



WIND MACHINES

Teacher's Guide Notes



Junkyard Wars

This popular television show is anything but trashy entertainment. Each episode takes place in a huge, specially constructed junkyard, where two teams of engineers and mechanics get 10 hours to build machines scrounged from junk. Later the teams put their contraptions to the test in a competition. Viewers watch as the teams work to meet the same challenge in different ways.

First comes a challenge: Build an object to perform a specific task. Then the teams swing into action, struggling to beat the clock. They revise their plans as necessary. Throughout the show, an expert gives opinions and evaluations of projects. The hosts make diagrams to describe engineering principles behind each team's efforts.

Using the Videos

Each of the enclosed two videos (about 45 minutes each) features an episode of *Junkyard Wars*. On the following page are onscreen discussion questions for students to discuss and answer. These and additional questions for students are on the reproducible pages at the end of this teacher's guide.

In a 45-minute class period, you will not have enough time to show an entire episode and have students work on their reproducibles. You may show the first segments and allow students to make hypotheses, answer questions, and evaluate some program events. Show the final segment featuring the outcome of the program challenge during the next class period.

In 60-minute class periods, you can show an entire episode and take sufficient time for students to complete their reproducibles. In 90- to 120-minute blocks, you can also conduct one of the four Classroom Challenges (laboratory experiments, projects, and demonstrations) included herein.

You may start some Classroom Challenges before or after you show the videos in class. You will want to assign the more substantial challenges after watching the videos.

It is helpful to keep some classroom lights on while watching a video so students can answer the onscreen discussion questions and make drawings on the reproducible pages. Pause the video when these questions appear.

Teacher's Guide Notes (cont.)



Episodes in This Kit

Episode I: Gliders

Episode challenge: Build a flying machine.

Program overview: The machine must be launched down a hill and sustain maximum flight time with one member onboard, so one team builds a monoplane with two aluminum wings and the other builds a complicated biplane.

Episode II: Sand Yacht

Episode challenge: Build wind-powered vehicles to sail across the salt flats.

Program overview: One team builds a sail out of aluminum and the other uses fabric.

Target Grades: 6–12

Curriculum Focus: physics, physical science, technology, drafting and design, mathematics

Scientific Principles: flight, Bernoulli's Principle, surface area, Newton's Laws

Onscreen Discussion Questions

(Pause the video so students can answer questions on the reproducibles, found on pages 14 and 15 in this teacher's guide. To match these time codes, set your VCR counter to zero at the beginning of the tape.)

Episode I: Gliders

After Segment 1 (3:36)

- How would you design a glider to carry a person? Sketch your design.
- Look for evidence of teamwork during the video. Are conflicts resolved successfully?

After Segment 2 (19:44)

- How have the teams' plans changed because of materials or time limitations?

After Segment 3 (31:42)

- In your opinion, which team has the best-built glider? Which team has the best overall design? Give evidence to support your answers.
- Predict which team you think will have their glider in the air longer. Give reasons for your choice.

Episode II: Sand Yacht

After Segment 1 (5:06)

- How do the plans proposed by the experts differ? What are the similarities in their plans?
- What are the pros and cons of using a metal sail?
- Look for evidence of teamwork during the video. Are conflicts resolved successfully? Give evidence of competitiveness between the teams.

After Segment 2 (20:39)

- How have the teams' plans changed because of materials or time limitations?

After Segment 3 (30:32)

- In your opinion, which team has the best-built sand yacht? Which team has the best overall design? Give evidence to support your answers.
- Describe one weakness in each team's final product (in other words, predict where their sand yacht might have a problem).

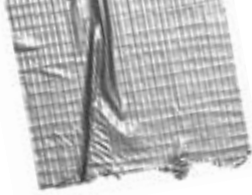
Safety Considerations

Please do not send your students into junkyards for these or any other projects! Designing and building objects is a great way for students to learn engineering skills and apply science and design principles, but you must give them ways to do this safely.

Some options:

- Provide materials and building time in class (especially for younger students).
- Allow students to purchase their supplies or use supplies from around the house (with permission, of course) within strict guidelines set up in advance, including types of materials and cost.
- Encourage parents to teach their children correct use of tools, forbidding all power tool use except while an adult is present. Never use welding torches or chain saws!

Do not assign projects that use explosives, very large forces, extremely high air pressures, or unprotected sharp objects. Consider all the worst-case scenarios and set your guidelines accordingly. As a general principle, design projects that are based on finesse or accuracy instead of raw power.



Assessments

Included in this guide are two assessment rubrics: one for the general evaluation of students in laboratory situations and one for the “Flying to Improve Your Grade” project. Make a transparency or copy of the rubrics to share with students ahead of time; they must know the criteria on which they will be evaluated.

The general rubric “Indicators of Student Involvement” is designed for use during Classroom Challenges #1–3. Realistically, you can evaluate two to four students per lab period. During the course of a quarter, make sure every student is evaluated at least once. But here’s the key: Don’t let the students know who is being observed in any particular lab period.

For the flying project, feel free to weight the criteria shown along the left column as you see fit. You may wish to emphasize or de-emphasize the importance of

the journals, or replace the journals with formal lab reports or technical drawings. You may also wish to replace the numerical goals for the students (10 penny-meters and above for the top score) with a more general ranking among the projects in your class that year.

For help in developing your own rubrics, visit the Web site <http://rubistar.4teachers.org/>. You’ll find dozens of sample rubrics that you can adapt for many different applications in your classroom.



National Science Education Standards

The National Science Education Standards, published by the National Academy of Science, provide guidelines for teaching science in grades K–12, as well as a coherent vision of what it means to be scientifically literate. To order the Standards, contact the National Academy Press, 2101 Constitution Ave. NW, Lockbox 285, Washington, DC 20005; <http://books.nap.edu>.

The activities in this teacher’s guide address the following national content standards:

Science as Inquiry (grades 5–12)

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry



Physical Science (grades 5–12)

- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

Science and Technology (grades 5–12)

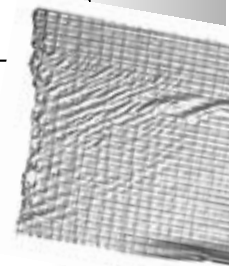
- Abilities of technological design
- Understandings about science and technology

National Council of Teachers of Mathematics

The National Council of Teachers of Mathematics (NCTM) has developed national standards to provide guidelines for teaching mathematics. To become a member of the NCTM, or to view the Standards online, go to <http://www.nctm.org>.

This lesson plan addresses the following math standards for grades 9–12:

- Algebra Standard: Understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships.
- Measurement Standard: Understand measurable attributes of objects and the units, systems and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements.



CLASSROOM CHALLENGES

#1: BERNOULLI BALL

Background Information

Before giving this challenge to students, discuss Bernoulli's Principle with the class. (An excellent summary of the principle and its applications is available in Paul Hewitt's *Conceptual Physics* textbook, both high school and college editions.)

Demonstrate some of these applications:

- Hold a piece of paper horizontally with its long edge just below your mouth. If you blow hard, the paper rises due to the reduced pressure at the top of the paper.
- Use a large box fan resting between two chairs and blowing upward to keep a beach ball levitated. Show that the beach ball resists moving side to side in the stream when it's tapped gently. When the ball moves toward the outer part of the air stream, the pressure on the ball is reduced toward the center of the stream where there is higher airflow, so the ball experiences a force pushing it back toward the center.
- Float two toy boats in a sink, aquarium, or other water container. Use a hand-held hair dryer or the "reverse end" of a vacuum cleaner to show that when air passes rapidly between the boats, they tend to push together. The reduced air pressure between the boats causes them to move together. (Tip: Caution students that they should never use a hair dryer near water.)

In each of these cases, be sure the students understand that the forces exerted on the objects are caused by the higher air pressure pushing the object, not by the lower air pressure "sucking" on the object.

Use the following activity as a fun addition to a Physics Olympiad competition or as a small lab or project. Let the students compete, and encourage them to practice at home.



Materials

- meter stick
- targets
- hair dryer
- stopwatch
- 15 Ping-Pong balls per team
- chair
- score sheet



Objective

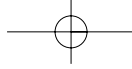
Contestants will demonstrate their ability to work with a Ping-Pong ball and hand-held hair dryer. They will attempt to get the ball into a three-dimensional bull's-eye target similar to those used in Skee-Ball. If a contestant can demonstrate good skill and land a Ping-Pong ball in the center of the target, that person will earn 100 points for their team. Each section of the bull's-eye will have a different number of points. The ball will be maneuvered by the hair dryer's airflow.

Team

Divide the class into teams of three to five students. Each team will receive 15 balls to aim at the target; the sum total of each shot contributes to the team's score. Each member of a three-person team will shoot five balls. In a four-person team, the first three participants will shoot four balls and the fourth person will shoot three. Each member of the five-person team will shoot three balls.

Additional Parameters

- A three-dimensional target will be provided for each team, along with a hair dryer. Make the target out of concentric buckets, embroidery hoops, or other similar objects.
- Each team member will stand 1.5 meters from the target. A chair will be placed with its back towards the target.



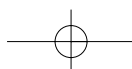
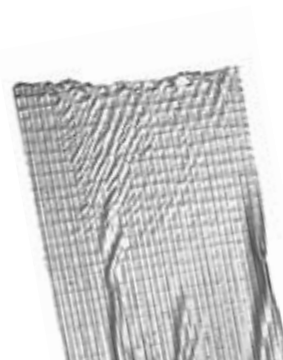
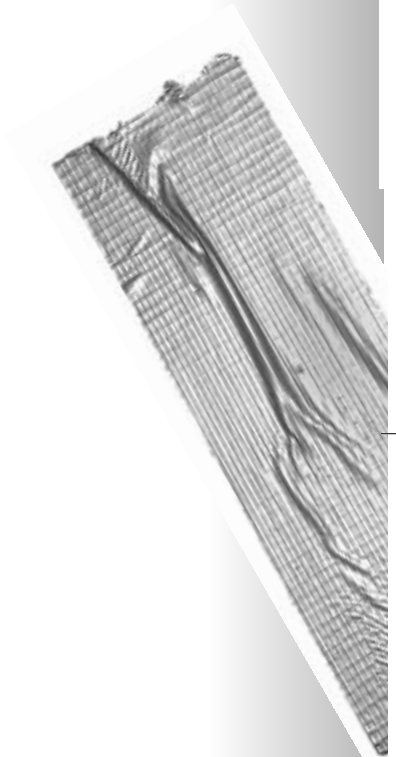
- Contestants will straddle the chair and face the target.
- Contestants will suspend a Ping-Pong ball in the air stream of the hair dryer and direct the ball into the target.
- Contestants can use air pressure only to move the ball. The hair dryer cannot make contact with the ball.

Judging

A judge will determine which circle the Ping-Pong ball lands in. If the contestant reaches over a designated line, the shot does not count. If the contestant should hit the Ping-Pong ball with the hair dryer, that shot is disqualified. Each team member will have 60 seconds to complete all three shots. The team with the highest total points earned within the time limit is the winner.

Rules

- Judges must set up targets measuring equal distances from target to chair.
- Keep accurate time scores for each round with a stopwatch.
- Keep a careful eye on each team so that the ball does not touch the player or hair dryer in any way.



#2: SAILING WITH THE WIND

Problem

Investigate the effect of wind direction on sail angle for maximum speed of a land yacht or sailboat

Note: This is a great lab exercise, but you may use it as a demonstration and collect data as a class if you don't have enough fans or expendable toy cars.

Materials

For each lab group:

- low-friction toy car, 20–30 cm in length
- lightweight, sturdy cardboard or plastic for a sail (mat board or foam board work well)
- duct or masking tape
- protractor
- 1/4" or similar dowel rods for mast and boom (optional)

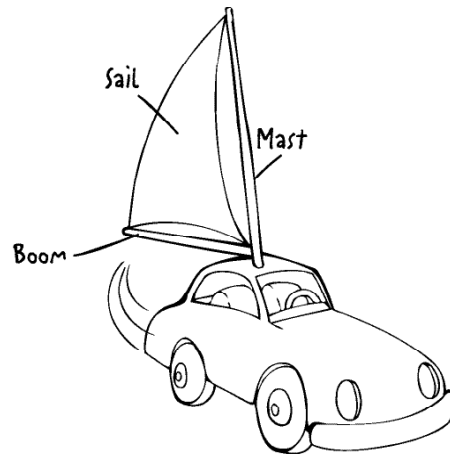
For the class:

- fans
- cones for a land-yacht course

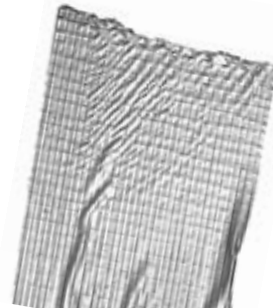


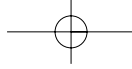
Procedure

1. Attach the sail to the car. You may be able to tape it in place if the sail and car are made of very stiff materials, or you may drill a vertical hole in the car slightly smaller than the diameter of the dowel. Glue the dowel in place to act as a mast. If necessary, attach the boom and the sail to the mast with tape.



2. For the first experiment, set the sail perpendicular to the wheels; it should divide the car front and back. Conduct a study measuring the velocity of the land yacht at different wind angles, with a tail wind being 0° and a headwind 180° . Keep the fan in the same place and measure the time it takes for the land yacht to travel a given distance: a few meters with a large fan or one meter with a small fan.
3. Change the direction of the sail to 45° relative to the wheels and repeat the experiment. Test ways to make the land yacht travel into the wind.
4. Compare the tail-wind speeds for the two sail orientations.





Extension activities

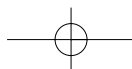
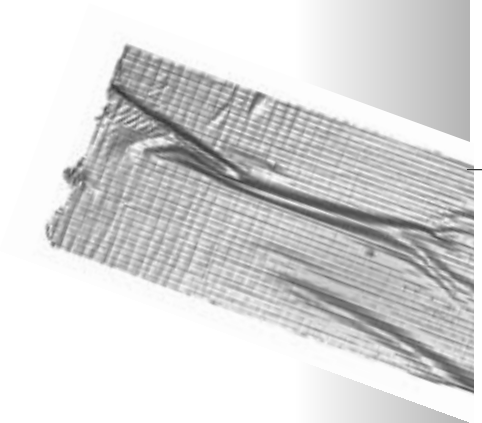
Math activity:

Have students make a graph of velocity (on the vertical axis) vs. wind angle (on the horizontal axis) for each sail position. They should try to determine the function (equation) that describes each curve.

For advanced students:

See http://www.pbs.org/safarchive/4_class/45_pguides/pguide_405/4545_ss.html for a project that involves a course similar to what is shown in the episode.

Students must design a land yacht that can be steered directly or by radio control to run a course that the teacher designs.



#3: PAPER AIRPLANE CONTEST

The activity below can be a fun addition to a Physics Olympiad competition or it can be used as a small lab or project. Let the students get a little bit competitive and encourage them to practice at home. A note of caution: Some administrators may not appreciate students' proficiency at throwing paper airplanes. Beware during the next student assembly!

Materials

For each student contestant:

- one 21.5-cm x 28-cm (8 x 11-inch) sheet of paper
- one strip of masking tape measuring 15 cm x 1.9 cm



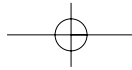
Objective





Construct and fly a paper airplane accurately.



Competition

1. Tell contestants they will receive only one sheet of paper and one strip of masking tape.
No other materials may be used in the construction.
2. Contestants must construct their airplanes at the contest site with the materials provided. They will be allowed 10 minutes for construction; no changes will be allowed after this period.
3. All planes must be able to fly! A contestant who throws a paper wad will be disqualified.
4. Contestants will launch their planes by hand from a standing position behind a restraining line. They may not use any mechanical devices.
5. Place the target on the floor centered 10 meters from the launch line. The plane that first touches down closest to the target wins. All distances will be measured from the center of the target.



  <h2 style="text-align: center;">RUBRIC</h2>   <p style="text-align: center;">Classroom Challenges #1-3 Indicators of Student Involvement</p>			
Categories	0-1 point	2-3 points	4-5 points
Intellectual Curiosity and Spirit of Investigation	<ul style="list-style-type: none"> • Fills in lab sheet only • Asks no questions or irrelevant questions; answers no questions • Not involved with lab • Does not complete experiment 	<ul style="list-style-type: none"> • Makes effort to understand the lab • Asks and answers clarifying questions about the lab • Mostly involved • Completes lab as directed • Passive participation 	<ul style="list-style-type: none"> • Strives for complete understanding • Asks and answers probing questions that extend understanding • Full, active participation • Goes beyond intended activity
Personal Responsibility	<ul style="list-style-type: none"> • Tardy or significant time wasted • Careless with equipment or does not handle equipment at all • Does not follow safety procedures • Cleans up insufficiently • Unprepared for lab activity 	<ul style="list-style-type: none"> • Time wasted or does not complete lab • Some carelessness or risky procedures • Cleans up partially 	<ul style="list-style-type: none"> • Makes good or excellent use of time • Uses lab equipment and facilities responsibly • Cleans up completely • Prepared for class, has needed materials for activity
Group Dynamics and Interactions	<ul style="list-style-type: none"> • Does not contribute to group • Minimal or negative interactions • Creates or encourages unrelated activities or discussions 	<ul style="list-style-type: none"> • Some contribution to group understanding • Mostly receptive to ideas and opinions of others • Creates some distractions 	<ul style="list-style-type: none"> • Contributes to group understanding through questions or explanations • Makes sure everyone in group understands • Receptive to ideas and opinions of others • Makes effort to reduce group distractions



#4: FLYING TO IMPROVE YOUR GRADE



Objective

Read this statement to students: Your mission is to design, test, and fly a rubber band-driven balsa wood plane that carries a cargo of pennies. The plane may be your own design or made or adapted from a kit available at hobby stores or by mail order. You may work with up to three team members. Each team gets three tries, and the best score counts for the team. Points are based on the number of penny-meters the plane carries aloft for each flight. For example, if a plane carries two pennies for four meters, the score is eight points (2 pennies x 4.0 meters = 8 penny-meters).

Additional Parameters

- All planes must take off from a runway measuring 1.25 m long, about 0.4 m wide and about 0.50 m above ground level.
- Measure the linear distance from the end of the runway to the point at which the plane touches down.
- All energy imparted to a plane must come from a single rubber band, through a single propeller, in the spirit of a propeller-driven plane. Students may not push or throw the planes; slingshot-type launchers are not allowed. Students may practice to determine the optimum rubber band-turning techniques.
- Fly the aircraft in a gym or another large open room.
- The team with the greatest penny-meter score that does not violate any parameters will be the winner. All other teams' scores will be scaled based on the winning team's score. (No team that tries hard will receive a function grade lower than C.)

Background Information

Aircraft Design Principles Below is a brief summary of aerodynamics. It is critical in helping students make effective alterations to a plane to optimize its cargo-carrying capacity. The lift force allows a plane to stay in the air. Lift supplied by a wing is approximated by

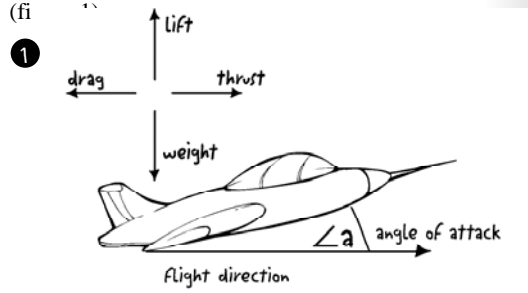
Equation 1

$$\text{Lift force} = (\rho / 2) (C_L V^2 A)$$

Where ρ is the density of the air,
 C_L is the coefficient of lift,
 V is the velocity of the plane, and
 A is the area of the wing, as seen from above.

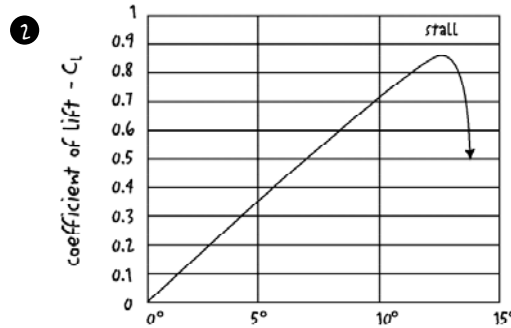
The first parameter, ρ , varies, but it is not something that can be adjusted without a great change of altitude. The other three parameters may be altered to optimize the lift force supplied by a wing. But, just as in real life, adjusting each parameter has advantages and disadvantages.

Coefficient of Lift, C_L : The coefficient of lift is related to the angle between the wing and the direction of flight. This angle is called the angle of attack, α .

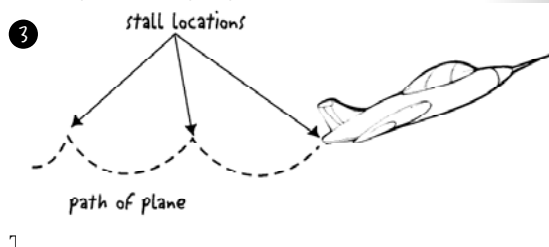


As α increases, so does C_L , but only up to an angle of 10–14°.

After that, the coefficient of lift decreases dramatically in a condition called **stall** (figure 2).

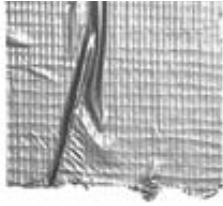


In this condition, there is suddenly very little lift. Stall can cause real-life airplane crashes and will affect a model plane's performance, too. A telltale sign of stalling in a model plane is a roller-coaster path of rising and falling (figure 3).



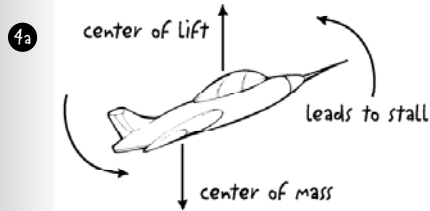
If the angle of attack does not exceed about 10°.

As the designer and builder of a plane, it is up to you to adjust the plane's geometry to avoid stall. Adjust the angle of the wings or shift the balance of the lift forces relative to the plane's center of mass. This acts as the

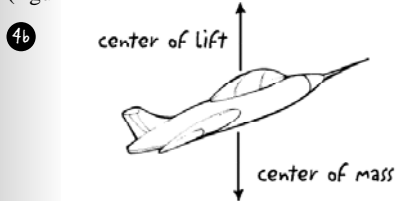


fulcrum on which the plane can rotate.

If the center of mass is too far toward the rear, the plane's balance shifts back, and the angle of attack incre



Shift the center of mass toward the front and the angle of attack will decrease (figure 4b)



Adjust the center of mass for your plane by shifting the location of its cargo. Or move the wings toward the back of the plane to shift the center of lift to the rear of the center of mass.

Velocity, V: The velocity of the plane is an important factor in the lift force that is generated (Equation 1). It is primarily controlled by the thrust of the propeller, the mass of the plane (Remember Newton's Second Law: The lighter the plane, the greater the acceleration for a given force), and the drag on the plane. Each of these factors may be adjusted to increase the velocity and hence the lift.

Thrust: The thrust of a plane comes from the rubber band that drives the propeller. The thrust could be improved by increasing the torque supplied (by using a stronger rubber band or giving it more turns). But this may result in too much stress on the aircraft's frame, which can cause catastrophic failure.

Mass: Increase velocity by reducing the mass of the plane. One of the best ways to do this is to replace some of the balsa wood in the wings with paper. Paper wing sections are much lighter, but still provide enough lift. Carefully plan the exact location at which to substitute paper for wood. The wings should be light, but not too fragile.

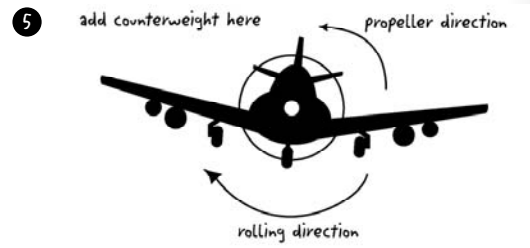
Drag: The drag on the wings is a function of the angle of attack. As the angle of attack increases, so does the drag. However, drag does not increase dramatically until the plane is near a stall condition, which is another reason to reduce the angle of attack to about 10°. Other ways to reduce drag involve adjusting the size and shape of the plane's body and the wheels used for takeoff.

Area, A: As wing area increases, so does lift (Equation 1). Often the wings supplied in balsa-wood kits are too small to carry any plane loaded with cargo. Consider expanding the area of the wing sections. Here are some suggestions:

- Build a larger balsa-wood wing frame, and cover it with tissue paper or plastic wrap instead of using the wing sections supplied.
- Make the wing as long as reasonable by using triangular sections.

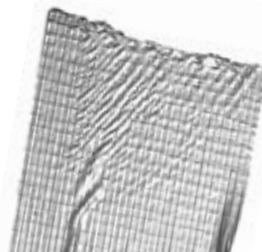
Rolling

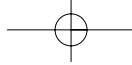
A problem often encountered with rubber band-driven planes is twisting or rolling caused by the unbalanced torque from the single propeller. Reduce this tendency by balancing the torque from the propeller with a counterweight, such as a penny placed on a wing section (figure 5).



Experimentation will help determine the best location for this counterweight.

(Activity based on "Rubber Band-Driven Airplane Contest," by Douglas Oliver and Terry Ng, The Physics Teacher, vol. 37, February 1999, pp. 108-109.)



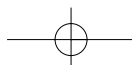


EVALUATION RUBRIC

Flying to Improve Your Grade



Categories	0-1 point	2-3 points	4-5 points
Function (Quantitative)	0-9.9 penny-meters	10-24.9 penny-meters	25 or more penny-meters
Function (Aerodynamics)	Does not take off from the runway or does not fly.	Flies with some stalling or rolling; takes off without aid.	Plane takes off easily; flies level.
Plan and Technical Drawing	Plan shows incorrect measurements, is not to scale, or is drawn or labeled inaccurately.	Plan provides clear measurements and labeling for most components.	Plan is neat with clear measurements; labeling and scale are correct for all components.
Construction	Construction appears careless or haphazard. Many details need refinement for an efficient or attractive plane.	Fairly careful construction and accurately followed plans, but 2-3 details need refinement for an attractive and efficient product.	Great care taken in construction; the plane is neat, attractive, and follows plans accurately.
Scientific Knowledge	Explanations by the majority of group members illustrate little or no understanding of the scientific principles applied in the airplane design and construction.	Explanations by the majority of group members illustrate mostly accurate understanding of the scientific principles applied in the airplane design and construction.	Explanations by all of the group members illustrate clear and complete understanding of the scientific principles applied in the airplane design and construction.
Individual Journal (Content)	Journal provides very little detail about the process of planning, constructing, and testing the airplane. Does not reflect group dynamics and the division of labor.	Journal provides much detail about the process of planning, constructing, and testing the airplane and provides some reflection on group dynamics and the division of labor.	Journal provides a complete record about the process of planning, constructing, and testing the airplane, including reflection on strategies and reasons for modifications and innovations. Clearly discusses group dynamics and the division of labor.
Individual Journal (Appearance)	Few entries made; they are not dated or are too messy to read.	Several entries made; most are dated and legible.	Several entries made; all are dated and legible.



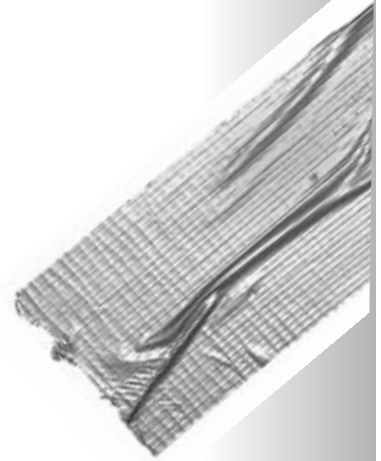
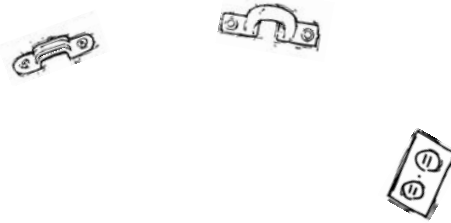
WEB SITES

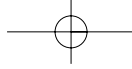
Teachers and students may find the following Web sites informative while working on the Classroom Challenges.

- <http://www.nalsa.org/index.htm> (North American Land Sailing Association)
- <http://www.nalsa.org/images.htm> (Images of land yachts)
- http://www.pbs.org/safarchive/4_class/45_pguides/pguide_405/4545_ss.html (Scientific American Frontiers information on sailboat design)
- <http://home.earthlink.net/~modellandyachts/>, <http://www.clear-point.org/CMYComl.htm>, and <http://www.rlandsailing.com/> (Scale model radio-controlled land yachts)
- <http://sailing.about.com/cs/landyachtplans/> (Plans, how-to's, other information on building and racing a boat)
- <http://www.fsea.org/frproject/highlist.htm> and www.handsonprojects.org (Future Scientists and Engineers of America; information on how to purchase kits for students to build model land yachts or forming an FSEA club at school)
- <http://users.ev1.net/~flexwing/> (Hang-glider designs by a private enthusiast)
- <http://library.thinkquest.org/2819/Hangar.htm> (A student-designed Web page for glider enthusiasts)
- <http://www.mansfieldct.org/schools/mms/staff/hand/Flight1.htm> (Information, links, and directions for making gliders as school projects)

To see Junkyard Wars on DiscoverySchool.com, visit the Web site below.

- <http://school.discovery.com/networks/junkyardwars> (Interactive games and puzzles; ideas for challenges, projects, and activities; and other teacher resources support the Junkyard Wars Classroom Video Kits.)





Episode I: Gliders

Name _____

After Segment 1

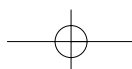
- How would you design a glider to carry a person? Sketch your design.
- Look for evidence of teamwork during the video. Are conflicts resolved successfully?
- Compare your hypothesis to the experts' proposals. Does your design look more like Barnaby's or Chuck's?

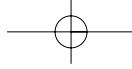
After Segment 2

- How have the teams' plans changed because of materials or time limitations?
- Continue to record instances where you see team members resolving conflicts or supporting each other's work.

After Segment 3

- In your opinion, which team has the best-built glider? Which team has the best overall design? Give evidence to support your answers.
- Predict which team you think will have their glider in the air longer. Give reasons for your choice.
- Describe the results for each team.
- Record the final times: Miami Gearheads: _____ / Hicks Family: _____
- Describe in sentences what occurred during each team's flights.





Episode II: Sand Yacht

Name _____

After Segment 1

- How do the plans proposed by the experts differ? What are the similarities in their plans?

- What are the pros and cons of using a metal sail?
 - PROS:
 - CONS:

- Look for evidence of teamwork during the video. Are conflicts resolved successfully? Give evidence of competitiveness between the teams.

After Segment 2

- How have the teams' plans changed because of materials or time limitations?

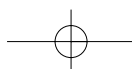
- Continue to record instances where you see team members resolving conflicts or supporting each other's work.

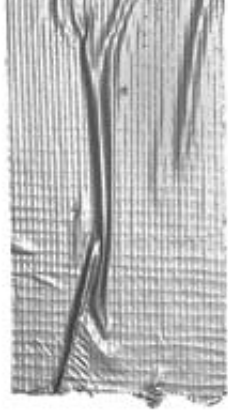
After Segment 3

- In your opinion, which team has the best-built sand yacht? Which team has the best overall design? Give evidence to support your answers.

- Describe one weakness in each team's final product (in other words, predict where their sand yacht might have a problem).

- Describe in sentences what occurs during the race.





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