available. Consider introducing a stronger material at a lower price. Allow student to sell back and purchase this new material, but they must also re-evaluate their budget. <p><u>Work for Student Down-Time:</u> For projects that require students to wait for glue to dry or pieces to set, it is helpful to provide them with some additional work. This will provide students with structure during waiting periods. Be sure to stress that this enrichment work has a due date and will be collected. Examples of such work is a packet of physics challenge problems based on the topics discussed the previous day, or a unique case study about bridges or bridge design.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Bridge Construction (cont.) 	<p><u>Bridge Construction (cont.):</u> Students have the entire day to implement their bridge proposals.</p>
	Evening	<ul style="list-style-type: none"> ▪ Bridge Construction (cont.) ▪ Testing and Evaluation Brainstorm 	<p><u>Bridge Construction (cont.):</u> Students continue to construct their prototype bridges. Their goal is to be finished by the end of evening session.</p> <p><u>Testing and Evaluation Brainstorm:</u> As a group, have students brainstorm three empirical tests for which they could subject their bridges. The tests should be designed such that their results will help them assess if they have solved the problem presented in the bridge design challenge.</p>

			Have students submit these tests to the instructor/TA for review. In Chapter 8, Karsnitz et. al. discusses testing and evaluation, which may help students decide on the best types of tests for their projects.
5	Morning	<ul style="list-style-type: none"> ▪ Selecting Tests ▪ Bridge Prototype Testing 	<p><u>Selecting Tests:</u> From the proposed bridge tests, the instructor/TA presents the three tests the students use. The tests should be selected based on their scientific merit and how well they address the bridge design challenge. Students should be able to record empirical data from the tests.</p> <p><u>Bridge Prototype Testing:</u> The rest of the morning is used to test the bridge designs. Some basic tests the students may perform are torsion/flexibility, air resistance/flow, and/or maximum weight. Tests that break the bridge prototype should be conducted last.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Evaluation and Redesign 	<p><u>Evaluation and Redesign:</u> Students must formally evaluate whether or not their design addressed the bridge design challenge effectively. You can have them do this in several ways:</p> <ul style="list-style-type: none"> • A formal written engineering report • A presentation to the class • A class discussion about their designs • Any alternative method of assessment you see fit. <p>It will be helpful to vary the method of assessment throughout the course. If you select a formal written report for this project, try to select another type for the next project.</p> <p>Redesign is one of the most crucial stages in engineering. There will undoubtedly be aspects of their designs that, after testing, do not meet the criteria of the bridge design challenge. At a minimum, students should have an opportunity to meet in their groups and discuss redesign ideas. If time in class allows, they should implement these ideas and test again. They can discuss their final conclusions in the evaluation.</p>
	Evening	<ul style="list-style-type: none"> ▪ Evaluation and Redesign (continued) ▪ Research the Next Project 	<p><u>Evaluation and Redesign:</u> Reserve some additional time to complete the evaluation and redesign phase.</p> <p><u>Research the Next Project:</u> The next student project is the solar powered vehicle. Their task for the evening is to research successful solar powered vehicles. Students should use these questions to guide their research:</p> <ul style="list-style-type: none"> • Has anyone successfully created a solar powered vehicle for human use? If so, who made them? Collect enough information to describe the vehicle. • What is a solar panel and how does it work? • What are the challenges when using solar power? • Could a “hybrid” vehicle consist of gasoline and solar power? Electricity and solar power? • Currently, what are the most popular uses of solar power?
6	Morning	<ul style="list-style-type: none"> ▪ Introduction to Electricity and Circuits 	<p><u>Introduction to Electricity and Electric Circuits:</u> Students will likely have little to no experience with electricity or circuits. Basic topics could include:</p> <ul style="list-style-type: none"> • Conductors and Insulators • Conductivity and Resistivity

		<ul style="list-style-type: none"> • Resistance • Materials • Current • Voltage • Circuit diagrams and circuit component symbols <p>Student will need to know how to calculate voltage and current, use Ohm's Law and Kirchoff's Laws.</p> <p>Some additional resources for teaching electronics can be found online. Youtube.com member "electroninstructor" has posted many informational videos about circuits. Visit the website at: www.youtube.com/user/electroninstructor.</p> <p>All of these topics are covered in Karsnitz et.al. Chapter 13 p. 346.</p>
Afternoon	<ul style="list-style-type: none"> ▪ Breadboard Experiments/Projects 	<p><u>Breadboard Experiments/Projects</u>: Students gain experience using different electrical components by designing circuits using a breadboard. From these exercises, students should be proficient at constructing basic or advanced circuit designs, drawing circuit diagrams, using a multimeter to take measurements from the circuit, soldering simple circuit components. Examples of such experiments/projects are:</p> <ul style="list-style-type: none"> • Experimenting with resistors in series and parallel. • Experimenting with batteries in series and parallel. • Adding switches to circuit designs. • Designing a simple circuit to light a bulb in series and parallel. <p>For additional ideas for circuit designs for students, try: http://www.opamp-electronics.com/tutorials/experiments.htm</p> <p>Students beginning the course with intermediate or advanced abilities in electronics may want to work on a more advanced project. An excellent resource for projects is <u>Electronics Projects for Dummies</u> by Earl Boyson and Nancy Muir. The projects are challenging and each provides complete material lists and detailed instructions.</p> <p>For excellent visual demonstrations of simple and advanced circuits, instructors can use Paul Falstad's Java circuit application at http://www.falstad.com/circuit/.</p> <p>Experienced instructors in circuit design wishing to do more advanced computer demonstrations of circuit designs may be interested in using LTspice, available free from www.linear.com.</p>
Evening	<ul style="list-style-type: none"> ▪ Review ▪ Circuit Design Problems ▪ Complete Breadboard Projects 	<p>There are multiple options for the evening session, but certainly not time for all. Choose which best fits your class requirements.</p> <p><u>Review</u>: Revisit the material covered in the morning session. Reinforce difficult concepts with review and answer any questions from the students. Karsnitz et. al. have several good review questions at the end of Chapter 13, as well as a summary of the chapter on pages 384 – 385.</p> <p><u>Circuit Design Problems</u>: Students work on more advanced circuit problems, calculating</p>

			<p>currents and voltages. Additional circuit components can be introduced.</p> <p><u>Complete Breadboard Projects:</u> Students can continue to work on their projects from the afternoon. These should be complete so the core engineering project can begin the following day.</p>
7	Morning	<ul style="list-style-type: none"> ▪ Introduction to Solar Power and Solar Cells ▪ Introduce Solar Powered Vehicle Project ▪ Brainstorming ▪ Identifying the Problem 	<p><u>Introduction to Solar Power and Solar Cells:</u> The cornerstone of the solar power vehicle project is an understanding of solar power and solar cells. Solar cells are briefly described on p. 367 of Karsnitz et. al. For additional information consider the following resources:</p> <p>http://www.howstuffworks.com/solar-cell.htm http://en.wikipedia.org/wiki/Solar_cell</p> <p>Students should have a firm grasp of the physics of solar cells before moving on to the design challenge.</p> <p><u>Introduce Solar Powered Vehicle Project:</u> The solar powered vehicle design project should be presented in a real-life situation. It must be given a place, a time, and have real economic and environmental consequences. Constraints must be included, such as passenger safety, maximum number of passengers, maximum speed, aesthetics, etc. See attached documentation for an example design challenge.</p> <p><u>Brainstorming:</u> Students should be placed in groups and allowed to brainstorm about the challenge, the problem, and a possible solution.</p> <p><u>Identify the Problem:</u> As in the first project, students should use the techniques of problem analysis and solution searching. See the bridge project for a more detailed description of these techniques. They are also discussed in depth in <i>Engineering by Design</i> by Voland.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Materials and Testing 	<p><u>Materials and Testing:</u> Students will have to do research on the materials available to design their solar powered vehicle. The solar powered vehicle has both mechanical and electrical systems.</p> <p>In this afternoon exercise, the students in groups must design three or four tests that have quantitative results. For the electrical systems, tests should have different types of motors, batteries, solar cells, wire, switches and any electrical components students experimented with during the previous day. For the mechanical system, students should be given several options for material to build the frame of the car, such as balsa wood, plastic sheets, card board, aluminum foil (remember to associate a cost with each type of material). Students should also experiment with axles and gears to find what combinations will optimize their designs.</p> <p>As students work through their experiments, they should draw some conclusions about how they want to employ the materials they will be working with.</p>
	Evening	<ul style="list-style-type: none"> ▪ Materials and Testing (cont.) ▪ Human Factors in Design 	<p><u>Materials and Testing:</u> Students complete any experiments or testing of materials.</p> <p><u>Human Factors in Design:</u> In Chapter 15, p. 404 – 427, Karsnitz et.al. covers human factors in design. While this is not the primary focus of the solar power vehicle design project, it should</p>

			<p>not be too far from students minds. Students can be engaged to read all, part, or the summary of the chapter. Consider a class discussion that focuses on some of the topics below:</p> <ul style="list-style-type: none"> • How do human factors influence the design of a passenger vehicle? • What would be different about designing a vehicle for men, women, children, or disabled persons? • Using the idea of universal design and the criteria on p. 415, what other designs can be identified in our every day life that fit these criteria? <p>Additionally, students may wish to put their knowledge into practice by evaluating a chair in the classroom to the specifications described in the chapter. This activity is described on p. 427 in the “Extra Mile” section.</p>
8	Morning	<ul style="list-style-type: none"> ▪ Topics in Mechanical Engineering ▪ Practice and Reinforcement 	<p><u>Topics in Mechanical Engineering:</u> As stated above, the solar powered vehicle design project has both mechanical and electrical systems. Students should be familiar with both systems before they begin planning their project. Topics you may consider covering with students can include:</p> <ul style="list-style-type: none"> • Kinematics, Kinematic Diagrams • Position, Velocity, Acceleration • Momentum • Energy (Potential and Kinetic), Work, Power • Types of Motion: linear, reciprocal, rotary, oscillating • Mechanical advantage • Gears, Gear Ratio, Compound Gears <p>Karsnitz et.al. covers these topics in Chapter 12, p. 320 – 345.</p> <p><u>Practice and Reinforcement:</u> Depending on the topics the instructor selects, the students will need practice and reinforcement with these new ideas. The instructor should prepare some practice problems either of a mathematical or conceptual nature. A standard introductory algebra-based or conceptual physics text can help address these problems.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Team Assignments and Responsibilities ▪ Project Planning ▪ Proposals for Prototypes Due to Instructor/TA 	<p><u>Team Assignments and Responsibilities:</u> Students are placed in teams and given a list of responsibilities of each team position. Within their team, students decide what role each person will take. Instructors should encourage student to take on different roles for each project.</p> <p><u>Project Planning:</u> Students are given almost all of this period to plan their project in their new roles. Construction of the prototype begins tomorrow, and a proposal is due by the end of the period (or evening period if students need extra time). Students must write a proposal based on their assessment of the problem, the constraints of the situation, and the available materials. Students must also submit a budget proposal and create a scaled schematic diagram on graph paper. The schematic should include both the external features of the car and also a diagram of the electrical system.</p> <p><u>Proposals for Prototypes Due to Instructor/TA:</u> Final proposals are due to the instructor/TA by the end of the period (or evening session). The instructor should review and return them to the students the following day.</p>

	Evening	<ul style="list-style-type: none"> ▪ Project Planning (cont.) ▪ Reinforcement of Mechanical Engineering Topics ▪ Case Study 	<p><u>Project Planning (cont.):</u> Reserve time for project planning. As projects become more complicated, students will need additional time to complete their proposals.</p> <p>Note: You may find the complexity of this project may be difficult for this age group of students. They may lack direction when working toward such a broad final goal. To aid certain groups, you may want to set mini-goals for them throughout the day, or you can standardize portions of the project like the final proposal or design schematics thus allowing them to have a concrete starting and ending point.</p> <p><u>Reinforcement of Mechanical Engineering Topics:</u> Practice problems assigned to reinforce the physics topics that were taught in the morning session.</p> <p><u>Case Study:</u> On p. 168, Karsnitz et. al. provides a good case study that focuses on the balance between design changes and the needs of the consumer. The case study is called, “<i>Designing a New Ketchup Bottle for the H.J. Heinz Company</i>”. While it does not focus specifically on mechanical or electrical engineering, it can give student a good idea how consumer feedback can shape a product.</p>
9	Morning	<ul style="list-style-type: none"> ▪ Return Project Proposals to Students ▪ Solar Powered Vehicle Construction ▪ Work for Student Down-Time 	<p><u>Return Project Proposals to Students:</u> Instructor/TA return project proposals to students with comments. Some groups will be expected to make modifications before beginning to implement their proposal. When the changes are approved by the instructor/TA, students may by purchasing materials.</p> <p><u>Solar Powered Vehicle Construction:</u> Student groups purchase materials from the instructor/TA and begin building their solar powered vehicles. Instructor/TA will give a brief introduction about any safety issues and the potential pitfalls. Students have the entire day to implement their proposals.</p> <p><u>Work for Student Down-Time:</u> ; For projects that require students to wait for glue to dry or pieces to set, it is helpful to provide them with some additional work. This will provide students with structure during waiting periods. Be sure to stress that this enrichment work has a due date and will be collected. Examples of such work is a packet of physics challenge problems based on the topics discussed the previous day, or a unique case study about solar power or alternative-power vehicles.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Solar Powered Vehicle Construction (cont.) 	<p><u>Solar Powered Vehicle Construction (cont.):</u> Students have the entire day to implement their solar power vehicle proposals.</p>
	Evening	<ul style="list-style-type: none"> ▪ Solar Powered Vehicle Construction (cont.) 	<p><u>Solar Powered Vehicle Construction (cont.):</u> Students continue to construct their prototype solar powered vehicle. Their goal is to be finished by the end of evening session.</p>
10	Morning	<ul style="list-style-type: none"> ▪ Testing and Evaluation Brainstorm ▪ Selecting Tests ▪ Solar Powered Vehicle Prototype Testing 	<p><u>Testing and Evaluation Brainstorm:</u> As a group, have students brainstorm three empirical tests to which they could subject their solar power vehicles. The tests should be designed such that their results will help students assess if their vehicles have solved the problem presented in the solar powered vehicle design challenge. The students should submit these tests to the instructor/TA for review. In Chapter 8, Karsnitz et. al. discusses testing and evaluation, which may help students decide the best types of tests for their projects.</p>

			<p><u>Selecting Tests:</u> From the proposed tests, the instructor/TA presents the three tests the students use. The tests should be selected based on their scientific merit and how well they address the solar powered vehicle design challenge. Students should be able to record empirical data from the tests.</p> <p><u>Solar Powered Vehicle Prototype Testing:</u> The rest of the morning is used to test the solar powered vehicle designs. Basic tests the students may perform on their cars include examining resistance to impact, speed, range, safety, etc.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Evaluation and Redesign 	<p><u>Evaluation and Redesign:</u> Students must formally evaluate whether or not their design addressed the solar powered vehicle design challenge effectively. You can have them do this in several ways:</p> <ul style="list-style-type: none"> • A formal written engineering report • A presentation to the class • A class discussion about their designs • Any alternative method of assessment you see fit. <p>It will be helpful to vary the method of assessment throughout the course. If you select a formal written report for this project, try to select another type for the next project.</p> <p>Redesign is one of the most crucial stages in engineering. There will undoubtedly be aspects of their designs that, after testing, do not meet the criteria of the solar powered vehicle design challenge. At a minimum, students should have an opportunity to meet in their groups and discuss redesign ideas. If time in class allows, they should implement these ideas and test again. They can discuss their final conclusions in the evaluation.</p>
	Evening	<ul style="list-style-type: none"> ▪ Evaluation and Redesign (continued) ▪ Research the Next Project 	<p><u>Evaluation and Redesign:</u> Reserve some additional time to complete the evaluation and redesign.</p> <p><u>Research the Next Project:</u> The next project for students is on aerospace engineering, specifically designing airfoils. The students' evening task is to research these systems. Students should use these questions to guide their research:</p> <ul style="list-style-type: none"> • What is aerospace engineering? • Who are some well known aerospace engineers? • What information can you discover about the physics of flight? • What is an airfoil? How does it help a plane fly?
11	Morning	<ul style="list-style-type: none"> ▪ The Wright Brothers: A Case Study in Flight ▪ The Physics of Flight: Part I 	<p><u>The Wright Brothers: A Case Study in Flight:</u> One of the most famous case studies in flight is the Wright brothers' first manned flight. The Wright brothers' first manned flight is an excellent example of the engineering design process. Many students will already be familiar with this case study, so it is a great place to start studying flight and aerospace engineering.</p> <p>On p. 34 of <i>Engineering by Design</i> by Voland, there is a detailed case history of the Wright brothers' attempts at manned flight. Students will see clearly how this classic paradigm fits into the engineering design process they have been using throughout the class.</p> <p><u>The Physics of Flight: Part I:</u> The instructor can cover any physics topics that are relevant to</p>

			<p>flight. Possible topics include:</p> <ul style="list-style-type: none"> • Vertical Motion, Free Fall • Gravity • Center of Mass, Center of Gravity • Lift, Drag, Thrust • Newton's Laws, Fluids • Airflow, Angle of Attack <p>Many of these topics can be found in an introductory physics text. Voland also covers the basics of flight on p. 505.</p> <p>It may be helpful to mix the case study and the physics of flight. Voland provide a chronological description of the Wright brothers' challenges and discoveries. Explanations about the physics behind these discoveries can be helpful to the students.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Flight/Airfoil Qualitative Research – Kite Construction 	<p><u>Flight/Airfoil Qualitative Research – Kite Construction:</u> It is important for students to get an intuitive sense of the forces that act on a flying/gliding object. With this in mind, constructing and flying simple A-frame kites will provide an idea of the type of forces on a wing in flight. As with all experiments, the students should keep notes or be evaluated in some way, even if it is just a qualitative experiment. Students should note:</p> <ul style="list-style-type: none"> • The forces they feel acting on the kite. • The way the wind affects the direction of the kite. • What makes the kite gain altitude or lose altitude. • What causes the kite to "lift off".
	Evening	<ul style="list-style-type: none"> ▪ Review ▪ Practice Problems 	<p><u>Review:</u> Revisit the material covered in the morning session. Reinforce difficult concepts with review and answer any questions from the students.</p> <p><u>Practice Problems:</u> To reinforce the physics content, students should practice some application-based physics problems. These can be conceptually or mathematically based. An introductory algebra-based physics text, or conceptual physics text may have some good examples of problems that can be adapted for the course.</p>
12	Morning	<ul style="list-style-type: none"> ▪ The Physics of Flight: Part II ▪ Introduce the Airfoil Design Project ▪ Brainstorming ▪ Identifying the Problem 	<p><u>The Physics of Flight: Part II:</u> The instructor should provide a detailed analysis of an airfoil in anticipation of the next design project. Consider reviewing:</p> <ul style="list-style-type: none"> • The Shape of the Airfoil • Angle of Attack • Airflow Over the Airfoil • Drag and Lift Forces • Construction of an Airplane Wing and Airfoil • Real Life Materials Used for Airfoils <p><u>Introduce the Airfoil Design Project:</u> The airfoil design project should be presented in a real-life situation. It must be given a place, time, and have real economic and environmental consequences. Constraints on the design must include physical size, weight, types of material, cost, etc. See attached documentation for an example design challenge.</p>

			<p>It is important to keep in mind the scale of this project. One of the best ways to test an airfoil is to subject it to wind. Typically a high powered directional fan, readily available from a retail store, is the best way to subject the prototype to wind. With this in mind, instructors may want to set constraints on the size of the prototype.</p> <p><u>Brainstorming:</u> Students should be placed in groups and allowed to brainstorm about the challenge, the problem, and a possible solution.</p> <p><u>Identifying the Problem:</u> As with previous projects, students should use techniques of problem analysis and solution searching. See the bridge project for a more detailed description of these techniques. They are also discussed in depth in <i>Engineering by Design</i>, by Voland.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Materials and Testing 	<p><u>Materials and Testing:</u> Students will have to do research on the materials available to design their airfoils. Instructors can provide students with several types of material, including balsa wood, cardboard, paper of different thicknesses and gloss, foam insulation, foil, assorted fabrics, etc. Each of these materials should have a different cost (students may or may not know the budget yet).</p> <p>In this afternoon exercise, the students in groups must design three or four tests that have quantitative results. Consider having students design tests based on airflow over certain surfaces. They can also consider the strength and weight of the materials that will form the frame of the airfoil. Students should run these tests with different materials, keeping notes to describe their tests and keeping data in tables. Conclusions will be drawn about which materials will be better for each aspect of the airfoil construction.</p>
	Evening	<ul style="list-style-type: none"> ▪ Case Studies: Flying Toys 	<p><u>Case Studies: Flying Toys:</u> There are a variety of different type of flying toys. On p. 511 – 515, Voland discusses two types of spinning flying toys that are similar to the Frisbee: the Skyro and the Aerobie.</p>
13	Morning	<ul style="list-style-type: none"> ▪ Simple Non-Powered or Powered Model Plane Construction – Observations of Flight ▪ Team Assignments and Responsibilities ▪ Project Planning 	<p><u>Simple Non-powered or Powered Plane Construction:</u> There are several simple glider or powered flight construction kits that are simple for students to use. Again, as a qualitative experiment, constructing and flying these planes can provide them with some insight into the forces that act on a plane in flight. Student can adjust the size and shape of the components and the center of mass. Students must record all of their observations.</p> <p><u>Team Assignments and Responsibilities:</u> Students are placed in teams and given a list of responsibilities of each team member. Within their team, they decide what role each person will take.</p> <p><u>Project Planning:</u> Students are given the majority of this period to plan their project in their new roles. Construction of the prototype begins tomorrow, and a proposal is due by the end of the period (or evening period if students need extra time). Students must write a written proposal based on their assessment of the problem, the constraints of the situation, and the available materials. They produce a clear budget sheet proposal. Students also create a scaled schematic diagram on graph paper of their proposed design.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Project Planning (cont.) 	<p><u>Project Planning (cont.):</u> Based on any additional testing, students can modify their project proposals.</p>

	Evening	<ul style="list-style-type: none"> ▪ Final Project Planning ▪ Proposals for Prototypes Due to Instructor/TA 	<p><u>Final Project Planning:</u> Project planning should be completed by the afternoon session, but if additional time is needed, the evening session can be used.</p> <p><u>Proposals for Prototypes Due to Instructor/TA:</u> Final proposals are due to the instructor/TA by the end of the evening session. The instructor should review them and return them to students the following day.</p>
14	Morning	<ul style="list-style-type: none"> ▪ Return Project Proposals to Students ▪ Airfoil Construction ▪ Work for Student Down-Time 	<p><u>Return Project Proposals to Students:</u> Instructor/TA return project proposals to students with comments. Some groups will be expected to make modifications before beginning to implement their proposal. When the changes are approved by the instructor/TA, students can begin their projects by purchasing materials.</p> <p><u>Airfoil Construction:</u> Student groups purchase materials from the instructor/TA and begin building their airfoils. The instructor/TA should give a brief introduction about any safety issues and the pitfalls of the project. Students have the entire day to implement their proposals.</p> <p><u>Work for Student Down-Time:</u> ; For projects that require students to wait for glue to dry or pieces to set, it is helpful to provide them with some additional work. This will provide students with structure during waiting periods. Be sure to stress that this enrichment work has a due date and will be collected. Examples of such work is a packet of physics challenge problems based on the topics discussed the previous day, or a unique case study about aerospace engineering.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Airfoil Construction (cont.) 	<p><u>Airfoil Construction (cont.):</u> Students have the entire day to implement their airfoil design proposals.</p>
	Evening	<ul style="list-style-type: none"> ▪ Testing and Evaluation ▪ Selecting Tests 	<p><u>Testing and Evaluation Brainstorm:</u> As a group, have students brainstorm three empirical tests for which they could subject their airfoils. The tests should be designed such that their results will help them assess if they have solved the problem presented in the airfoil design challenge. The students should submit these tests to the instructor/TA for review. In Chapter 8, Karsnitz et. al. discusses testing and evaluation, which may help students decide on the best types of tests for their projects.</p> <p><u>Selecting Tests:</u> From the proposed tests, the instructor/TA present the three tests the students use. The tests should be selected based on their scientific merit and how well they address the airfoil design challenge. Students should be able to record empirical data from the tests.</p>
15	Morning	<ul style="list-style-type: none"> ▪ Airfoil Prototype Testing ▪ Advanced Testing: Lift and Angle of Attack ▪ Evaluation and Redesign 	<p><u>Airfoil Prototype Testing:</u> The morning is used to test the airfoil designs. Basic tests involve subjecting airfoils to high winds. They can design tests similar to those proposed in the <u>Advanced Testing</u> section below.</p> <p><u>Advanced Testing: Lift and Angle of Attack of the Airfoil:</u> A general procedure for testing is provided below:</p> <ul style="list-style-type: none"> • Construct a small airfoil. • Using a stand (popsicle stick with some modeling clay as a base), attach to the airfoil. The airfoil should stand on its own. • Record the mass of the airfoil and stand on a scale.

			<ul style="list-style-type: none"> • Place a high powered directional fan at a measured distance in front of the airfoil. Turn the fan on. Be sure the airfoil is the same distance from the fan for each test. • Record the mass. The change in mass is a measure of the amount of lift created by the airfoil. • Repeat the procedure above with different prototype airfoils. <p>Additional Testing:</p> <ul style="list-style-type: none"> • Repeat the procedure above with each airfoil at different angles of attack. • Collect data for each angle of attack and organize it in a chart. <p><u>Evaluation and Redesign:</u> Students must formally evaluate whether or not their design addressed the airfoil design challenge effectively. You can have them do this in several ways:</p> <ul style="list-style-type: none"> • A formal written engineering report • A presentation to the class • A class discussion about their designs • Any alternative method of assessment you see fit. <p>It will be helpful to vary the method of assessment throughout the course. Try to choose a different evaluation method than one used for previous design challenges.</p> <p>As mentioned before, redesign is one of the most crucial stages in engineering. There will undoubtedly be aspects of their designs that, after testing, do not meet the criteria of the airfoil design challenge. At a minimum, students should have an opportunity to meet in groups and discuss redesign ideas. If time in class allows, they should implement these ideas and test again. They can discuss their final conclusions in the evaluation.</p>
	Afternoon	<ul style="list-style-type: none"> ▪ Informal Course Feedback ▪ Post-Test ▪ Clean Up and Inventory 	<p><u>Informal Course Feedback:</u> If time permits, it can be enlightening to gain informal feedback from students. One method is to have each student write a brief letter to the engineering students planning to take this course. Ask the student to evaluate the types of projects they completed and provide helpful suggestions about the challenges they faced.</p> <p><u>Post-Test:</u> Administer post-test. Provide blank instrument and results to academic dean.</p> <p><u>Clean Up and Inventory:</u> The instructor, TA, and students should work together to clean up the classroom and inventory supplies.</p>