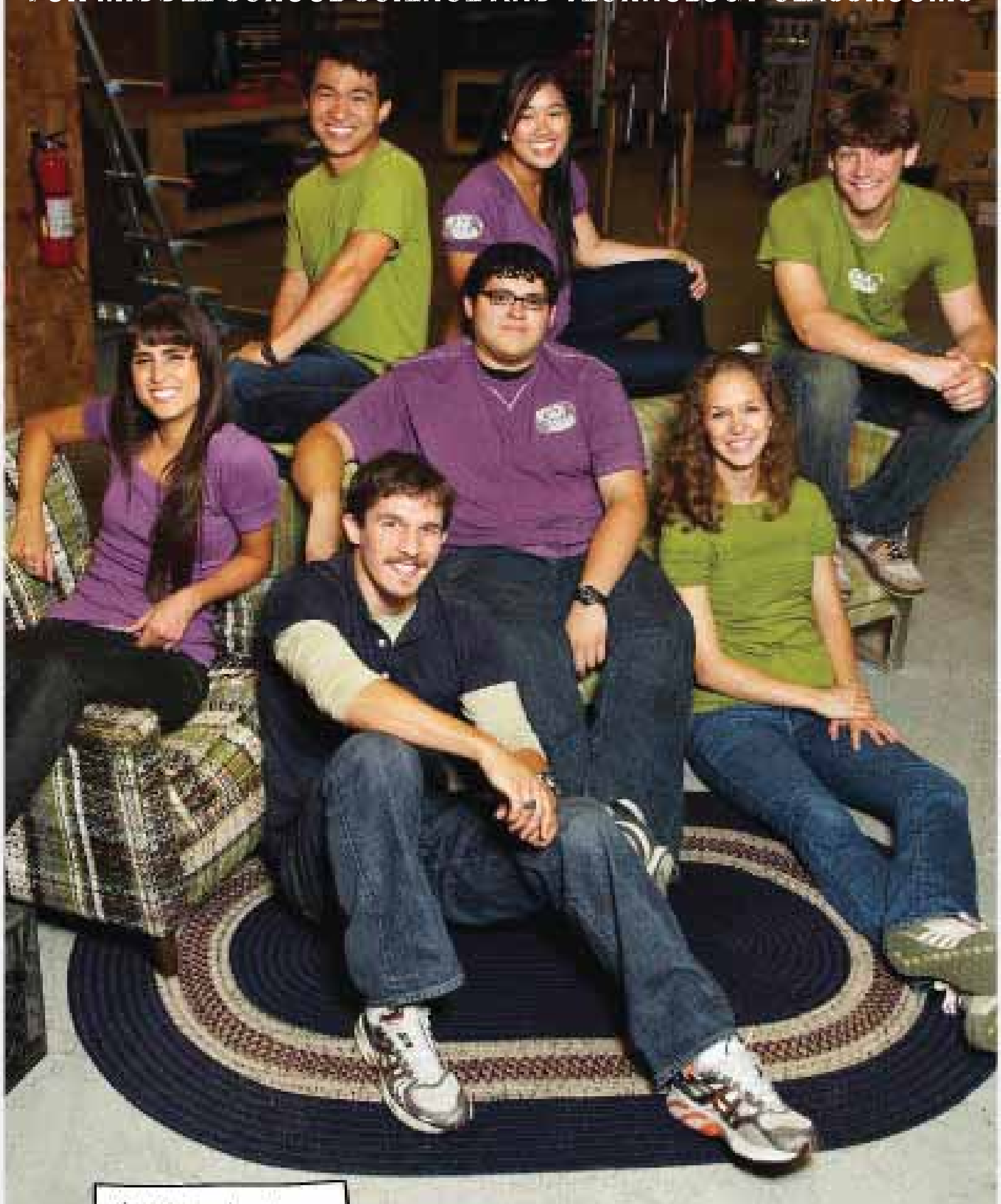
DESIGN SQUAD®

as built on TV™

TEACHER'S GUIDE

FOR MIDDLE SCHOOL SCIENCE AND TECHNOLOGY CLASSROOMS



HANDS-ON ENGINEERING CHALLENGES TO BOLSTER YOUR ELECTRICITY, SOUND, AND FORCE UNITS

PBS

Dear Teachers,

Intel welcomes you to the Emmy and Peabody Award-winning PBS series, *Design Squad®*! Our sponsorship of *Design Squad* is an important component of our commitment to education and to inspiring tomorrow's innovators.

Intel believes that young people are the key to solving global challenges. *Design Squad's* substantive focus on math, science, and the design process is closely aligned with our mission of engaging young people's curiosity and developing their critical thinking and problem-solving skills. We believe that *Design Squad's* ability to bring innovation to life by showcasing engaging, real-life applications of engineering will increase students' interest in the subject and in creative careers that turn science into reality.

We encourage you to use this *Design Squad Teacher's Guide*—in concert with the television series and the media-rich Web site—to help your students investigate and solve challenging problems that just may change the world.

Sincerely,

Shelly Esque
President, Intel Foundation

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Design Squad® goes to school! This guide is written especially for middle school teachers of science, technology, engineering, and mathematics (STEM). Its hands-on, standards-based activities focus on force, electricity, and sound—topics found in nearly every physical science curriculum. In the process of tackling the guide's open-ended challenges, students develop a working understanding of core science concepts, deepen their understanding of the design process, and increase their motivation to learn science, technology, engineering, and math.

INTRODUCTION

UNIT 1: ELECTRIFYING GAMES

Explore circuits by designing a pinball-style game with motors and buzzers.

UNIT 2: SOUNDS GOOD

Explore sound by making stringed instruments and rockin' out.

UNIT 3: BREEZY BLIMPS

Explore Newton's Laws, force, and air pressure by making blimps out of balloons.

APPENDIX

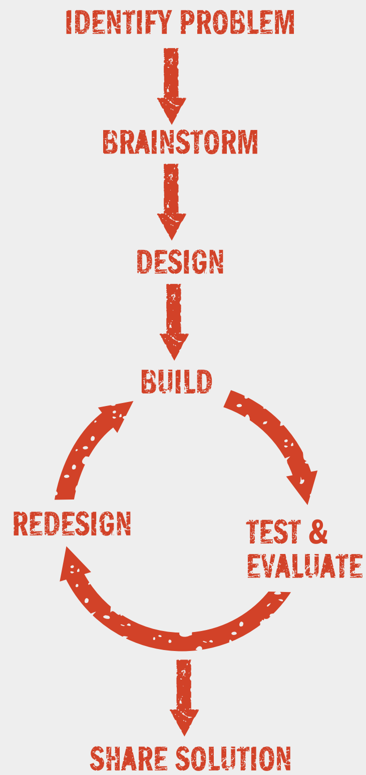
DESIGN SQUAD as built on TV

Competition plus engineering equals fun! *Design Squad* gets kids thinking like engineers and shows them that engineering can be fun, creative, and something they can do. Watch it on PBS and visit the Web site to get episodes, games, dozens of hands-on challenges, and much more.

Use this guide to deepen students' understanding of science concepts and the engineering design process, provide opportunities for teamwork and hands-on problem solving, and present engineers as creative problem solvers who design things that matter and improve people's lives.

INTRODUCING THE DESIGN PROCESS

Engineers' initial ideas rarely solve a problem. Instead, they try different ideas, learn from their mistakes, and then try again. The steps engineers use to arrive at a solution are called the ***design process.*** As students work through a challenge, use the questions below to tie their work to specific steps of the design process.



The design process is a great way to tackle almost any task. In fact, you use it each time you create something that didn't exist before (e.g., planning an outing, cooking a meal, or choosing an outfit).

BRAINSTORM

- What are some different ways to tackle today's challenge?
- Off-the-wall suggestions often spark GREAT ideas. How creative can you be?

DESIGN

- Which brainstormed ideas are really possible, given your time, tools, and materials?
- What are some problems you need to solve as you build your project?
- How can a sketch help clarify your design?

BUILD

- What materials will you need?
- What can you learn by looking at other students' projects?

TEST, EVALUATE, AND REDESIGN

- Why is it a good idea to keep testing a design?
- What specific goal are you trying to achieve, and how will you know if you've been successful?
- How does the design meet the criteria for success presented in the challenge?

SHARE SOLUTIONS

- What's the best feature of your design? Why?
- What were the different steps you did to get your project to work?
- What was the hardest problem to solve?
- Did you have to do something a few times to get it to work? What?
- If you had more time, how would you improve your project?

APPLYING THE DESIGN PROCESS

The design process is built into each challenge. As students work through a challenge, they'll see that the steps of the design process encourage them to think creatively to solve a problem.

"Engineering activities tend to allow for more creativity and differences in thinking than science labs. They ask students to be creative, problem solve, and work directly with materials."

Rosemary B.
Fairgrounds Middle School
Nashua, NH

WATCH CLIPS OF THE DESIGN PROCESS IN ACTION

There is a short video clip of each design process step on the *Design Squad* Web site. By watching the *Design Squad* teams work through each step of the design process, students will learn to think creatively when solving a problem and strengthen their critical-thinking abilities. Also, if your class is struggling with any particular step or with group dynamics, these videos offer a convenient way to talk through an issue. Download the clip(s) you want from the “Teacher’s Guide” page at **pbs.org/designsquad**.

Identify the Problem (1½ minutes)
Understanding the problem paves the way for solving it. This clip lets you emphasize to students the importance of defining the challenge(s) clearly before getting started. As a class, discuss how the *Design Squad* teams prepare to design and build furniture out of cardboard.

Brainstorm (1½ minutes)
Coming up with many possible solutions is a powerful way to begin a project. This clip shows *Design Squad* teams generating lots of ideas for devices that a dancer can use in an underwater performance. As a class, discuss what made this brainstorm successful.

Design (1 minute)
Now it’s time to choose the best solution and plan how to build it. In this clip, the *Design Squad* teams squabble about when to stop designing and start building their specialized bikes. As a class, discuss possible solutions for moving a team forward when there is disagreement.

Build, Test, Evaluate, and Redesign (1 minute)
Once kids settle on a design, it’s time to build, test, and redesign it. This clip shows that things don’t always work as planned. As a class, discuss how the *Design Squad* teams learn from their testing results and figure out how to redesign and make improvements.

Share Solutions (2 minutes)
Presenting one’s work to others is a constructive way to conclude a project. As a class, discuss how the *Design Squad* team’s presentation validates the team’s work, places it in a broader context, and lets the team members reflect on how effectively they communicated and collaborated.

Let the *Design Squad* teams model the steps of the design process for your students. Download these five brief videos from the Teacher’s Guide page at **pbs.org/designsquad**.

EXPAND YOUR SKILLS

Build your skills and confidence in guiding students through engineering activities using the design process. Through this free, self-guided, NASA–*Design Squad* online training, you’ll see what the design process looks like in the classroom, learn a host of implementation strategies, and experience the fun and relevance of engineering. Find it at: **pbs.org/designsquad/educators**.

HOW TO USE THIS GUIDE

This guide will help you integrate standards-based design challenges into your science, technology, engineering, and mathematics (STEM) units.

The Unit Overview is a roadmap to the unit.

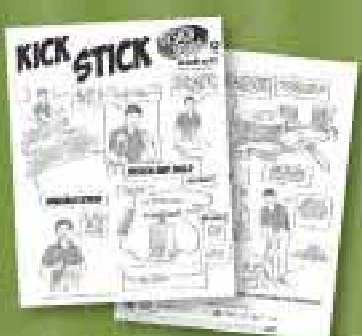
START WITH THE UNIT OVERVIEW

Each unit opens with an overview that describes the activities and shows how they can enrich your curriculum and target what you want your students to learn. Use the overview to choose the challenge(s) that fit your curricular goals and the time you have available. Each challenge is designed to take 50 minutes.

The Teacher Notes give you all you need to facilitate a challenge with students.

REVIEW THE EASY-TO-USE TEACHER NOTES

- **Preparation:** Lists things to do to get ready for the activity.
- **Introduce the challenge:** Presents the challenge and puts it in a *Design Squad* context by having students watch a short, relevant video clip from the show.
- **Brainstorm:** Identifies the activity's key elements and offers talking points to jump-start student thinking about ways to meet the challenge and apply related science concepts.
- **Summarize the problem to solve:** Asks students to identify the specific tasks they'll need to accomplish in the class period and to consider how to order them. This pre-planning helps students make effective use of class time.
- **Build, test, and redesign:** Lists issues that might surface during a challenge and suggests strategies you can use with students who face these issues.



The Handout helps students build and troubleshoot their projects.

COPY THE STUDENT HANDOUT

Nate Ball is a mechanical engineer and the 20-something host of *Design Squad*. His cartoon alter ego serves as a mentor and guide, introducing the challenges, offering tips for carrying out the projects, and encouraging students to find creative solutions and achieve success.

DRIVE HOME THE UNIT'S SCIENCE AND ENGINEERING

Make a unit relevant by helping students see how the unit's science and engineering matter beyond the walls of the classroom. In each unit's *Making It Real* session, students present their work and discuss how they've applied the design process and the unit's science concepts. They also watch short video clips featuring young engineers doing interesting, rewarding work. These clips help students relate their own work to real-world engineering applications—they discover that they're thinking and working like engineers. *(In our testing, we found that it's far more constructive to have this presentation and discussion at the end of a unit, rather than at the end of a challenge, when students are so engaged in what they're doing that it's counterproductive to divert them from the task at hand.)*

ELECTRIFYING GAMES

IN THIS UNIT: Students explore circuits by designing a pinball-style game that uses motors, balls, and buzzers.*

UNIT TABLE OF CONTENTS

Kick Stick challenge (pages 6–9)

- **Overview:** Students build a "kick stick" by attaching a set of arms to a battery-operated motor, mounted on a paint stirrer. When the motor's shaft spins, it rotates the arms, which students use to kick a Ping Pong® ball across the floor. Students then design and build a switch to control the motor and troubleshoot the circuit.
- **Learning outcomes:** Students will be able to design and build an electrical circuit and discuss how a switch opens and closes it. They will be able to explain why the circuit is a series circuit and identify materials as conductors or insulators. Finally, they will be able to describe how they used the design process to design and build their kick sticks.

Electric Gamebox challenge (pages 10–13)

- **Overview:** Students use their kick sticks to launch a Ping Pong ball at a target, which has a pressure-sensitive switch. This switch activates a buzzer when the ball hits it. Students apply what they learned about circuits and the design process in *Kick Stick* to design and perfect the switch and troubleshoot the circuit.
- **Learning outcomes:** Students will be able to explain how switches and series circuits work and describe how they used the design process to design and build a pressure-sensitive switch.

Making It Real (pages 14–15)

- **Overview:** Students present their games and discuss the science and engineering behind their designs. They also watch two short videos: They meet a young engineer who designs toys, and they see how the *Design Squad* teams use the design process to refine their automatic ball kickers.
- **Learning outcomes:** Students will be able to identify the science concepts exhibited in their work (e.g., electric current, conductors, insulators, circuits, and switches), explain how the design process encourages them to think creatively to tackle a challenge, point out how they are thinking and working like engineers, and cite examples of how engineering is a profession centered on improving people's lives.

PLANNING YOUR TIME

Only have one class period available? Do *Kick Stick*.

Two class periods? Do *Kick Stick* and *Making It Real*.

Three? Do all three sessions.

"My students are far more receptive to learning things if they can actually do it, try it, and play with it."

Linda A.
Worcester Academy
Worcester, MA

*For specific STEM standards, see Appendix, page 48.

"Ping Pong" is a registered trademark of Parker Brothers, Inc.

KICK STICK CHALLENGE

First, students brainstorm and sketch ideas for their kick stick's circuits, switches, and kicking arms.

Then, students apply what they know about circuits, conductors, and switches and learn how to use wire strippers and tear duct tape.

The Challenge: Build a handheld "kick stick" that uses a motor-driven, spinning arm to kick a Ping Pong ball across the floor.

Preparation

- ☐ Copy the *Kick Stick* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Just for Kicks Challenge*** (1 minute) and ***Series Circuits*** (30 seconds). Be prepared to project them.
- ☐ Gather these materials (per student). See page 44 for suppliers.
    - 3-volt motor (the kind with gear attached to shaft)
    - AA battery in a battery holder
    - cardboard
    - rubber faucet washer (¾-inch or larger)
    - paper clips
    - duct tape
    - wire strippers
    - aluminum foil
    - 2 craft sticks
    - hook-up wire (e.g., 22-gauge, stranded)
    - paint stirrer
    - Ping Pong ball
    - scissors

1 Introduce the challenge (5 minutes)

- Tell students that today's challenge is to design and build a kick stick, which they can hold in their hand and use to kick a Ping Pong ball across the floor.
- Show the ***Just for Kicks Challenge*** video in which the *Design Squad* teams invent automatic ball kickers to help a professional soccer team practice.
- Discuss similarities between the *Kick Stick* challenge and the automatic ball machine from the *Design Squad* clip. *(Both send a ball flying, use batteries, motors, and circuits, are useful, and are a lot of fun.)*
- Show the ***Series Circuits*** animation. Take a moment to review the basics of electric circuits, such as open and closed circuits, series circuits, and switches.

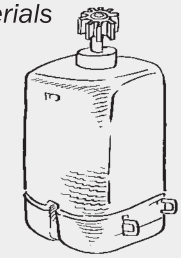
2 Brainstorm (10 minutes)

Brainstorm the circuit

- Show how the battery and motor work by connecting them and running the motor. Ask students to direct you in tracing the path of the electricity. *(They should tell you to start at the negative battery terminal, run your finger along the wire to the motor, and then exit the motor and follow the other wire to the positive battery terminal.)*
- What happens when there's a gap in the circuit? *(The current stops flowing. Review the terms open and closed circuits.)*
- How does a switch control whether a circuit is open or closed? *(Switches open and close a gap in a circuit.)*
- Is this circuit wired in series or parallel? *(Series, because the current travels a single path as it goes from the negative to the positive battery terminal.)*
- The paint stirrer is the "stick" part of the kick stick. Can you attach the battery and motor anywhere to the paint stirrer and still make a circuit? Explain. *(Yes. As long as there's an unbroken conducting path, electricity can flow from one terminal to another. Since proximity doesn't matter, the components can go anywhere: top, bottom, front, back, next to each other, or far apart. Students can use wire to bridge any gaps.)*

Brainstorm the design process

- Brainstorm how you could use a spinning shaft to get a Ping Pong ball moving. *(Attach a blade or set of blades to the shaft so they can hit a ball when the motor spins.)*
- Look at the materials you have for making the blades. What are the materials, and what are their strengths and weaknesses? *(Stiff blades [craft sticks, paper clips] as well as softer duct-tape strips [rolled tightly] can firmly kick a ball. Point out that while tape is soft, it can deliver a lot of force when it spins quickly. Encourage students to experiment with the different materials to decide what to use for blades and how to orient them.)*
- The motor's shaft is tiny. The large washer slips onto the gear and spins when the shaft spins. Brainstorm ideas for attaching blades to this washer. *(The washer provides a wide platform that students can tape their blades to.)*



Brainstorm the engineering

- Engineers create and improve things that matter to people. Why are games important? *(People love playing games, whether they're card games, board games, or video games. The message is: Making games matters because games entertain people.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you make your kick stick? *(Where to put the battery and motor; how to turn it on and off; how to build a working circuit; what material to use for the blades; how to attach the blades to the motor; and how to attach everything to the paint stirrer)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning the materials into a kicker that can kick a Ping Pong ball. Distribute the handout, and have them sketch their ideas.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Duct tape is hard to tear:** You can speed students' progress by demonstrating how to tear duct tape. You can also tear strips in advance and put them at the tables.
- **The washer doesn't fit:** If the washer hole is too large to fit properly on the motor gear, wrap a tiny piece of duct tape around the gear. Adjust it until the fit is snug.
- **It's hard to connect wire to the motor:** Straighten the motor contacts, but do it gently to avoid breaking them off.
- **Switches are unreliable:** A switch that has small contacts can be hard to close. Have students attach a paper clip or large piece of foil to the ends of their wires. The larger contacts will make it easier to close the circuit.

Next, using a paint stirrer as the stick, students attach batteries, motors, and wires. Each design is unique.

Finally, students test their kick sticks by hitting Ping Pong balls across the floor, playing games they invent.

KICK STICK

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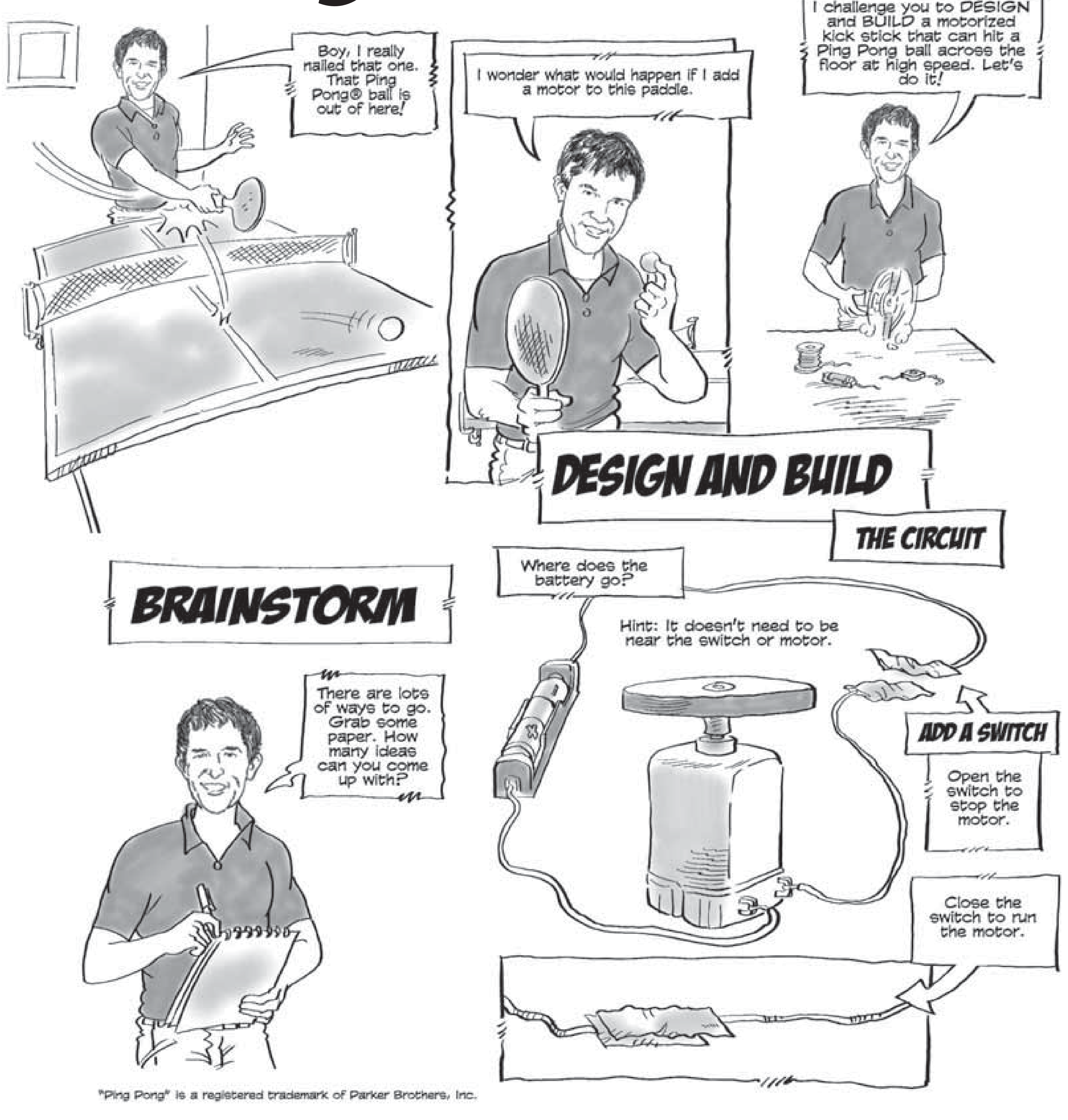


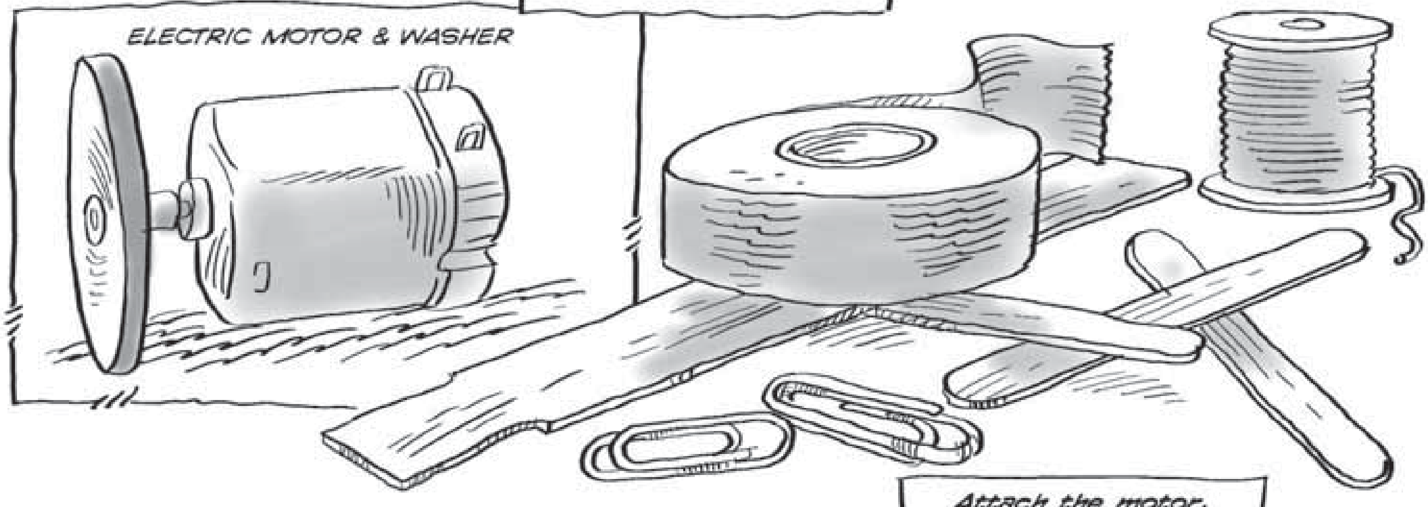
"Ping Pong" is a registered trademark of Parker Brothers, Inc.

DESIGN AND BUILD

THE KICKER BLADE

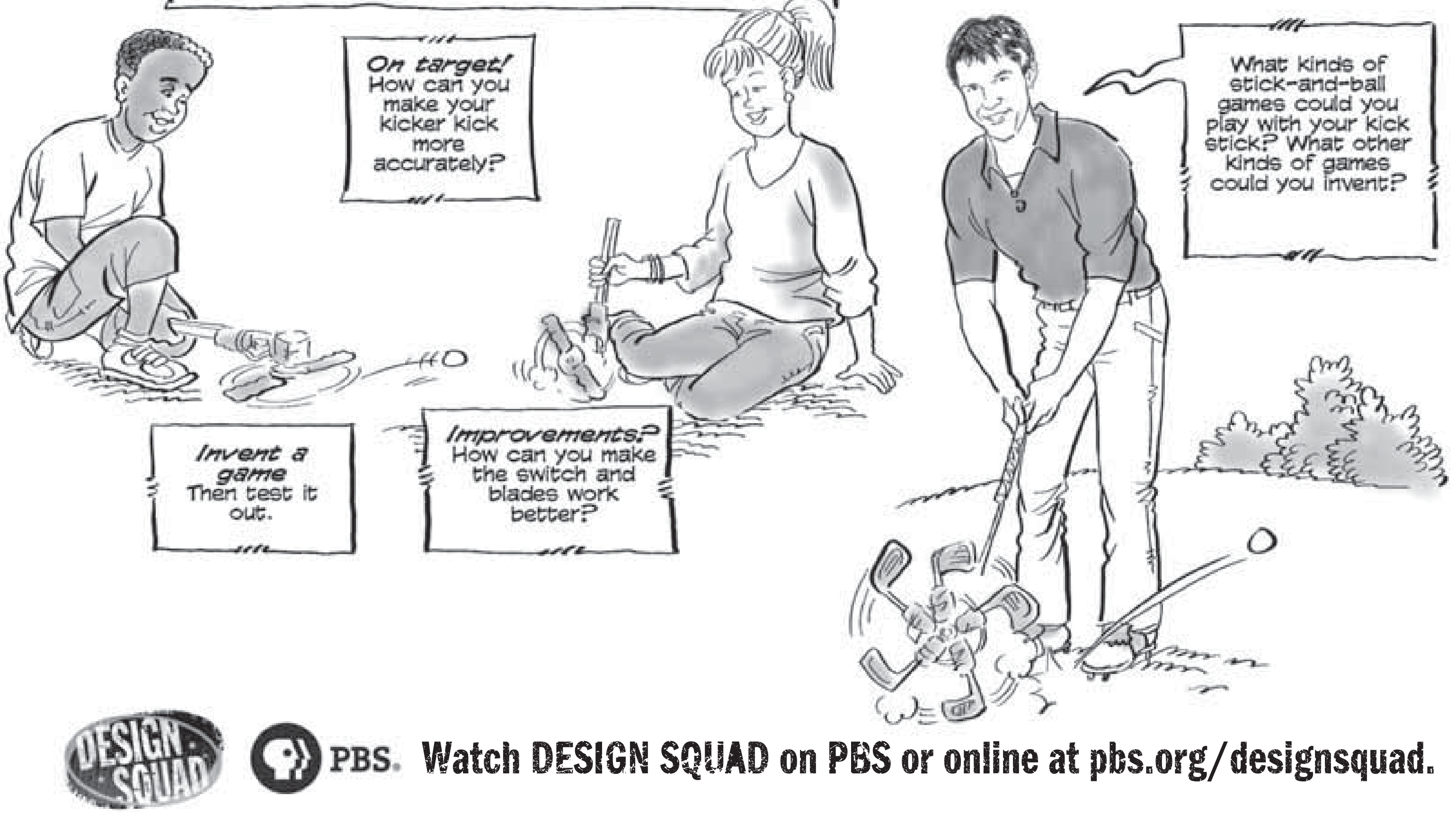
Kicker blade materials
Did you choose duct tape? Craft sticks? Paper clips? Paper? All these will work. Test what gives a Ping Pong ball a solid kick.

Where will the motor go?
In the middle of the stick? At the end pointing out? At the end pointing down?



Attach the motor, washer, and blades
Put the washer on the motor gear. Tape your blades to the washer.

TEST AND REDESIGN



Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.

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WGBH

ELECTRIC GAMEBOX CHALLENGE

First, students use copier-paper box tops (with their convenient built-in sides) for their game boards.

The Challenge: Invent a pinball-like game where your kick stick hits a Ping Pong ball into a target that buzzes.

Preparation

- ☐ Copy the *Electric Gamebox* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Design Process: Teamwork*** (1 minute) and ***Switches*** (1 minute). Be prepared to project them.
- ☐ Gather these materials (per student). See page 44 for suppliers.
  - kick stick from the previous session
  - battery, either 9 V and connector or AA and holder (see step 4)
  - buzzer
  - paper clips
  - scissors
  - aluminum foil
  - wire strippers
  - shallow box (e.g., copier-paper box top, lettuce box, berry box, etc.)
  - duct tape
  - paper cup (4 oz.)
  - Ping Pong ball
  - hook-up wire (e.g., 22-gauge, stranded)

1 Introduce the challenge (5 minutes)

Point out that, in the *Design Squad* TV challenge, the client is a soccer player whose job is to kick a soccer ball into a goal. Tell students that today's challenge is similar—to invent a game where their kick sticks hit a Ping Pong ball into a target that buzzes when the ball hits it. The target could be a cup, a hole, or a goal—the choice is theirs. Ask:

- What are some ball-and-target games you like? *(Pinball, bowling, mini-golf, billiards, air hockey, foosball, hockey, soccer, basketball, etc.)*
- What kinds of things use pressure-activated switches? *(Automatic door; seat belt sensor; vending machine; elevator button; door bell; computer keyboard; etc.)*

2 Brainstorm (10 minutes)

Brainstorm the circuit

- Hold up a buzzer and ask students how they would make it buzz. *(Attach it to a battery.)*
- Connect the leads of the battery holder and buzzer. Ask: What do you notice when you connect the different-colored wires from the battery to the buzzer? *(Let students figure out that the buzzer only works when the leads are connected red-to-red and black-to-black. This is because, to work, a buzzer uses an internal* ***electromagnet****. If the current runs the wrong way, the electromagnet doesn't work and the buzzer can't buzz.)*
- How can you rig up a switch so the buzzer buzzes when the ball hits a target mounted on a wall? *(The target could be a sheet of foil hanging down, which gets pushed back onto a contact [e.g., wires or paper clips] when the ball hits the foil.)*
- How can you rig up a switch so the buzzer buzzes when the ball falls into a cup? *(The ball could drop into a cup and land on some foil. This pushes the foil down onto contacts at the bottom of the cup, closing the circuit. Students could also wrap a ball in foil. When the ball falls into the cup, the foil would bridge the gap between two contacts.)*

Then, students design pressure-sensitive targets that buzz when hit by a Ping Pong ball.

- Show the ***Switches*** animation. The switches in the animation run circuits connected to components like computers rather than to buzzers, as in *Electric Gamebox*. Still, students will see how switches work and that there are different ways to open and close a circuit.

Brainstorm the design process

- Show the ***Design Process: Teamwork*** video. Discuss the Green Team's comments and have students brainstorm strategies that could enhance teamwork, such as listening and adjusting one's style to help things work smoothly.

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you make your game? *(What kind of game board to make; where the target will go; how to add a switch and a buzzer to the target; and how to build a circuit)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning the materials into a game with a buzzing target. Distribute the handout, and have them sketch their ideas.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Cutting cardboard:** Since students will be cutting corrugated cardboard, provide scissors that are up to the task. If necessary, show students how to cut thick materials without hurting themselves. Point out that it's easier to cut a square hole than a round hole, and that, since a cup is flexible, students can easily push it into a square hole.
- **Planning ahead:** A cup with a battery and/or buzzer attached won't fit through the hole. Push the cup through the hole, and *then* have students attach the wires, paper clips, battery, and buzzer.
- **The buzzer doesn't buzz:** Weed out defective buzzers by having students check that their buzzers work before they start building. (Make sure their leads are red-to-red and black-to-black.) Also make sure the circuit works by using your fingers to close it manually. Finally, buzzers work best when supplied with lots of electricity. Check that the batteries are fresh. Students can also connect two AA batteries in series, doubling the voltage. Finally, consider using 9-volt batteries with battery caps. With 9 volts, the buzzers will roar to life the instant the switch closes, a real advantage considering that a Ping Pong ball may only close a switch for a very brief moment.
- **Switches work inconsistently:** A switch that has small contacts can be hard to close. Have students attach a paper clip or large piece of foil to the ends of their wires. The larger contacts will make it easier to close the circuit. Also, some switches use a sheet of foil that hangs down. When the ball hits the foil, the sheet swings back, onto a wire. This closes the circuit, and the buzzer buzzes. If there's no sound, be sure that students have positioned the contact wire at the correct height—about where the ball hits the target.

Next, students test their kick sticks and gameboxes, making adjustments as needed.

Finally, in *Making It Real*, students discuss the science and engineering behind their designs and describe how they are thinking and working like engineers.

ELECTRIC GAMEBOX

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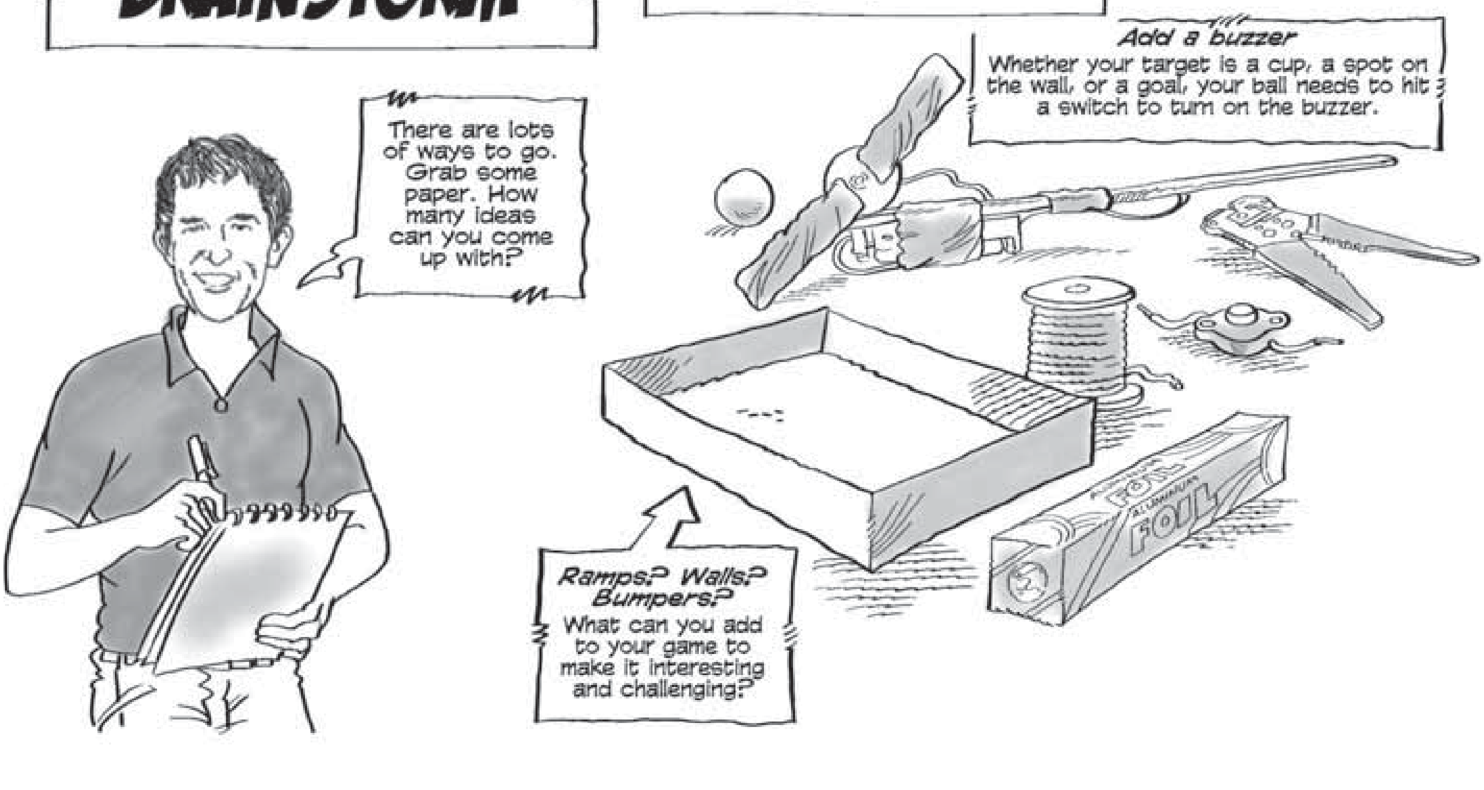
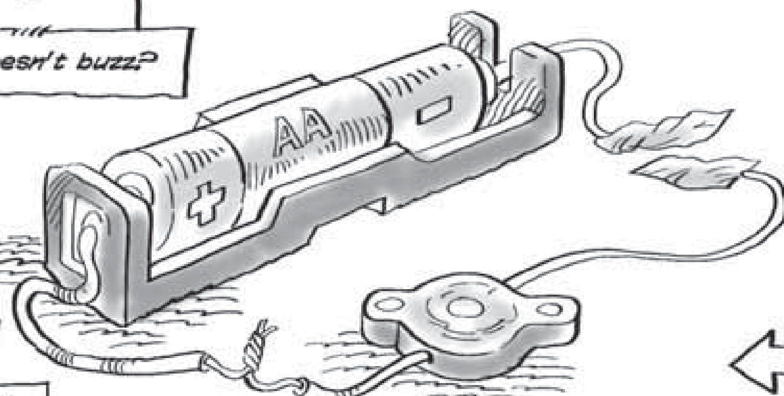
BRAINSTORM

DESIGN AND BUILD



TEST

Target doesn't buzz?



Connections secure?
Make sure there's good contact between all wires.

Switch in the right spot?
Use your fingers to open and close the switch to make sure it works. Check that the ball closes the circuit and buzzes the buzzer.

Color-coded
Are your wires connected red-to-red and black-to-black?

GAME TIME

Find a partner
Play each other's game.

REDESIGN

1. What worked well in your game?

____

____

____

2. What is one way you could make your game better?

____

____

____

How do you know a game is *great?* People play it again and again and again!

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NOYCE FOUNDATION · UEF · NCEES National Council of Examiners for Engineering and Surveying · ASME · IEEE Celebrating 125 Years · NORTHROP GRUMMAN Foundation

MAKING IT REAL:

DRIVING HOME THE ELECTRIFYING GAMES UNIT

DESIGN SQUAD

SHOW KIDS THE RELATED TV EPISODE

Show students *Just for Kicks*, the full-length *Design Squad* episode related to the *Electrifying Games* unit, where the *Design Squad* teams design and build a device that automatically feeds a stream of balls to a professional soccer player. Watch it online at: **pbs.org/designsquad**.

"Students attempted several changes to "fix" the problem with their designs. They observed other students' trials and created new prototypes in an attempt to resolve problems their peers experienced. They were also able to explain why they needed these changes."

Diana C.
Abigail Adams Middle School
Weymouth, MA

***Overview:* Students take their work beyond the walls of the classroom, using a combination of presentations, videos, and discussion. They present their kick sticks and gameboxes, discuss how they demonstrate the unit's science concepts, point out how they are thinking and working like engineers, and discuss how engineering is a field centered on improving people's lives.**

Preparation

☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Just for Kicks Judging*** (4 minutes), ***Design Process: Testing & Frustration*** (1 minute), and ***Judy Lee*** (2 minutes). Be prepared to project them.

1 Raise student awareness of engineering (5 minutes)

Our world is molded by the engineering that surrounds us. Yet, many students are unaware of what engineers do. Probe students' ideas about engineering. Ask:

- What do engineers do? *(Because few students—or even adults—can answer this question fully, it is a provocative opener. List students' ideas.)*
- Then ask: What things in this room were probably designed or made by engineers? *(There is very little in the room other than the people, plants, and dirt that does not bear the mark of an engineer. For example, the classroom lights, the clean drinking water, and the filtered, air-conditioned air are all brought to you courtesy of engineers!)*

2 Relate students' work to science and engineering (25 minutes)

Show the ***Just for Kicks Judging*** and the ***Design Process: Testing & Frustration*** videos. Ask:

- How is the process you followed similar to the one the kids on *Design Squad* did? *(Both the students and the* Design Squad *teams brainstormed lots of ideas, then built, tested, and revised their designs, and finally presented their solutions to others.)*
- When testing shows that things aren't going according to plan, what are some ways to redesign, even as time is running out? *(Make sure you understand why things aren't working as expected; do the simple things first; get everyone's input; divide up the tasks)*

Students are proud of having met the challenge. Have them show their work. Use the following questions to help them talk about the process they went through.

- How did what you learned about circuits and switches in *Kick Stick* help you when you designed and built your electric gamebox?
- What were some of the problems you solved as you built, tested, and redesigned your kick stick and electric gamebox?
- What clues did you learn from testing that helped you improve your design?
- In what ways did you think and work like an engineer as you made your kick stick and electric gamebox? *(Followed the design process; applied science concepts; made something people want; used creativity; tackled interesting challenges)*

3 Meet an engineer (10 minutes)

View the ***Judy Lee*** video to introduce students to an engaging young engineer involved in exciting challenges and doing interesting, creative work. Judy designs toys and other products. In the video, she reinforces the design process, the importance of teamwork, and the fun side of engineering.

- After watching, have students recap Judy's brainstorming rules. *(Sketch as you think; defer judgment; encourage wild ideas; build on others' ideas; and go for quantity)*
- What would people expect in a ball-and-target game they bought? *(Fun; everything works; easy to play; doesn't wear down or wear out; challenging but not impossible to succeed; different levels of play; exciting payoff like a buzzer; cool design; etc.)*
- Tell students that their designs are ***prototypes***—models for testing and improving a design in order to develop a final product. Ask: If Judy Lee's company wanted to produce your kick sticks and games, what improvements could you recommend to make them work better or be more fun?

4 Make the engineering real (10 minutes)

Use the following questions to help students see how their work relates to engineering and see that engineers design things that matter and improve people's lives. Ask:

- Why are games important? *(People love playing games, whether they're card games, board games, or video games. The message is: Making games matters.)*
- How is what you're doing in *Kick Stick* and *Electric Gamebox* related to what engineers do? *(Games are fun and enrich people's lives. Since engineers work to improve the world, they are often involved in designing games and equipment that make life more fun.)*
- Who might be interested in buying a buzzer-equipped ball-and-target game? *(Schools and afterschool programs, kids, parents, recreation centers, camps, game manufacturers, hospitals; etc.)*
- What are some ways that engineers are involved in making games? *(Designing sports equipment; programming video games; manufacturing board games; applying new materials and technology; inventing new game ideas; etc.)*

Extension Ideas

- Share photos of your students' designs and see what others have made. Visit DS XCHANGE, *Design Squad*'s online community at **pbs.org/designsquad**.
- Find lots of build-it-yourself circuit gadgets at: **buildinggadgets.com/index_circuitlinks.htm**.

Interdisciplinary Connections

- *History*: Have students look up toys from the past. What toys were popular 100 years ago? How did kids play or entertain themselves in the past?
- *History/Technology:* If you lived at a time when small motors and batteries were unavailable, how could you make your blades spin? How could you make your game work without electricity?

Students develop a working knowledge of circuits in *Kick Stick*, take their understanding further in *Electric Gamebox*, and explore the relevance of the science and engineering in *Making It Real.*

Engineers design and build things that matter to people, including games and equipment that makes life more fun.

TELL US WHAT YOU THINK

Take our quick online survey, and we'll send you a *Design Squad* class pack (while supplies last—see back cover for details).

UNIT 2: SOUNDS GOOD

IN THIS UNIT, students explore sound by making stringed instruments and headphones and then playing tunes.*

UNIT TABLE OF CONTENTS

- **Overview:** Students change a virtual string's tension, length, and gauge to create different pitches and write a melody—just what they do in a "non-virtual" way in *Build a Band*.
- **Learning outcomes:** Use *String Thing* to: a) introduce the unit by defining relevant terms and giving students experience manipulating the variables they'll work with in *Build a Band*, or b) end the unit, as a culminating activity, review, or assessment of the unit's concepts.

- **Overview:** Students stretch four rubber bands around, over, or across a shoebox and tune them to different pitches by adjusting the strings' tensions and lengths. To maximize volume, they design an instrument that transmits vibrations well whenever a string is plucked. Finally, they work in pairs to tune their instruments and play a melody.
- **Learning outcomes:** Students will be able to design and build a tunable instrument and discuss how a string's tension, length, and gauge affect pitch. They will also be able to describe how they used the design process to design and build their instruments.

- **Overview:** Students apply what they learned about sound in *Build a Band* to design and build a headphone system. They choose either a string-telephone system or a tube-based option to carry the sound waves from the instrument to their ear. Then they determine the best place to attach the string or tube—where the instrument vibrates a lot when a string is plucked.
- **Learning outcomes:** Students will be able to explain how sound waves travel and describe how they used the design process to design and build a headphone.

- **Overview:** Students present their instruments and discuss the science and engineering behind their designs. They also watch two short videos: They meet a young engineer who uses sound to navigate a submarine, and they see how the *Design Squad* teams use the design process to refine their instruments.
- **Learning outcomes:** Students will be able to identify the science concepts exhibited in their work (e.g., sound energy, pitch, waves, amplitude, frequency, and wavelength), explain how the design process encourages them to think creatively to tackle a challenge, point out how they are thinking and working like engineers, and cite examples of how engineering is a profession centered on designing and building things that matter to people.

* For specific STEM standards, see Appendix, page 48.

PLANNING YOUR TIME

Only have one class period available? Do *Build a Band*.

Two class periods? Do *Build a Band* and *Making It Real*.

Three? Do *Build a Band*, *Headphone Helper*, and *Making It Real*.

When should I do *String Thing*? Use *String Thing* to introduce or end a unit—or both! For details, see page 17.

"Solving a real problem is a turn-on, especially for kids with learning problems."

Rosemary B.
Fairgrounds Middle School
Nashua, NH

STRING THING ONLINE GAME

String Thing is an interactive online game on the *Design Squad* Web site. In the game, students change a virtual string's tension, length, and gauge to create different musical pitches. These are the same kinds of changes they'll be making in the *Build a Band* challenge.

A class can complete *String Thing* in as little as 20 minutes, or the game can fill an hour. Use the game as an introduction to define relevant terms (e.g., frequency, pitch, gauge) and as a way to give students experience manipulating the variables they'll work with in *Build a Band.* Alternatively, use it at the end of the unit as a culminating activity, a review, or as an assessment of concepts and factors related to sound.

Preparation

- ☐ Decide if you'll do *String Thing* to introduce or end your sound unit—or both.
- ☐ Bookmark *String Thing* (Visit pbs.org/designsquad and click on "Play Games.")
- ☐ Copy the *String Thing* handout (one per student).
- ☐ Provide one computer per student pair, or project *String Thing* onto a screen to do as a class.

Procedure (20–50 minutes)
Distribute the handout and have students complete it, either in pairs or as a class. Review the terms ***tension, gauge,*** and ***length*** on the handout. If students are playing *String Thing* in pairs, give them 10–15 minutes before you start reviewing the questions together as a class.

Answers to questions on the student handout:

3. List three ways to lower a string's pitch. *(Lengthen it; reduce its tension; or increase its gauge.)*
4. Drag a long string and a short string onto the grid. Change the tension or gauge of these strings so they play the same pitch. Describe what you did. *(To raise a string's pitch, increase the tension, decrease its gauge, or both. To lower a string's pitch, decrease the tension, increase its gauge, or both.)*
5. Which changes the pitch more: increasing the gauge of a string by one click, or the length of a string by one fret? *(Gauge changes the pitch more than length does.)*
6. How do you play the highest note possible? *(Use a short, thin, tense string.)*
7. List some reasons why adult voices are usually lower than kids' voices. *(Pitch depends on the length and thickness of vocal chords. Long, thick vocal chords are lower pitched than short, light vocal chords. That's why adults have lower ranges than kids do—125 hertz [vibrations per second] for men, 210 hertz for women, and 300 hertz for boys and girls.)*

USING STRING THING WITH STUDENTS

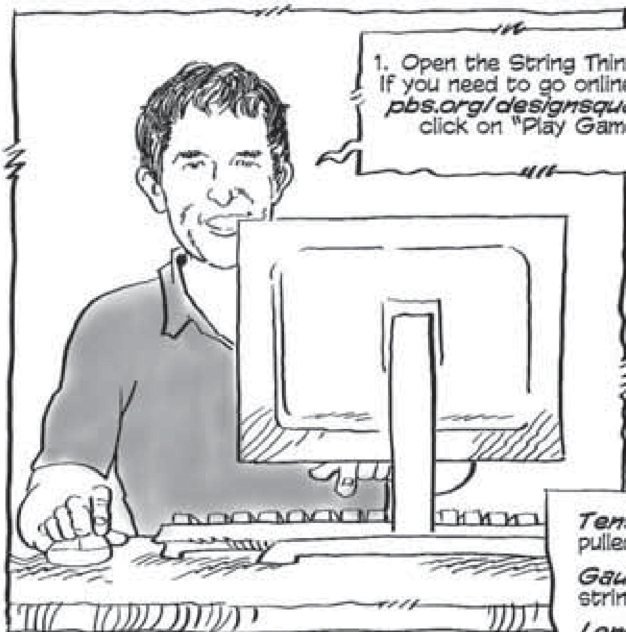
Depending on computer access, *String Thing* can be done as homework, in small groups on classroom computers, or as an activity with the whole class using an interactive whiteboard or computer projector.

***"Design Squad** is the full package. This program brought cohesiveness to my unit."*

Doug S.
Concord Middle School
Concord, MA

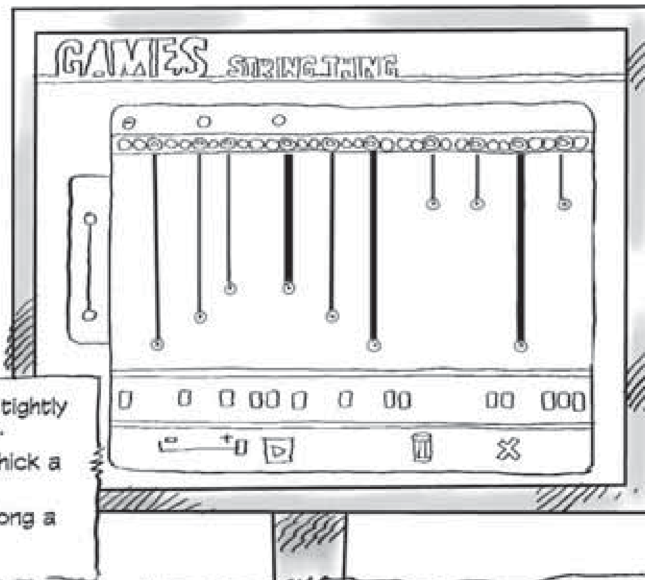
THE STRING THING GAME

DESIGN SQUAD
PBS
as built on TV
pbs.org/designsquad



1. Open the String Thing game. If you need to go online, go to *pbs.org/designsquad* and click on "Play Games."

2. Drag strings onto the grid. Click on them to change their properties.



Tension is how tightly pulled a string is.

Gauge is how thick a string is.

Length is how long a string is.

3. List three ways to lower a string's pitch.

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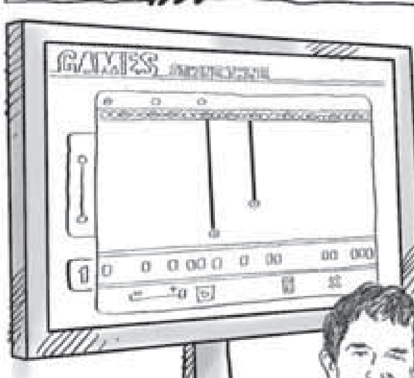

4. Drag a long string and a short string onto the grid. Change the tension or gauge of these strings so they play the same pitch. Describe what you did.

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5. Which changes the pitch more: increasing the gauge of a string by one click, or the length of a string by one fret?

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6. How do you play the highest note possible?

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7. List some reasons why adult voices are usually lower than kids' voices.

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Major funding for *Design Squad* provided by

NSF · intel Education · the Lemelson foundation improving lives through invention

Additional funding for *Design Squad* provided by

NOYCE FOUNDATION · NCEES National Council of Examiners for Engineering and Surveying · ASME · IEEE Celebrating 125 Years · NORTHROP GRUMMAN Foundation

WGBH

BUILD A BAND CHALLENGE

The Challenge: Build a four-stringed instrument that can play a tune.

Preparation

- ☐ Copy the *Build a Band* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Sound Energy*** (30 seconds) and ***Pitch*** (1 minute). Be prepared to project them.
- ☐ Gather the materials (per student):
  - duct tape
  - scissors
  - 2 pencils
  - 4 craft sticks
  - 4 rubber bands (2 medium, 2 thin)
  - shoebox (both lids and boxes can be used to make an instrument)

1 Introduce the challenge (10 minutes)

- Have students touch the front of their throats and say something. Ask: How is what you feel related to sound? *(Students will feel their vocal chords vibrate. The vibrations cause sound waves that travel out through the mouth and into the air.)*
- Have them first make a high-pitched and then a low-pitched sound. Ask: How do your vocal chords feel as you change the pitch? *(Vocal chords tighten to produce higher-pitched sounds and relax to produce lower-pitched ones. They also vibrate at a higher frequency for higher pitches.)*
- Show ***Sound Energy.*** Discuss sound, vibration, and how our ears process sound.
- Ask students to list different kinds of stringed instruments. *(Guitar; ukulele; violin; cello; bass; mandolin; banjo; harp; piano; zither; dulcimer, etc.)* Tell them that today's challenge is to design and build a four-stringed instrument that can be used to play a tune.
- Who might be interested in a low-cost, low-tech instrument? *(Kids, parents, schools, recreation centers, camps, afterschool programs, people interested in new kinds of sounds. The message is: Music matters, because people love music and there will always be a demand for instruments and sound systems.)*

2 Brainstorm (10 minutes)

Brainstorm sound and pitch

- Remind students that instruments produce the sounds and pitches we call music. Then show the ***Pitch*** video to explain why we hear faster vibrations as higher pitches.
- What causes different pitches? *(Things vibrating at different frequencies)*
- What can affect a string's pitch? *(Its length, tension, and gauge)*
- How will a rubber band's thickness affect its pitch? *(With tension and length equal, a thicker rubber band will produce a lower pitch than a thinner one will.)*
- How is what you did with your vocal chords related to pitch? *(Throat muscles change the vocal chords' tension and thickness [i.e., gauge], producing different pitches. A vocal chord's length depends on the size of a person's throat and changes as a person grows. That's why adults' voices are lower than kids' voices.)*

Students build a four-stringed instrument and investigate how a rubber-band string's length, thickness, and tension affect pitch.

Students use duct tape to hold the rubber-band strings in place and tune each one to a different pitch.

Students tune their instruments by adjusting the length and tension of the rubber bands.

Finally, students pair up and play a tune together.

Brainstorm the design process

- You can slip rubber bands around a box or cut the rubber bands open, making strips that you tape down. Brainstorm ways to keep a rubber-band strip securely in place. *(Tape down one end. Then drape the other end over the box edge and tape it down so the rubber band pulls against the edge of the box. Students can also pass rubber bands through holes they poke in the box.)*
- Brainstorm ways to keep the box from interfering with how the rubber-band strings vibrate. *(Make a "bridge" by slipping pencils or craft sticks under the strings to raise them off the surface.)*
- Brainstorm some ways to tune a rubber-band string to a different pitch. *(Stretch or loosen it or make it longer or shorter.)*

3 **Summarize the problem to solve** (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you make your instrument? *(What box to use; what side of the box to put the rubber bands on; how to make strings out of rubber bands; how to attach the strings; how to tune the strings; how to make the instrument loud)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning these materials into a four-stringed instrument. Distribute the handout and have them sketch their ideas.

4 **Build, test, and redesign** (25 minutes)

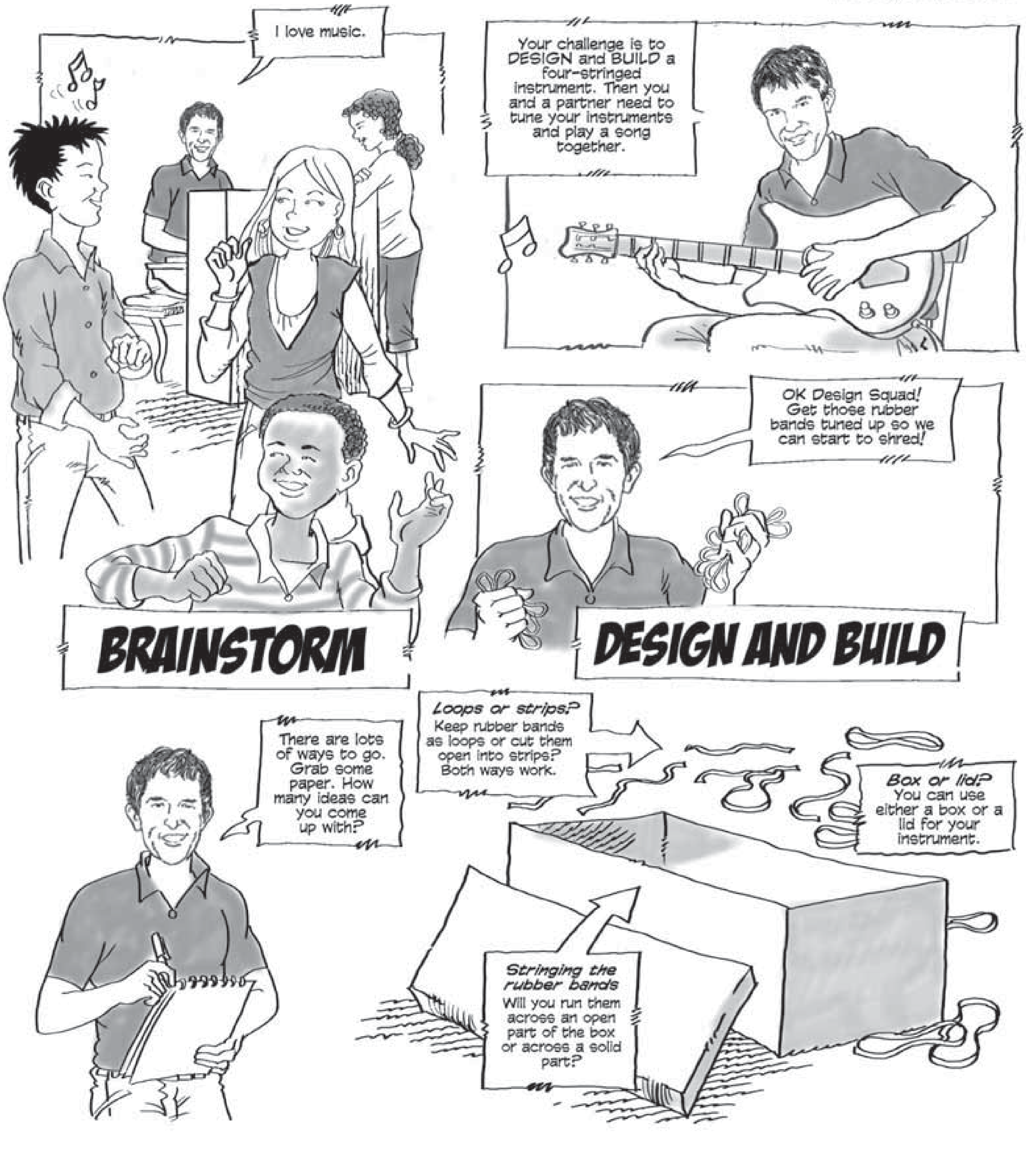
Here are some strategies for dealing with issues that may come up during building:

- **Trouble hearing:** Keep the room as quiet as possible and have students remove anything that interferes with the strings' vibrations traveling through and then out of the instrument, such as excess tape.
- **Trouble with tuning:** To lower the pitch a little, stretch out the rubber band, making it just slightly longer. Also, raising or lowering the height of the bridge will change the tension and increase or decrease the pitch. Finally, students can adjust a rubber band's tension by sliding it a tiny bit one way or another across the bridge or box edge. The friction between the edge and the rubber band will hold the rubber band in its new position.
- **Trouble playing a melody:** Remind students that fretting a string, either by pushing it down against the box or by pinching it, will give them different pitches from each string. Have them try: *We Will Rock You*, *Happy Birthday*, or theme songs from TV shows and movies, such as *Pink Panther* or *The Addams Family*.

BUILD A BAND

as built on TV

pbs.org/designsquad

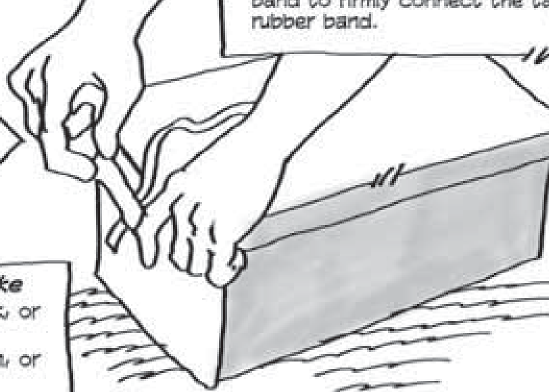


DESIGN AND BUILD

Tip: Taping down rubber bands
Put tape over the end of a rubber band. Then run your fingernail along the rubber band to firmly connect the tape and rubber band.

Attach your strings

- Wrap one end over a box edge and tape it. This way it pulls on the box, not just on the tape.
- Stretch the other end to where you want it, and tape it.

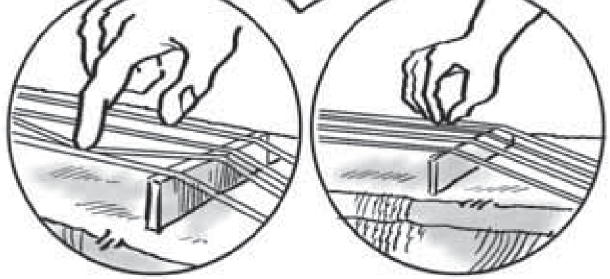


Find 4 pitches you like

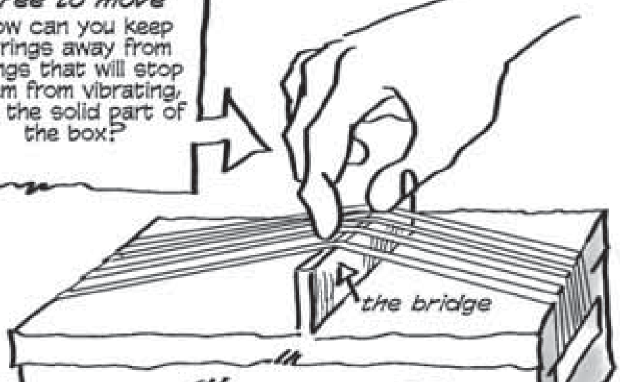
- Low pitch = Long, thick, or loose strings
- High pitch = Short, thin, or tight strings

TEST AND REDESIGN

Tip: Get extra notes
Press fingers along a string or pinch it. That changes its length. Mark the notes you like.



Free to move
How can you keep strings away from things that will stop them from vibrating, like the solid part of the box?



More vibrations = louder!
Get the string's vibrations to go cleanly from the strings to the box material. Too much tape, loose parts, or a bulky bridge will reduce the vibrations.

Music is important to almost everyone, so there will always be a demand for musicians, not to mention the instruments and sound equipment they need! Rock on!

SHARE

Find a partner, tune both instruments, and play a song.

PBS. **Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.**

Major funding for *Design Squad* provided by

theLemelsonfoundation
improving lives through invention

Additional funding for *Design Squad* provided by

HEADPHONE HELPER CHALLENGE

The Challenge: Add a headphone to your instrument to make it easier to hear.

Preparation

- ☐ Copy the *Headphone Helper* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Rock On Challenge*** (1 minute) and ***Design Process: Teamwork Issues*** (3 minutes). Be prepared to project them.
- ☐ Make a simple string telephone (two cups connected by a string).
- ☐ Gather these materials (per student). See page 44 for suppliers.
  - *Build a Band* instruments
  - 2 paper cups (6 ounce or larger)
  - thin string (e.g., kite string)
  - large paper clips
  - scissors
  - duct tape
  - paper-towel tube or, even better, a 3-foot section of a wide plastic hose (e.g., sump pump discharge hose, which is 24 feet long, flexible, inexpensive, and readily available at hardware and home supply stores)

1 Introduce the challenge (5 minutes)

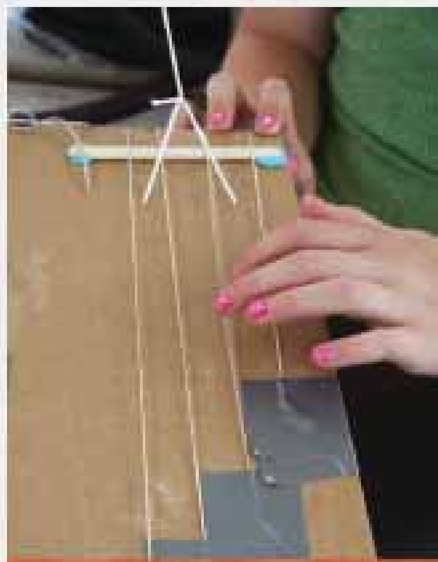
- Show ***Rock On Challenge.*** Ask: How is what you're doing similar to what the *Design Squad* teams do? *(Both groups have to build original stringed instruments out of everyday materials that can be tuned and play a range of notes.)*
- Ask students: What are some ways to improve the instruments you built in *Build a Band*? *(Answers will vary, but increasing the volume will likely be mentioned.)*
- Tell students that today's challenge is to add a headphone to their instrument to make it easier to hear it.

2 Brainstorm (10 minutes)

Brainstorm sound energy

- What could you use to help carry sound waves from your instrument up to your ear? *(A tube; a string telephone with one end attached to the instrument; a stethoscope; an electronic system with a pickup; a radio system with a transmitter; etc.)*
- Explain that headphones work by picking up an instrument's vibrations. Hold up a student's instrument and have the class trace the path that sound travels from the string to the ear. *(Some of the string's vibrations travel directly into the air. They also go through the bridge and into the box, table, and air. These vibrations then travel through the air to the ear. Mention that materials and designs that absorb or dampen vibrations, like a bulky bridge or excess tape, reduce the volume.)*
- Show students your string telephone, and point out that sound waves travel through a solid—the string. Have students trace how the sound travels. *(The voice produces sound waves that travel into a cup and get the string vibrating. The string carries these vibrations to the second cup. This cup begins vibrating and moves the air in and around it, reproducing the original sound, which can be heard by the person holding the second cup.)*
- Show students a length of tubing and ask: How does sound travel through an air-filled tube? *(Sound energy vibrates the column of air trapped in the tubes. The vibrating column of air vibrates your eardrums, reproducing the sound.)*

Students pinpoint where their instrument vibrates a lot and attach a tube or string telephone to carry the sound waves directly to their ear.



One team used a string telephone with a double string to capture twice the number of vibrations.

A tube can carry sound waves. Students can attach it to the surface or insert it into the box.

In *Making It Real*, students discuss the science and engineering behind their designs and describe how they are thinking and working like engineers.

Brainstorm the design process

- Show ***Design Process: Teamwork Issues.*** Ask: What are some strategies you can use to make sure all team members are included? *(Ask for ideas; agree on a plan; choose roles; assign tasks; use people's strengths; etc.)*
- Brainstorm ways that enable a string telephone or tube to trap as many vibrations as possible. *(String telephone: Use more than one string; use string that vibrates well; attach the strings firmly to the box. Tube: Add a cup to one or both ends as a sound collector. Both: Attach to a place on the instrument where there's lots of vibration, such as next to or under the bridge; keep the string or tube length as short as possible, because sound diminishes with distance.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you design your headphone system? *(What kind of headphone to make; where and how to attach it; how to get the headphone to pick up the instrument's vibrations; whether to add a headband or an earpiece, such as a cup at the end of the tube; etc.)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning the materials into a headphone system. Distribute the handout and have them sketch their ideas.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Reattach strings:** Give students time to retape the strings on their instruments if the tape let go overnight.
- **Maximize vibrations:** To avoid dampening the vibrations, encourage students to use as little tape as possible, avoid using a bulky bridge, and keep the headphone from interfering with the strings' movements.
- **Keeping the string telephone's string tight:** Students can add weights or have a partner hold down the instrument to keep it in place.
- **Attaching the tube:** Students can tape the tube to the box or cut a hole in the box and insert an end into the air space.

HEADPHONE HELPER

DESIGN SQUAD
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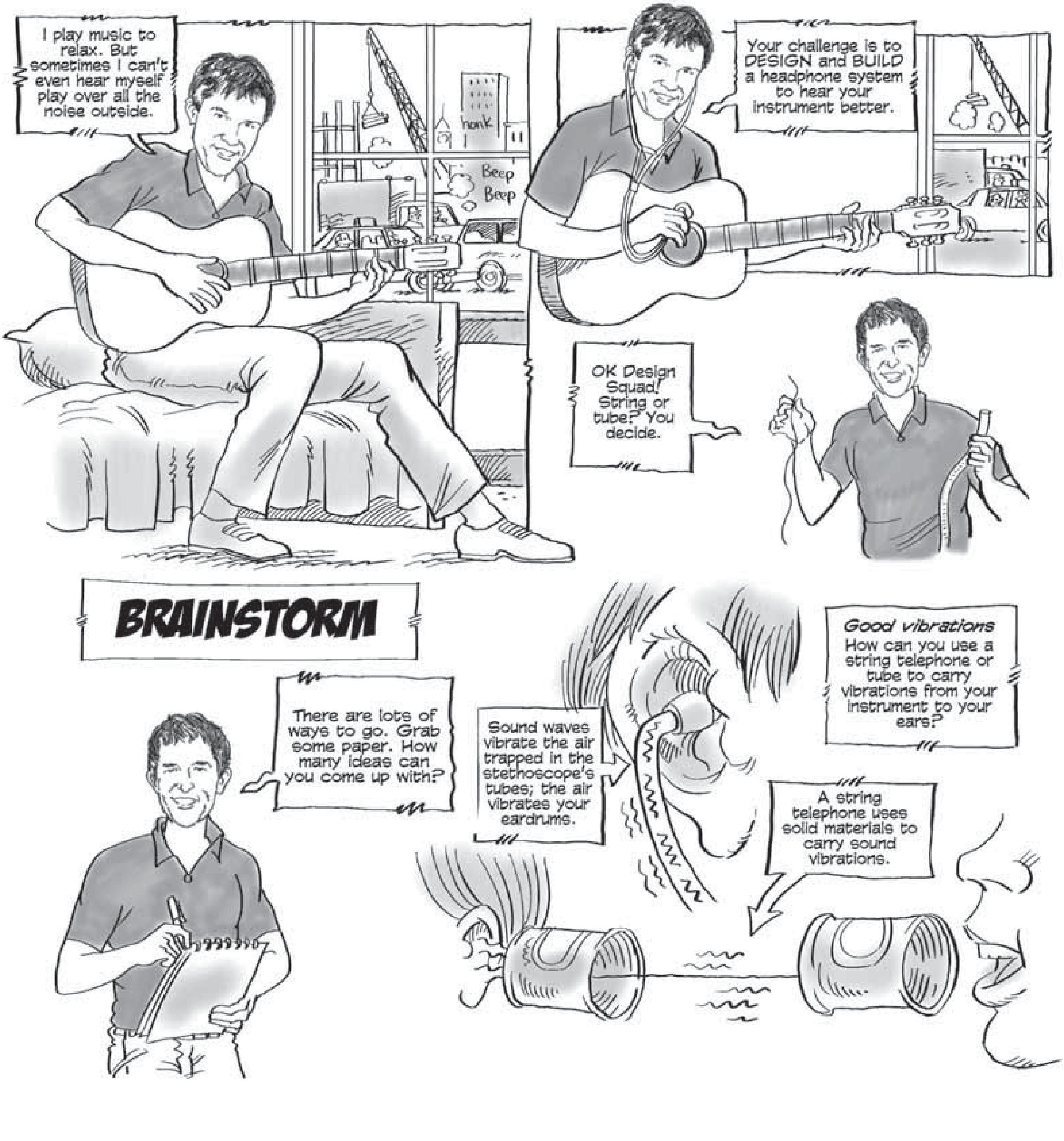
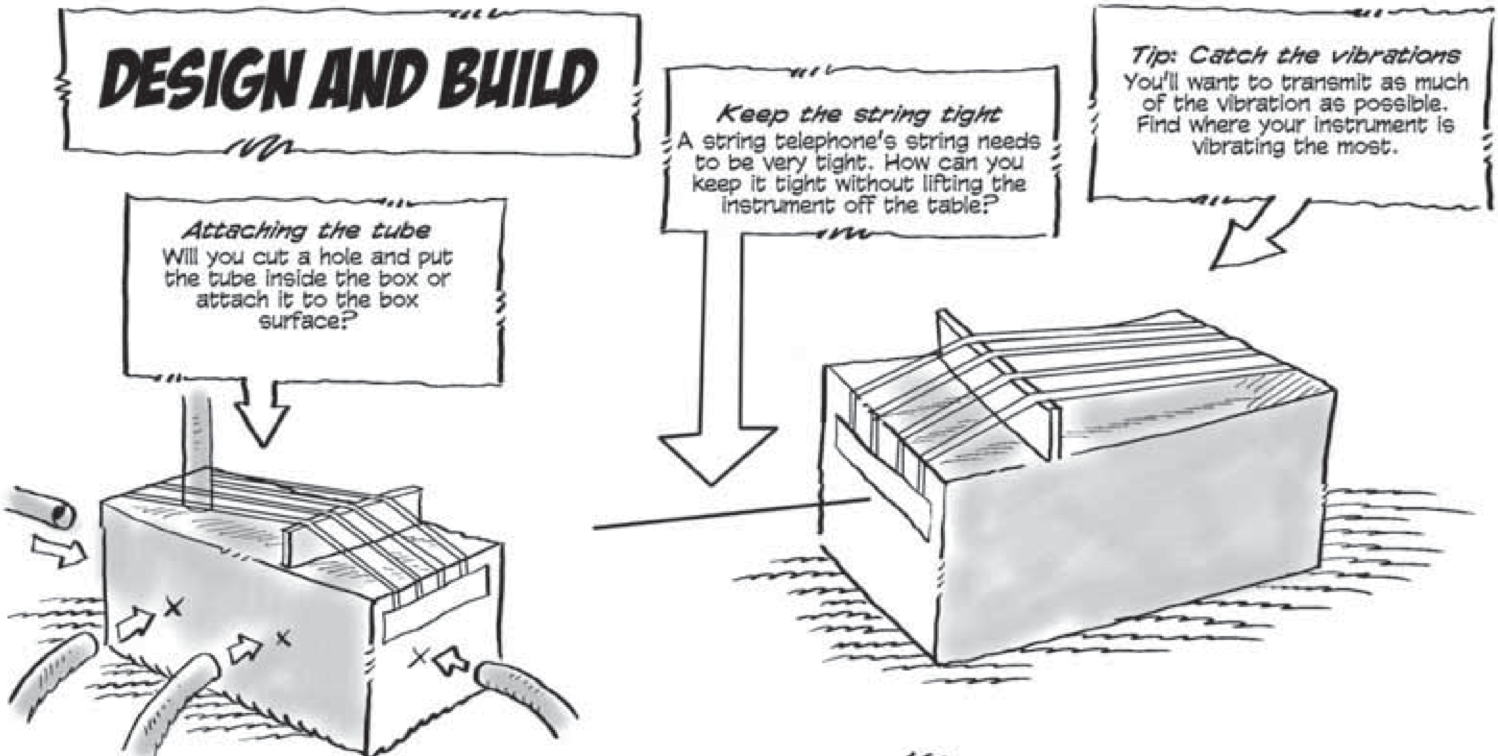
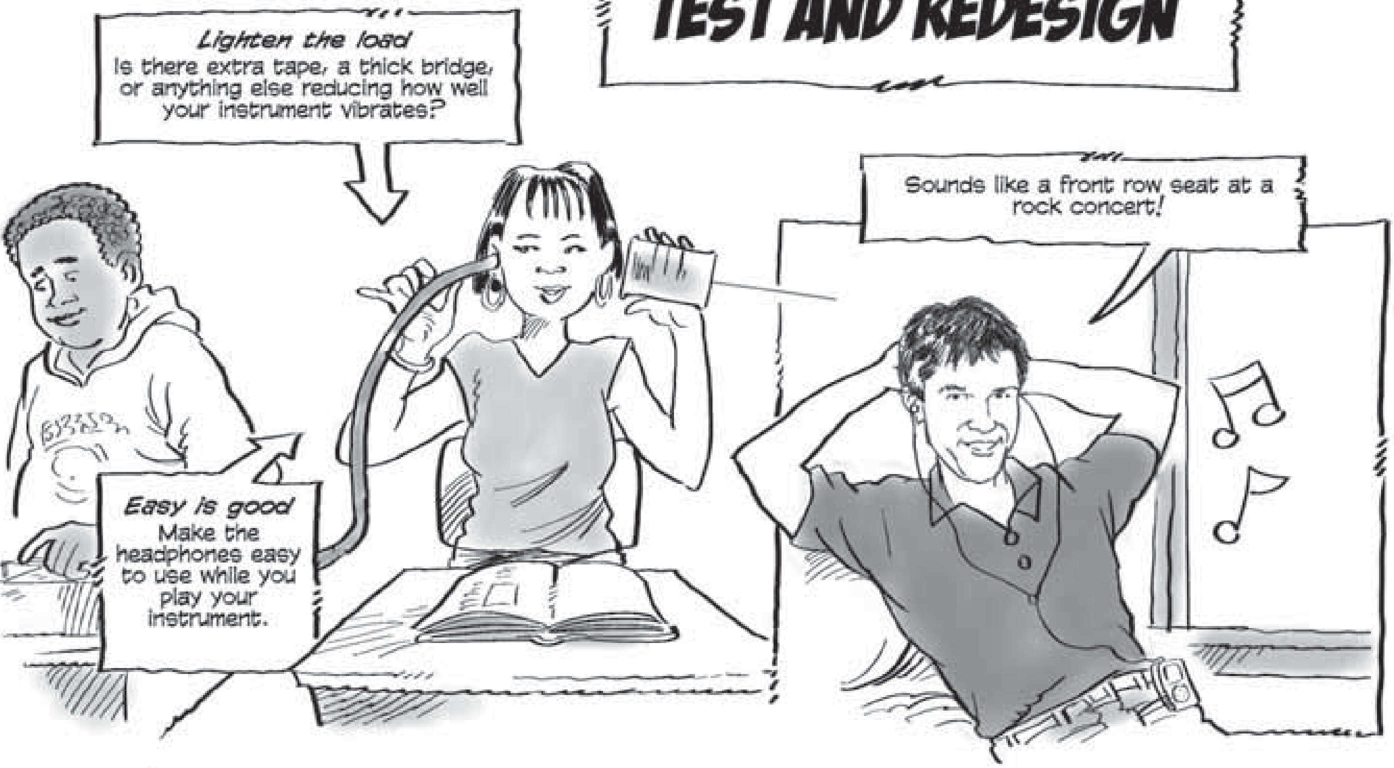


DESIGN AND BUILD



TEST AND REDESIGN



Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.

Major funding for *Design Squad* provided by

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MAKING IT REAL:
DRIVING HOME THE SOUNDS GOOD UNIT

Overview: Students take their work beyond the walls of the classroom, using a combination of presentations, videos, and discussion. They present their instruments, discuss how they demonstrate the unit's science concepts, explain how the design process encourages them to think creatively, and discuss how engineering is a field centered on designing and building things that matter.

Preparation

- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Rock On Judging*** (2½ minutes), ***Design Process: Brainstorming About Pitch*** (3½ minutes), and ***Darrin Barber*** (1½ minutes). Be prepared to project them.

1 Raise student awareness of engineering (5 minutes)
Our world is molded by the engineering that surrounds us. Yet, many students are unaware of what engineers do. Probe students' ideas about engineering. Ask:

- What do engineers do? *(List students' ideas.)*
- Then ask: What things in this room were probably designed or made by engineers? *(There is very little in the room other than the people, plants, and dirt that does not bear the mark of an engineer.)*

2 Relate students' work to science and engineering (20 minutes)
Show ***Rock On Judging***, in which the band evaluates the instruments that were designed and built by the *Design Squad* teams and selects a winner. Then ask: How is the process you followed similar to the one the kids on *Design Squad* did? *(Both the students and the* Design Squad *teams brainstormed lots of ideas, then built, tested, and revised their instruments, and presented their designs to others.)*

Show ***Design Process: Brainstorming About Pitch***, in which the *Design Squad* teams discuss the variables affecting pitch and brainstorm designs. Have students present their instruments and headphones. Use the following questions to explore key points in the video and unit:

- How did your design transfer the strings' vibrations through and out of the instrument? *(Students should talk about how their designs and materials effectively transmitted vibrations and how they eliminated things that absorbed vibration, such as excess tape.)*
- How did you produce different pitches on your instrument?
- How did what you learned about sound in *Build a Band* help you when you designed and built your headphones?
- What were some of the problems you solved as you built, tested, and redesigned your instrument and headphones?
- If you could improve one thing about your instrument or headphone, what would it be?
- Tell students that their instruments and headphones are ***prototypes***—models for testing and improving an invention. Ask: What would you look for in an ideal stringed instrument? *(Loud; easily tunable; easily playable; wide range of pitches; parts vibrate well together; affordable; cool design; etc.)*

SHOW KIDS THE RELATED TV EPISODE

Show students *Rock On*, the full-length *Design Squad* TV episode related to the *Sounds Good* unit, where the *Design Squad* teams design and build original instruments for an avant-garde rock band. Watch it online at: **pbs.org/designsquad.**

"The discussion, animations, and videos had my students linking the concepts to the engineering process."

Harini A.
Belle Haven Elementary School
Menlo Park, CA

Students develop a working knowledge of sound in *Build a Band*, take their understanding further in *Headphone Helper*, and explore the relevance of the science and engineering in *Making It Real*.

3 Meet an engineer (10 minutes)

- View the ***Darrin Barber*** video to introduce students to an engaging young engineer who uses sonar—traveling, bouncing sound waves—to navigate a submarine. Darrin also talks about how engineering is one of the "coolest" jobs he can imagine.
- After watching, review how sonar works. *(A device sends sound waves out into the water. When they hit an object, they bounce back. Listening devices on the submarine pick up these reflected waves. By analyzing the patterns of the returning waves, people can determine where the object is. Note that bats use a similar system to detect their prey.)*
- Darrin mentions that every day he uses the math and science he learned in high school. Ask: How might the math and science you learn in school be important on board a submarine? *(It would help you understand how the equipment works, what the signals mean, how to navigate around the ocean, and how to explain to others what's going on.)*

4 Make the engineering real (10 minutes)

Use the following questions to help students see how the work they did relates to engineering and see that engineers design things that matter and improve people's lives. Ask:

- Who might be interested in a low-cost, low-tech musical instrument? *(Kids, parents, schools, recreation centers, camps, afterschool programs, people interested in new kinds of sounds [like* White Noise, *the band in* Rock On*]. Instrument manufacturers would be interested in a prototype instrument. The message is: Music matters—people love music and there will always be a demand for instruments and sound systems.)*
- Engineering opens the door to many interesting careers, such as navigating a submarine. What are some challenges that an engineer might tackle? *(Designing instruments and amplification and recording systems; making pitch-correction systems for singers; applying new materials and technology; writing programs for computers and electronic instruments; developing personal music players; figuring out ways to integrate sound and video; designing cutting-edge telephones; developing sonar and radar systems; etc.)*
- In what ways did you think and work like an engineer as you made your instrument and headphone? *(Followed the design process; applied science concepts; made something people want; used creativity; tackled interesting challenges)*

TELL US WHAT YOU THINK

Take our quick online survey, and we'll send you a *Design Squad* class pack (while supplies last—see back cover for details).

Extension Ideas

- Share photos of your students' designs and see what others have made. Visit DS XCHANGE, *Design Squad*'s online community at **pbs.org/designsquad**.
- Tell students about inventions that produce high-frequency pitches. Teens can hear them, but most adults can't. Storeowners use these devices to annoy and drive away loitering teens. Teens use the high-pitched tones as cell phone ring tones that adults can't hear! Ask students to think of other applications. Take this high-pitch hearing test and listen to the related National Public Radio podcast at: **npr.org/templates/story/story.php?storyId=5434687**.
- Watch *Design Squad* host Nate Ball demonstrate a pen that plays music as it draws: **youtube.com/watch?v=mG6tkthHH2A.**

Interdisciplinary Connections

- *Music:* Work with a music teacher to identify tunes the students may be familiar with and to get larger groups playing together.
- *Music:* Compare the design features (form and function) of various stringed instruments: violin, guitar, banjo, harp, washboard bass, zither, and piano. Focus on how they achieve pitch and amplitude, the number and type of strings, the size and shape of the sound boards, the methods of producing vibrations and projecting sound, and other design features.
- *Technology:* Use computer-based recording software to record one or more instruments. Students can multitrack, add effects, add percussion, loop their compositions, make a ring tone, and even burn a CD.
- *Shop*: Students can make an instrument out of wood. It could have a neck (like a guitar), be a frame (like a harp), or be a box (like a dulcimer, zither, or autoharp). They can experiment with different string materials, sound holes, sound boxes, soundboards, and tuning systems.

In their presentations, students talk about how sound travels through an instrument and how eliminating things that absorb vibration increases the volume.

The design process encourages students to think creatively about tackling a challenge.

UNIT 3: BREEZY BLIMPS

IN THIS UNIT, students explore force, Newton's laws, air pressure, and buoyancy by making blimps out of helium-filled balloons.*

UNIT TABLE OF CONTENTS

- **Overview:** Students make a helium-filled Mylar® balloon hover by adding weight and making it neutrally buoyant. They move the balloon around the room without touching it by using a sheet of cardboard to make small pockets of low-pressure air into which the balloon moves.
- **Learning outcomes:** Students will be able to make a floating object neutrally buoyant and explain how a balloon moves in response to differences in air pressure. They will also use the design process to achieve neutral buoyancy and perfect a technique for moving the balloon.

- **Overview:** Students apply all they learned in *Sky Floater* to design and build a blimp that glides efficiently on a straight course across a room.
- **Learning outcomes:** Students will be able to explain how drag affects a blimp's flight, how its length affects its axis of rotation, and how blimps demonstrate Newton's 1st Law. They will also use the design process to design and build a neutrally buoyant blimp that has a long axis of rotation, is aerodynamic, and is able to travel in a straight path.

- **Overview:** Students add a balloon-powered propulsion system to their blimps to make them fly across the room under their own power.
- **Learning outcomes:** Students will be able to explain how a blimp demonstrates Newton's 3rd Law and describe how they used the design process to get their "jet" to propel their blimps along a straight course.

- **Overview:** Students present their blimps and discuss the science and engineering behind their designs. They also watch two short videos: They meet a young engineer who keeps a large blimp running smoothly, and they see how the *Design Squad* teams use the design process to redesign the blimps they made to film a rock concert from above.
- **Learning outcomes:** Students will be able to identify the science concepts exhibited in their work (e.g., force, Newton's laws, mass, buoyancy, aerodynamics, axis of rotation, friction, and air pressure), explain how the design process encourages them to think creatively to tackle a challenge, point out how they are thinking and working like engineers, and cite examples of how engineering is a profession centered on improving people's lives.

PLANNING YOUR TIME

Only have one class period available? Do *Sky Floater*.

Two class periods? Do *Sky Floater* and *Making It Real*.

Three class periods? Do *Sky Floater*, *Sky Glider*, and *Making It Real*.

Four? If your students are very engaged with this unit and are able to work with patience and precision, include *Blimp Jet*.

"As a teacher for 31 years, the only thing that really excited middle school students is hands-on activities."

Bill D.
Fairgrounds Middle School
Nashua, NH

* For specific standards, see Appendix, page 48.

"Mylar" is a registered trademark of Dupont Teijin Films U.S. Limited Partnership.

SKY FLOATER CHALLENGE

The Challenge: Make a balloon hover at eye level for five seconds, and then make it move by creating air currents.

Preparation

- ☐ Copy the *Sky Floater* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Band Cam Challenge*** (1 minute) and ***Buoyancy*** (1½ minutes). Be prepared to project them.
- ☐ Gather these materials (per student):
  - 1 helium-filled Mylar balloon
  - paper
  - large garbage bags for storing the balloons (12 fit in a 42-gallon bag)
  - paper clips of various sizes
  - large binder clip for anchoring a balloon (optional)
  - scissors
  - clear tape
  - corrugated cardboard (about 8 inches square)
  - If you have high ceilings, use 2 brooms as "jaws" to capture escaped balloons.

NOTE: *You can get Mylar balloons at party stores, florists, dollar stores, drug stores, and supermarkets, often for a dollar each. However, multiple class sections can use the same balloons for Sky Floater. Have students clean off their balloons at the end of the period so they're ready for the next class. If you plan to do Sky Glider as well, stagger the unit with your different sections since the first class will need their balloons for at least two days. Helium-filled Mylar balloons reliably provide lift for a week. In our testing, over half our balloons maintained excellent lift for up to two weeks.*

The first task is to weight a balloon to make it neutrally buoyant.

1 Introduce the challenge (5 minutes)

- Tell students today's challenge is to first get a helium-filled balloon to hover and then to move it around the room without anyone touching it. Mention that this challenge is similar to one that the kids did on the *Design Squad* TV show.
- Show ***Band Cam Challenge***, in which the *Design Squad* teams build a blimp to film a stage concert. Point out that in both the classroom and *Design Squad* challenges, kids need to control and direct their balloons.

2 Do Part 1 of *Sky Floater* (10 to 15 minutes)

- Show students the materials. Ask: How can you stop a balloon from floating upward? *(Add weight.)*
- Distribute the handout and have students do Part 1. Tell them to tie the balloon ribbon in a bundle close to the neck of the balloon so it doesn't drag on the floor or catch on things.
- If drafts are an issue, have students use their bodies to block currents, not move around too much near the balloon, and work away from air vents, doors, and windows.
- Part 1 takes anywhere from 5 to 15 minutes. Stop everyone after 15 minutes.

Students make their balloons hover at face level for at least five seconds.

3 Process the science and engineering (10 minutes)

Show the ***Buoyancy*** video, which describes how a helium-filled balloon floats. Ask:

- What are the forces affecting this balloon? *(Gravity and lift)*
- What do you know about these two forces when a balloon is ***neutrally buoyant*** (i.e., when it hovers)? *(The force of gravity equals the force of lift.)*

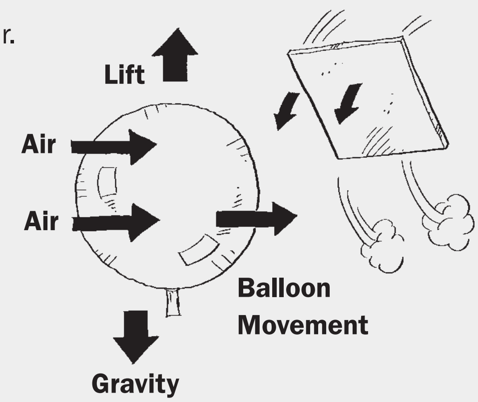
Students move their balloons around the room. They use cardboard to create a low-pressure air pocket. Nearby air moves into these air pockets, carrying the balloon with it.

Once they learn how to move their balloons, students step them around a partner, one low-pressure air pocket at a time.

- Why do the balloons rise? *(Air is denser than helium—it has more particles per unit volume than helium does. The denser air pushes the less-dense helium aside, producing an upward force called a* ***buoyant force****. In our testing, kids called air a "bully.")*
- How is neutral buoyancy an example of Newton's 1st Law? *(If the forces of lift and gravity are equal and opposite, the balloon won't rise or fall.)*
- When will the balloon stop rising? *(When it hits the ceiling or rises to a point where the density of the air outside the balloon equals the density of the helium inside the balloon. When these two densities are equal, there is no longer a buoyant force.)*
- What steps of the design process did you use to make the balloon neutrally buoyant? *(Identified the problem; brainstormed how to make the balloon hover; tested different ways to weight the balloon; refined our systems; shared solutions; etc.)*

4 Give the class a "driving" lesson (5 minutes)

Borrow a neutrally buoyant balloon from one of your students. Ask the class to predict*: How will this balloon move when I fan a piece of cardboard next to the balloon but not at it?* Demonstrate by taking a square of cardboard and sharply sweeping it alongside the balloon in one swift motion (i.e., no fanning back and forth). Surprise! The balloon moves unexpectedly *toward* where you swept the cardboard. Repeat on the other side, and above and below the balloon.



Explain that the balloon is surrounded by air. When you sweep the cardboard beside the balloon, you temporarily remove some of the air, producing an area with fewer air molecules (i.e., lower pressure). Surrounding air molecules rush in to equalize the pressure, carrying the balloon with them. By creating a succession of low-pressure air pockets, kids can move the balloons around the room a few inches at a time. End by demonstrating that rapid fanning at a balloon makes it hard to control the balloon's movement. Fanning results in chaotic air currents. They will move a balloon, but in an unpredictable way.

5 Do Parts 2 and 3 of *Sky Floater* (10–15 minutes)

Have students experiment with different techniques for moving a balloon in a circle around a partner. If time permits, they could also do an obstacle course or race other teams.

SKY FLOATER

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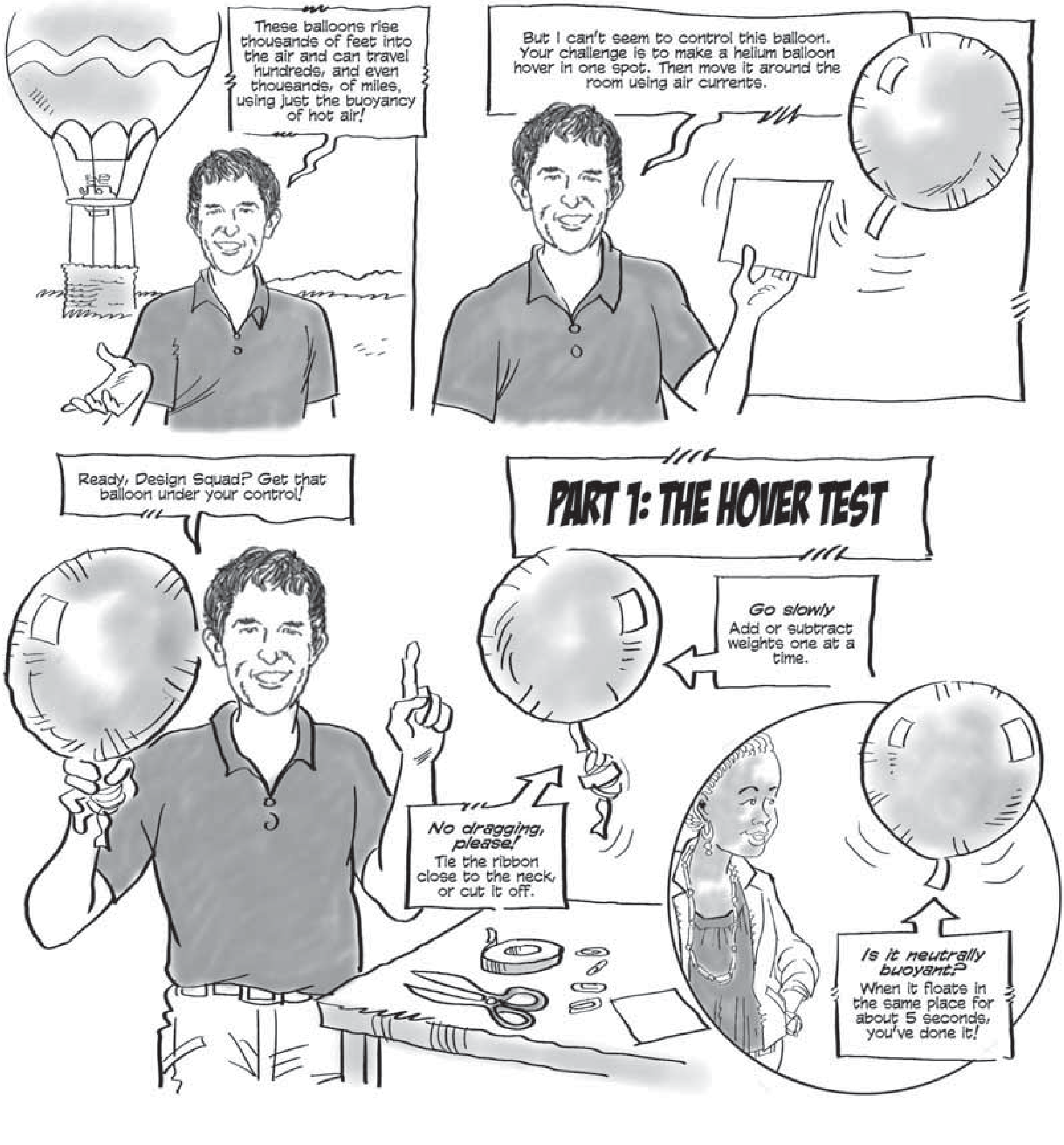


Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.

Major funding for *Design Squad* provided by

Additional funding for *Design Squad* provided by

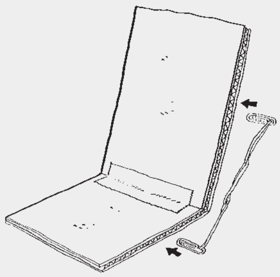
SKY GLIDER CHALLENGE

The Challenge: Build a blimp that travels in a straight path across the room.

First, students make a neutrally buoyant blimp out of two balloons. Many used a paper tube to connect their balloons.

Preparation

- ☐ Copy the *Sky Glider* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Air Resistance*** (1 minute), ***Axis of Rotation*** (1 minute), and ***Design Process: Testing the Axis** of Rotation* (1½ minutes). Be prepared to project them.
- ☐ Set up 3–4 launching stations. For each station, you'll need 2 sheets of corrugated cardboard (approx. 11 x 17 inches), duct tape, rubber bands, and paper clips.
- ☐ Gather these materials (per team of two):
  - *Sky Floater* balloons
  - clear tape
  - copier paper
  - scissors
  - small paper clips



Launching Station
Insert the paper clips so the rubber bands gently lift the launcher's back.

1 Introduce the challenge (5 minutes)

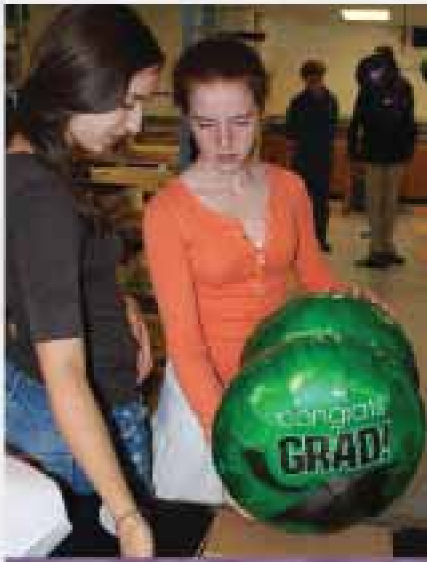
- Tell students that today's challenge is to build a blimp that can travel a straight path across the room. Point out how this activity is similar to the *Band Cam* challenge: The blimp must be neutrally buoyant and travel in a predictable way.
- Ask: Who might be interested in using blimps? *(People interested in moving heavy loads and using energy-efficient transportation. Blimps also make excellent eyes-in-the-sky for things like filming sporting events, TV broadcasts, surveillance, search-and-rescue missions, and observing wildlife.)*

2 Brainstorm (10 minutes)

Brainstorm air resistance

Tape together the wide faces of two balloons. Set them in motion using the launcher. Point out that the device launching the balloons is an example of one object transferring its kinetic energy to another.

- What keeps this pair of balloons from going across the room? *(Air resistance)*
- Drop a sheet of paper, first with the wide face perpendicular and then with it parallel to the floor. Ask: Which has the most ***drag*** (i.e., a force that resists an object's movement)? *(There is more drag when the wide face is parallel to the ground, and the paper falls more slowly.)*
- What are some things that are streamlined to cut easily through air or water? *(Sports cars, blimps, submarines, planes, fish, birds, etc.)*
- To reduce drag and move efficiently through the air, which face of a balloon should face forward? *(The narrowest one, so that it can slice through air)*
- What could you use to firmly hold two balloons in this orientation? *(A paper tube or tubes)*
- Show ***Air Resistance*** in which the *Design Squad* teams discuss how drag slows down flying objects.



Then, students use a rubber band-powered launching station to gently set their blimps in motion.

Next, students get their blimps to “fly” straight and far by streamlining them and lengthening their axis of rotation. Some students used fins to help their blimps travel straight.

Finally, in *Making It Real*, students discuss the science and engineering behind their designs and describe how they are thinking and working like engineers.

Brainstorm axis of rotation

- Show ***Design Process: Testing the Axis of Rotation.*** Point out how the Purple Team’s blimp is held at just one point, making it easy for the blimp to spin.
- Spin the two balloons with your hands. Ask: Why do they spin so easily? *(They have a short* ***axis of rotation****—the point around which an object spins. Also, there is little force, such as air resistance, stopping the spin.)*
- What shape do objects that must travel long distances through the air—such as javelins, footballs, arrows, and rockets—have in common? *(They are much longer than they are wide.)*
- Show ***Axis of Rotation,*** in which the *Design Squad* teams stabilize a boat by lengthening its axis of rotation. In *Sky Glider*, students will lengthen the axis of rotation to help their blimps travel straight.

Brainstorm the design process

- Brainstorm ways to make a blimp from two balloons so it will have low air resistance. *(Students should suggest designs that have as little material as possible hitting the air as the blimp moves forward.)*
- Brainstorm ways to make a blimp from two balloons so it will travel straight and not spin. *(Students should suggest designs where there is a wide separation between the balloons.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you’ll need to figure out as you make your blimp? *(How to: attach the two balloons; make them neutrally buoyant; launch them gently; keep them on a straight course; streamline them so they fly far; etc.)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning the materials into a blimp that can glide straight and far. Distribute the handout and have them sketch their ideas.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Travel far:** Have students make streamlined designs to reduce air resistance.
- **Travel straight:** In our testing, students found that fins helped a blimp glide straight. As a blimp begins to veer from a straight course, the fin’s wide side begins to hit a lot of air, taking advantage of drag and producing a force that helps the blimp resist turning. (NOTE: Wings only provide lift at high air speeds. Buoyant, lighter-than-air craft, such as blimps, go too slowly to make use of wings, so wings just add unnecessary, burdensome weight.)
- **Launch the same way:** Remind teams to launch their blimps the same way every time (i.e., use the same launcher, start from the same position, etc.). Otherwise, it’s hard to know what affects a blimp’s flight—a design change, the launcher, or the launching technique.
- **Record data:** Have teams record the distance traveled and keep track of any rising, falling, spinning, or traveling in an arc.
- **Storage:** Keep blimps intact until you finish the *Making It Real* session.

SKY GLIDER

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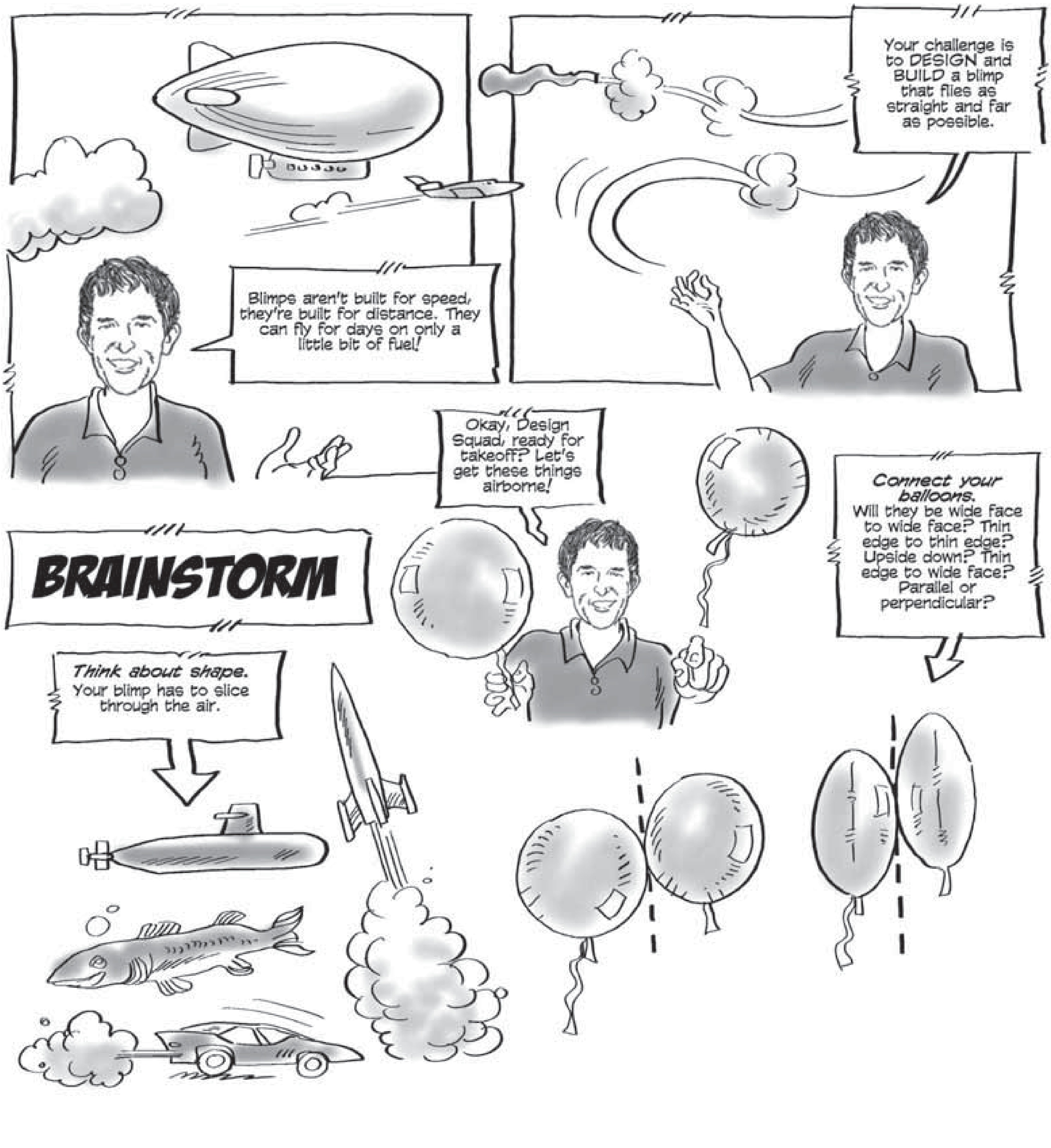
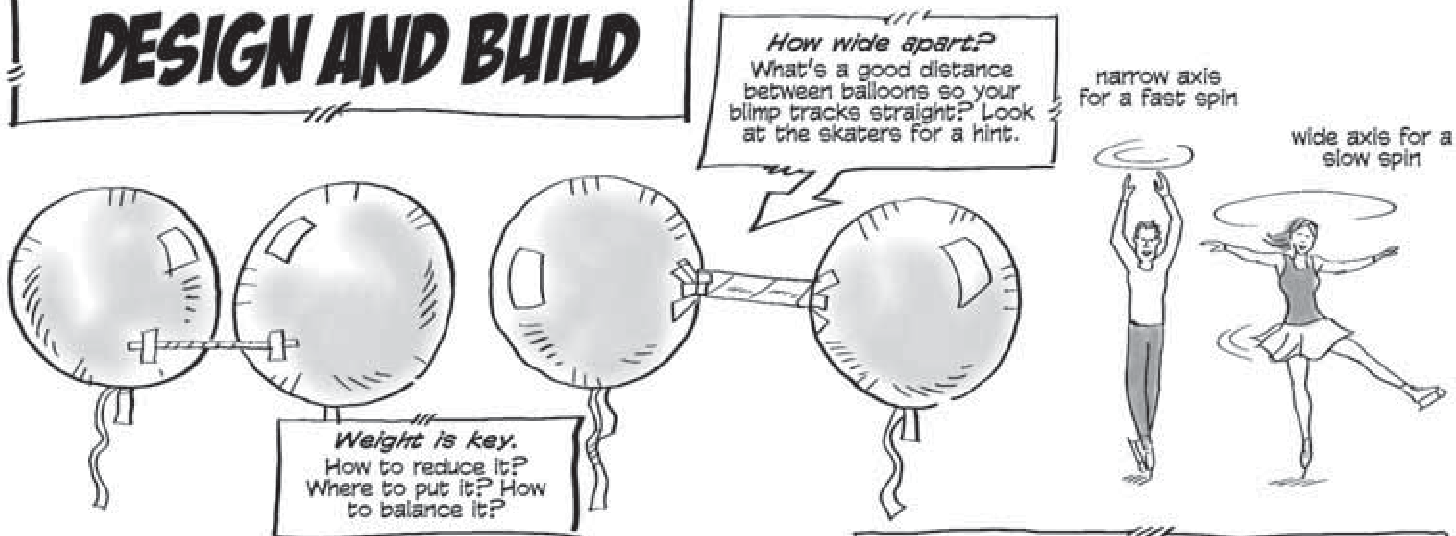
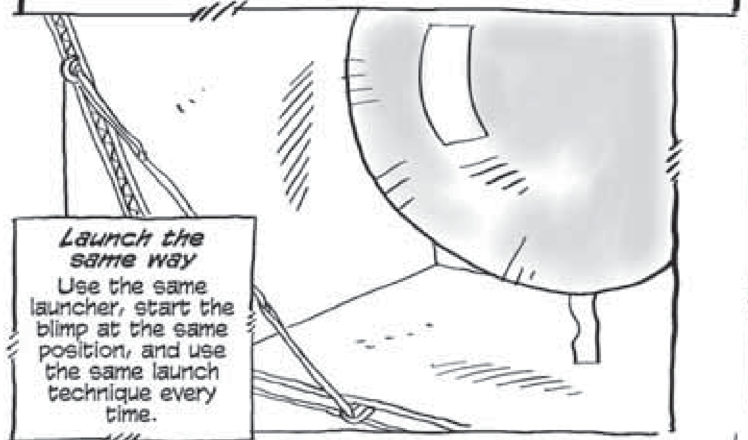


DESIGN AND BUILD



TEST AND REDESIGN



Measure and record
Record the distance of each test flight and how straight the blimp went.

Farther! Straighter!
After each test, think about ways to improve your design. Record the changes you made and their effects.

1. ______________________________
____
____

2. ______________________________
____
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3. ______________________________
____
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Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.

Major funding for *Design Squad* provided by
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Additional funding for *Design Squad* provided by

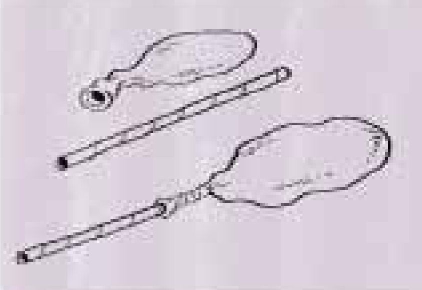
BLIMP JET CHALLENGE

The Challenge: Add a jet-propulsion system (i.e., a balloon) so that a blimp flies straight and far under its own power.

NOTE: *In Blimp Jet, there are many more variables than in Sky Glider. Because it can take many rounds of testing to get a blimp to travel a straight path, students must be patient and be able to work precisely.*

Preparation

- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Newton's 3rd Law*** (1 minute) and ***Thrust & Newton's Laws*** (1 minute). Be prepared to project them.
- ☐ Gather these materials (per team of two). See page 44 for suppliers.
  - blimps from previous challenge
  - 4 sheets of paper
  - clear tape
  - balloon pump
  - scissors
  - 6 drinking straws (narrow and wide)
  - 12- to 16-inch latex party balloon (Long "rocket" balloons also work but hang down awkwardly.)



Make a blimp jet
To propel a blimp, make a "jet." Fit a straw into the balloon's neck. Seal it tightly with tape.

1 Introduce the challenge (5 minutes)

- Tell students that today's challenge is to add a jet propulsion system (in this case, a party balloon) so their blimps fly under their own jet power. Hold up a latex party balloon and a straw and make a jet. (See illustration.) *(Mention that the straw can help control how fast air escapes from the balloon.)*
- How can you use this jet to provide ***thrust***—a pushing force—to a blimp? *(Attach the jet to the blimp. To assure that the end of the jet stays pointing exactly where students want it to point, they should attach it to a stable, easy-to-access place, such as the frame connecting the two Mylar balloons. Demonstrate how to use a pump to inflate the balloon. Point out how the straw lets you inflate the balloon without having to detach the jet from the blimp.)*
- What force does the jet's thrust overcome? *(Inertia and air resistance [i.e., drag])*

2 Brainstorm (10 minutes)

Brainstorm Newton's 3rd Law

- How is this jet an example of Newton's 3rd Law? *(Inside a sealed balloon, the air pushes out equally on all sides, so there is equal force on all parts of the balloon. But when you open the neck of the balloon, the air rushes out of the hole. When this happens, one area of the inside surface—the area with the hole—has less pressure on it than the other parts. The forces inside the balloon are now unbalanced—there is a greater force pushing on the area opposite the hole. So, the balloon moves in the direction of the greater force—the area opposite the hole. Since the balloon is attached to the blimp, this unbalanced force also pushes the blimp forward.)*
- Which way should the straw point? *(Opposite the direction students want the blimp to travel. Very small adjustments of where the straw points have a noticeable effect on how the blimp travels. This is why students must be willing to work carefully and precisely.)*

An inflated jet makes a blimp look ungainly, but it doesn't significantly impair the blimp's flight.

Students attach paper fins to help a blimp fly straight. This particular design won't travel as far as a more streamlined blimp, due to air resistance.

Accomplishing the challenge—getting a blimp to travel straight and far—gives kids a real sense of achievement.

- Watch both ***Newton's Laws*** videos. In one, the *Design Squad* teams use Newton's 3rd Law to propel and steer a fan-propelled boat. In the other, they build a flying football goalpost and grapple with balancing gravity and thrust. Discuss how their blimp jet similarly provides thrust using an action-reaction principle. Also point out the importance of reducing weight.

Brainstorm the design process

- Brainstorm good places to attach the jet. *(A bottom-heavy blimp is more stable; make sure the air stream flows freely and is not blocked by blimp parts.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you add a jet to your blimp? *(Decide how to: mount the jet; inflate the balloon; make minor adjustments easily; document each test flight to understand how to modify the blimp and jet; etc.)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways to add a jet.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Modify the balloon pump:** Tips on commercial balloon pumps are too big to fit into straws. Insert a thin straw into the pump tip and seal it with tape. Now the thin straw can slip into a balloon jet's straw.
- **Make blimps neutrally buoyant:** To compensate for the added weight of the balloon jet, students will need to adjust their blimps to make them neutrally buoyant again.
- **Orient the blimp:** Top-heavy blimps don't stay level. Encourage students to tape the balloon jet toward the bottom of the blimp.
- **Tape the jet firmly in place:** The balloon jet wiggles if kids tape it in only one place. To anchor it well, students should tape it to the frame in at least two places.
- **Control the jet power:** The amount of air leaving the balloon jet makes a difference. If air escapes too quickly, the initial thrust is powerful, but it rapidly peters out. If the air escapes too slowly, there's too little thrust to overcome inertia and air resistance. Students might need to modify the straw to adjust the rate of the escaping air. Just make sure that the end of their straw still fits into the pump. Overfilling balloons will, of course, pop them. More air is not always the answer!
- **A second class period?** Students can achieve success in one class period and have a fun, memorable experience with Newton's 3rd Law. But devoting two sessions to *Blimp Jet* will really let students refine their systems.

MAKING IT REAL:
DRIVING HOME THE BREEZY BLIMPS UNIT

Overview: Students take their work beyond the walls of the classroom, using a combination of presentations, videos, and discussion. They present their blimps, discuss how they demonstrate the unit's science concepts, point out how they are thinking and working like engineers and discuss how engineering is a field centered on making the world a better place.

Preparation

- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Design Process: Teamwork*** (1½ minutes), ***Design Process: Testing & Redesign*** (30 seconds), ***Band Cam Judging*** (4 minutes), and the ***Mark Caylao*** engineer profile (2½ minutes). Be prepared to project them.

1 Raise student awareness of engineering (5 minutes)

Our world is molded by the engineering that surrounds us. Yet, many students are unaware of what engineers do. Probe students' ideas about engineering. Ask:

- What do engineers do? *(List students' ideas.)*
- Then ask: What things in this room were probably designed or made by engineers? *(There is very little in the room other than the people, plants, and dirt that does not bear the mark of an engineer.)*

2 Relate students' work to science and engineering (25 minutes)

View ***Band Cam Judging***, in which team members discuss how to meet the *Band Cam* challenge. Then ask:

- How did the teams create lift? *(Varied the amount of helium; reduced the frame's weight; added propellers; redesigned based on testing; etc.)*
- How could the teams redesign their faulty blimp? *(Balance the weight better; adjust propellers to provide more balanced thrust; make sure it's neutrally buoyant; increase the axis of rotation to reduce spin; lighten the load; etc.)*
- How is the process you followed similar to the one the kids on *Design Squad* did? *(Both the students and the teams brainstormed lots of ideas, then built, tested, and revised their blimps, and presented their designs to others.)*

Show ***Design Process: Teamwork***, in which the *Design Squad* teams discuss frustrations inherent in teamwork. Then show ***Design Process: Testing & Redesign***, in which the Green Team, formerly at odds in *Teamwork*, works together to come up with an effective solution to a problem. Have students present their blimps. Use the following questions to explore key points in the video and unit:

- What could you suggest to help the Green Team work effectively together? *(Listen to each other; adjust one's style to help things work smoothly; get input from each team member; agree on a plan; choose roles; assign tasks; use people's strengths; etc.)*
- What were some problems you solved as you built and tested your blimp?
- Was it harder to get a blimp to travel straight or to travel far? Why?
- What are some general characteristics that help a blimp work well? *(Lightweight; neutrally buoyant; long axis and fins to prevent spinning; streamlined to minimize air resistance; etc.)*

DESIGN SQUAD

SHOW KIDS THE RELATED TV EPISODE

Show students *Band Cam*, the full-length *Design Squad* TV episode related to the *Breezy Blimps* unit, where the *Design Squad* teams design and build a remote-controlled aerial camera system to film a live concert. Watch it online at: **pbs.org/designsquad**.

"My students loved the hands-on aspect of this and really rose up to the challenges. I learned that I should not be afraid to challenge my kids, and I should do more open-ended projects with them."

Harini A.
Belle Haven Elementary School
Menlo Park, CA

Students develop a working knowledge of force in *Sky Floater*, take their understanding further in *Sky Glider*, and explore the relevance of the science and engineering in *Making It Real*.

3 Meet an engineer (10 minutes)

- View the ***Mark Caylao*** video to introduce students to an engaging young engineer involved in designing, building, and running one of the world's largest blimps. Of engineering, he says, "It's the best job you can have. I love it!"
- Mark mentions that every day he uses things he learned in high school. Ask: What subjects might you study to prepare to do the things Mark does? *(Math, science, and tech. ed. would help you understand how blimps work, and how to design, build, operate, navigate, and maintain one.)*
- What were some of the things Mark mentioned liking about being an engineer? *(He calls it the perfect job because he likes the traveling; being able to fly; being part of the team that designs, builds, and operates blimps; and doing important work, such as testing air quality and monitoring whales.)*

4 Make the engineering real (10 minutes)

Use the following questions to help students see how the work they did relates to engineering and see that engineers design things that improve people's lives.

- Who might be interested in using blimps? *(Blimps provide quiet, energy-efficient transportation and can carry heavy loads and hover easily. They can be used in logging operations, in search-and-rescue missions, and to carry cameras to observe wildlife, conduct surveillance, and film TV broadcasts.)*
- How might engineers be involved with blimps? *(Designing sturdy, aerodynamic blimps and efficient propulsion systems; inventing new, sturdy, lightweight materials for making blimps; designing blimp-based transportation systems and infrastructure, such as terminals, hangars, and manufacturing systems; finding sources of gas to fill blimps; etc.)*
- In what ways did you think and work like an engineer as you made your blimp? *(Used creativity; followed the design process to design, build, and test an aerodynamic blimp that travels a straight path; applied science concepts—buoyancy, force, and Newton's laws; made a prototype of something people want—an efficient mode of transportation; etc.)*

Extension Ideas

- Share photos of your students' designs and see what others have made. Visit DS XCHANGE, *Design Squad*'s online community at **pbs.org/designsquad**.
- Using photos, contrast the design—the form and function—of a stunt plane (built for sharp turns and quick maneuvers), supersonic jet (speed), and blimp (distance, hovering, fuel economy). Focus on overall shape, axis of rotation (short for stunts, long for steady flight), streamlining, fins and wings, and the size and location of the cockpit or cabin.

Interdisciplinary Connections

- *Math:* Calculate how big a spherical balloon has to be to lift a pound, given that the lift of helium is one ounce per cubic foot. Since the volume of this sphere must be at least 16 cubic feet, then: $\frac{4}{3} r^3 = 16$ cubic feet; r = 1.56 feet. *(The diameter must be at least 3.12 feet.)*
- *Social Studies:* Research the history and current use of blimps in travel, law enforcement, warfare, wildlife studies, search and rescue, and other fields.

TELL US WHAT YOU THINK

Take our quick online survey, and we'll send you a *Design Squad* class pack (while supplies last—see back cover for details).

USING DESIGN SQUAD MEDIA RESOURCES

Design Squad is a multimedia experience, with rich educational resources designed to inspire the next generation of engineers. Find all of these resources at: **pbs.org/designsquad**.

Design Squad TV Episodes
Design Squad takes the competition and intensity of reality TV and merges it with great educational content. In the show, kids use the design process to solve real-world challenges and learn to work as a team. We've taken clips from episodes and produced a library of 1- to 3-minute video segments that relate well to the guide's challenges. In the Teacher Notes, we suggest when and how to use them to introduce or wrap up a challenge.

ProFiles
In these 2- to 3-minute videos, meet dozens of engaging young engineers who demonstrate that engineering is a rewarding, creative career where you get to work with great people, solve interesting problems, and design things that matter. In *Making It Real*, we list relevant ProFile videos and suggest ways of using them.

Online Design Squad games
Students can use their problem-solving and engineering skills online to "save" small, cute creatures called Fidgits with the multiplayer game *DESIGNit, BUILDit, FIDGiT*. With *String Thing* (a game used in the *Sounds Good* unit), students can change the tension, gauge, and length of strings and compose music.

DS XCHANGE
In this online community, students can submit photos and sketches of their own designs and see what other kids have made. Also use DS XCHANGE as a source of project ideas for your students.

Resources for Educators
Find five guides chock full of *Design Squad* challenges, all with student handouts and step-by-step leaders' notes. (See page 46 for details.) You can also get signs, posters, certificates, and other resources to decorate your classroom, recognize students' work, and run events.

Online NASA–*Design Squad* Professional Development Training
Take this self-guided online workshop for educators and afterschool leaders to build skills and confidence in guiding kids through hands-on engineering activities. This free training shows you what the design process looks like in the classroom, offers tips on using the *Design Squad* resources, and emphasizes the fun and relevance of engineering.

MATERIALS LIST

All of the materials in this guide can be found at local electronics, hardware, craft, grocery, and office supply stores. For large quantities, search online. For example:

3-volt motor with gear
Item #RM3 with plastic pinion
solarbotics.com

Item #273-258
radioshack.com

9-volt batteries
Item #6AM6VPXA-10
zbattery.com

Item #19978
atbatt.com

9-volt battery connector
Item #9V-10Conn1
batteryspace.com

Item #BST-3
allelectronics.com

AA battery holders
Item #BCAA
batteryspace.com

Item #270-401
radioshack.com

Balloon pumps
Item #140033
halloween24.com

Item #BAL100EA
windycitynovelties.com

Buzzers
Item #KPI-2210L
(570) 726-6961
americanpiezo.com

Item #273-053
radioshack.com

Corrugated cardboard (11 x 17 inches)
Item #S-3585
uline.com

Item #2611711
papermart.com

Faucet washer, flat and rubber (¾ inch or larger)
Item #4138095
buyhardwaresupplies.com

Item #4138095
www.acehardwareoutlet.com

Hookup wire (e.g., 22-gauge, stranded)
Item #278-1224
radioshack.com

Item #H03447-10U
hobbyengineering.com

Latex balloons (12-inch)
Item #12JAS-699
balloonideas.com

Item #912100
bargainballoons.com

Paint stirrers (14-inch)
Item #PSP14B
jamestowndistributors.com

Item #201855
thegreathardwarestore.com

Ping Pong balls
(Note: sold by the gross)
Item #SUPINGB
rinovelty.com

Item #Z1140
zymetrical.com

Plastic hose
Item #00917821000
sears.com

Item #BWP-NA105
backyardcitypools.com

Wire stripper and cutter
Item #503606
bicwarehouse.com

Item #KT-11047
cableorganizer.com

If you are buying small quantities, try these types of stores:

Electronic: Wire strippers, buzzers, batteries and battery connectors, motors with gears
Hardware: Plastic hose, flat faucet washers, paint stirrers
Craft: Latex balloons, Mylar balloons, balloon pump
Grocery: Latex balloons, Mylar balloons
Office: Corrugated cardboard
Sporting Goods: Ping Pong balls
Dollar Store: Helium-filled Mylar balloons, balloon pumps

PERFORMANCE RUBRIC

DESIGN SQUAD as built on TV.

Challenge name: ______________________

Names of team members: ______________________

____

Identifying the problem(s) and brainstorming solutions	Showed a clear understanding of the problem(s) to solve. Independently brainstormed solutions.	Needed some teacher direction to define the problem(s) and brainstorm possible solutions.	Needed lots of teacher direction to define the problem(s). Little if any independent brainstorming.	**Points:**
Working as a team member	Worked well together. All team members participated and stayed on task.	Some team members were occasionally off task.	Most team members were often off task and not cooperating or participating fully.	**Points:**
Using the design process	Team brainstormed many design ideas and tested and improved the design. Final design complete or nearly complete and shows creative problem solving.	Some team members were occasionally off task.	Team brainstormed few design ideas and did little testing or redesigning. Final design lacks clear design idea(s).	**Points:**
Processing the science and engineering	Team gave a strong presentation of its solution to the challenge and showed clear understanding of the science concepts and design process.	Team gave a basic presentation of its solution to the challenge and showed basic understanding of the science concepts and design process.	Team gave a weak presentation of its solution to the challenge and showed little understanding of the science concepts and design process.	**Points:**
				Total Points:

Major funding for *Design Squad* provided by

the Lemelson foundation improving lives through invention

Additional funding for *Design Squad* provided by

MORE DESIGN SQUAD CHALLENGES

Like the challenges in this guide? There are 32 more on the *Design Squad* Web site—five guide's worth! Read the details below and download them for free at: **pbs.org/designsquad**.

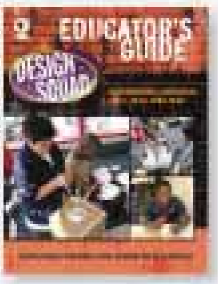
Educator's Guide
Show students the fun, creative side of engineering by having them design secret alarms, electronic dance pads, rubber band-powered racecars, tall towers, moving sculptures, and automatic ball servers. Science topics include circuits, energy, motion, force, and structures.

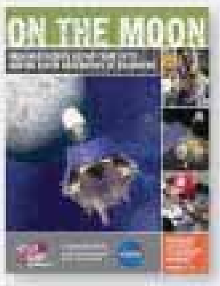
On the Moon
NASA and *Design Squad* team up to bring you engineering design challenges focused on NASA's moon missions. Kids investigate force, energy, structures, and motion by designing and building rockets, landing systems, rovers, cranes, zip lines, and solar hot water heaters.

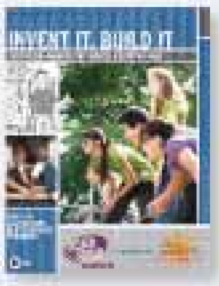
Invent It, Build It
Show your students that engineering is about working to make the world a better place. Students use the design process to invent solutions to environmental, social, and everyday problems.

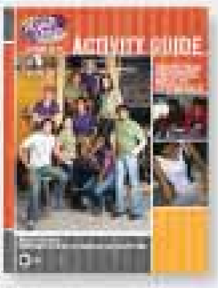
Activity Guide
Use these five hands-on design challenges to spark students' interest in science and engineering. They'll build kayaks, paper tables, zip-line delivery systems, paddle-powered boats, and grabbing devices. Science topics include buoyancy, force, structures, energy, motion, and simple machines.

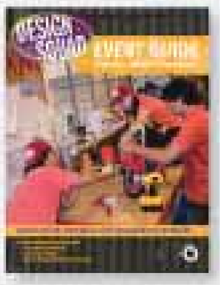
Event Guide
Need quick activities for a science night, event, or extra period? Engage students with fun hands-on engineering design challenges that require few materials and little set up. Science topics include energy, structures, force, motion, circuits, and simple machines.











COMING SOON!

Design Squad is working in partnership with the Museum of Science (Boston, MA) to develop a series of engineering and science units for middle schools. The hands-on activities bring the power of engineering to life for students. Check the *Design Squad* Web site for more information.

"[The challenges] involve problem solving and a lot of hands-on discovery."

Diana C.
Abigail Adams Middle School
Weymouth, MA

RELATED RESOURCES

Ages 3-6

Celebrate the curiosity and adventure of young children with simple science exploration.

peepandthebigwideworld.org

Ages 3-6

Discover science, engineering, and math in the world around us.

pbskids.org/curiousgeorge

Ages 8–11

Try ZOOM's fun science and engineering activities, featuring ideas sent in by real kids.

pbskidsgo.org/zoom

Ages 9-12

Investigate environmental issues and take action to protect the planet.

pbskidsgo.org/greens

Ages 6–10

Put problem-solving skills to the test to tackle science challenges inspired by ones seen on the show.

pbskidsgo.org/fetch

Ages 11 and up

Dig deep into science topics with classroom-ready resources from the most-watched science television series on PBS.

pbs.org/wgbh/nova

Ages 11 and up

Find out the latest research and meet intriguing personalities in science and technology.

pbs.org/wgbh/nova/sciencenow

Ages 14-18

Meet inspiring women engineers who make a real difference in the world. Find out whether engineering might be your dream job.

engineeryourlife.org

Educators

Use this media-rich library of teaching resources to make concepts come alive in engaging and interactive ways.

teachersdomain.org

EDUCATION STANDARDS

Standards	Grades	Topic	No.	Kick Stick	Electric Gamebox	Making It Real	Build a Band	Headphone Helper	Making It Real	Sky Floater	Sky Glider	Blimp Jet	Making It Real
National Science Education Standards	Grades 5–8	History and Nature of Science		●	●	●	●	●	●	●	●	●	●
		Science and Technology		●	●	●	●	●	●	●	●	●	●
		Physical Science		●	●		●	●		●	●	●	
		Science as Inquiry		●	●	●	●	●	●	●	●	●	●
ITEA Standards for Technological Literary	Grades K–12	The Designed World	18										●
			17					●	●				
			16	●	●	●	●	●	●	●	●	●	●
		Abilities for a Technological World	11	●	●	●	●	●	●	●	●	●	●
		Design	10	●	●	●	●	●	●	●	●	●	●
			9	●	●	●	●	●	●	●	●	●	●
			8	●	●	●	●	●	●	●	●	●	●
		Technology and Society	6			●			●				●
			4			●			●				●
		The Nature of Technology	3	●	●	●	●	●	●	●	●	●	●
			2	●	●	●	●	●	●	●	●	●	●
			1	●	●	●	●	●	●	●	●	●	●
Massachusetts Science and Technology/ Engineering Curriculum Framework	Grades 6–8	Physical Science	13	●	●	●	●	●	●	●	●	●	●
			11							●	●	●	●
			2							●	●	●	●
			1							●	●	●	●
		Transportation Technologies	6.4							●	●	●	●
			6.3							●	●	●	●
		Communication Technologies	3.1					●	●				
		Engineering Design	2.4	●	●	●	●	●	●	●	●	●	●
			2.3	●	●	●	●	●	●	●	●	●	●
			2.2	●	●	●	●	●	●	●	●	●	●
			2.1	●	●	●	●	●	●	●	●	●	●
		Materials, Tools, and Machines	1.1	●	●	●	●	●	●	●	●	●	●

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Page 14: Mika Tomczak
Page 27: Mika Tomczak
Page 41: Parrish Kennington
All other photos: Lauren Feinberg

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BOSTON, MA 02135

Nonprofit Organization
U.S. Postage
PAID
Boston, MA
Permit No. 51738

DESIGN SQUAD
as built on TV

Design Squad **gets kids and teens thinking like engineers and shows them that engineering is fun, creative, and something they can do themselves.**

Tell us what you think about the guide.

* The *Design Squad* class pack is subject to change; available only while supplies last.

Major funding for *Design Squad* provided by

NSF · intel Education · the Lemelson foundation — improving lives through invention

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NOYCE FOUNDATION · UEF · NCEES National Council of Examiners for Engineering and Surveying · ASME · IEEE Celebrating 125 Years · NORTHROP GRUMMAN Foundation