# UNIT 1: ELECTRIFYING GAMES

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

## UNIT TABLE OF CONTENTS



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

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



### 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***

# 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.

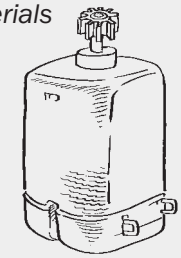
**2 Brainstorm** (10 minutes)

**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.

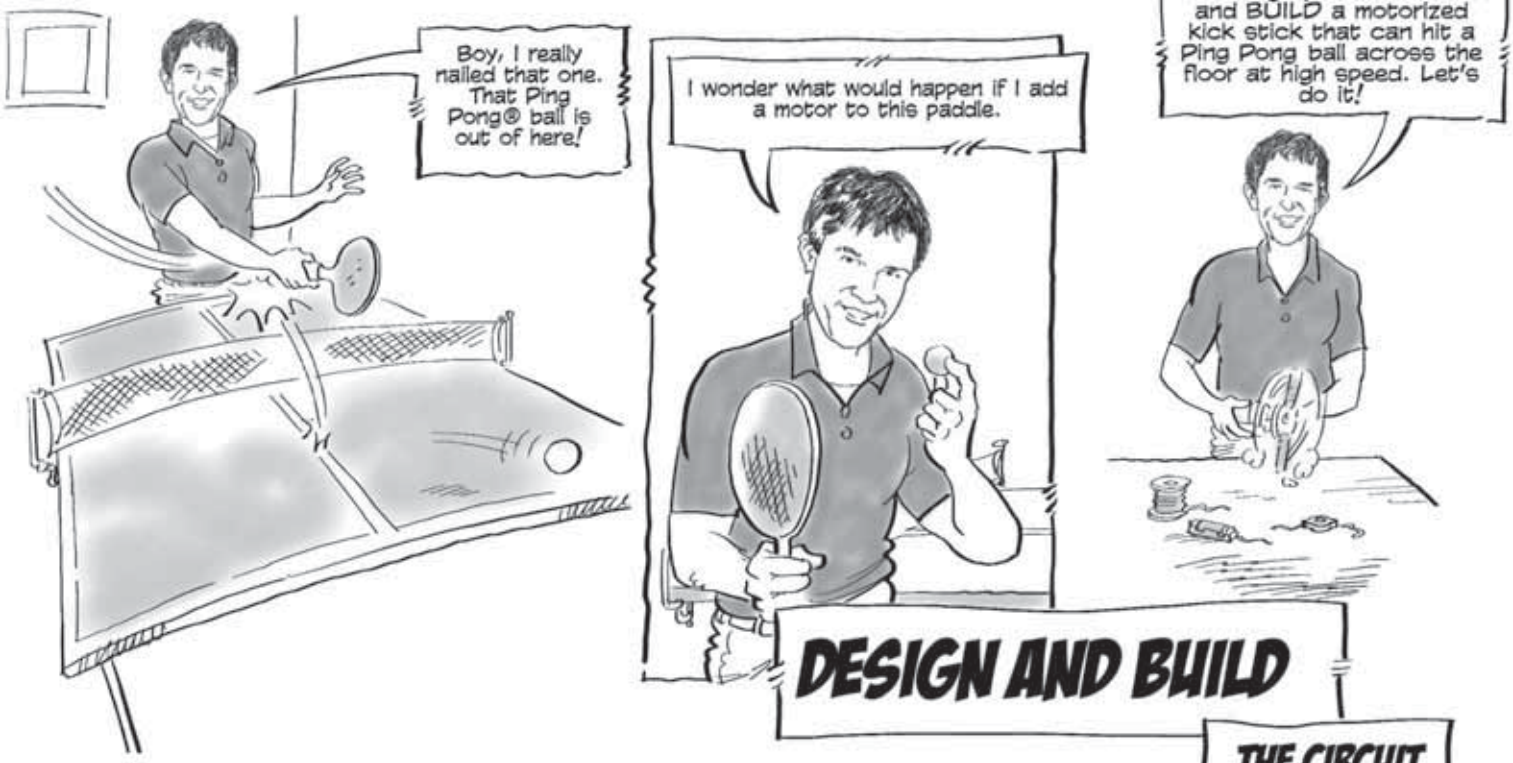
# KICK STICK

DESIGN SQUAD

PBS

as built on TV

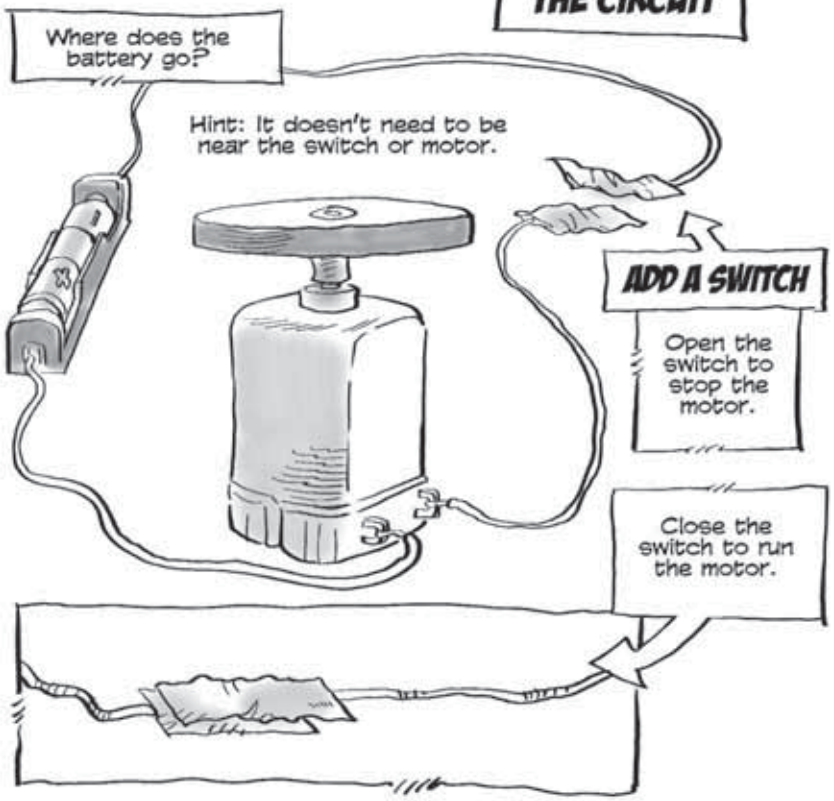
pbs.org/designsquad




## DESIGN AND BUILD

### BRAINSTORM


### THE CIRCUIT

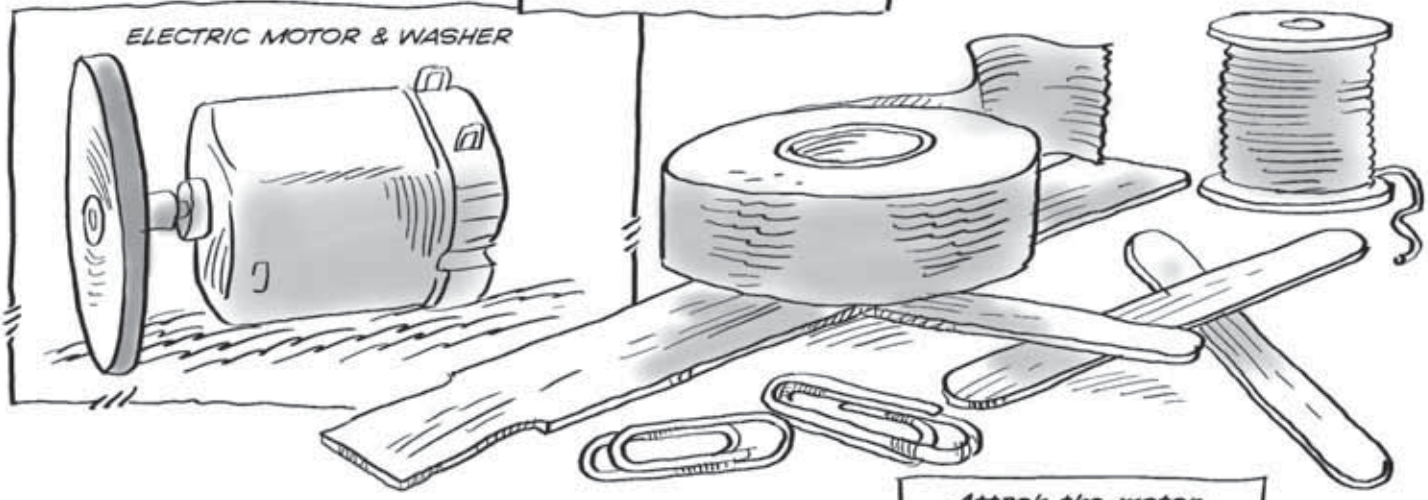


# DESIGN AND BUILD

## 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

**On target!**
How can you make your kicker kick more accurately?

**Improvements?**
How can you make the switch and blades work better?

**Invent a game**
Then test it out.

What kinds of stick-and-ball games could you play with your kick stick? What other kinds of games could you invent?

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


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

# ELECTRIC GAMEBOX CHALLENGE

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

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

**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.)*

- 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

DESIGN SQUAD

PBS

as built on TV

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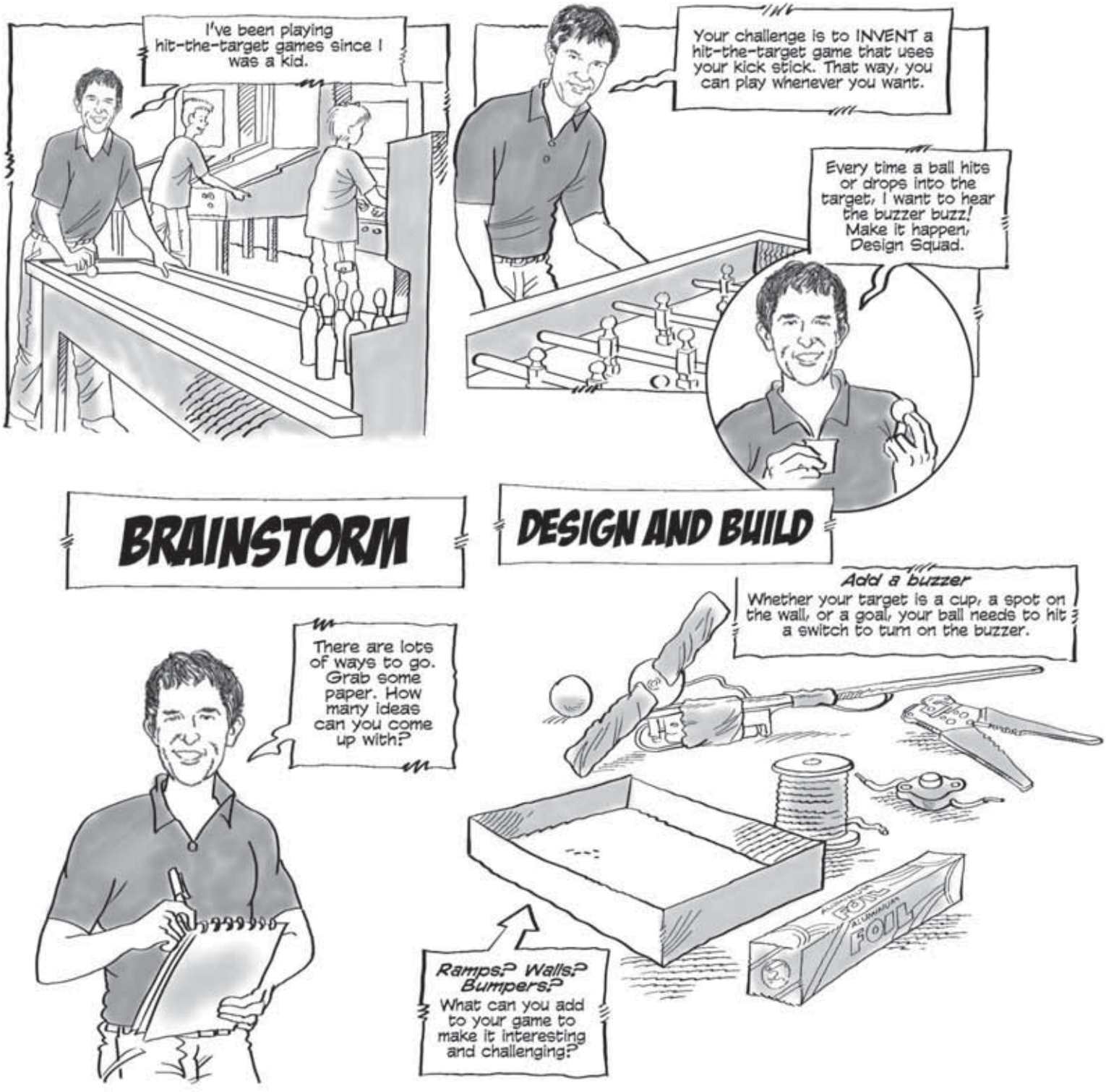
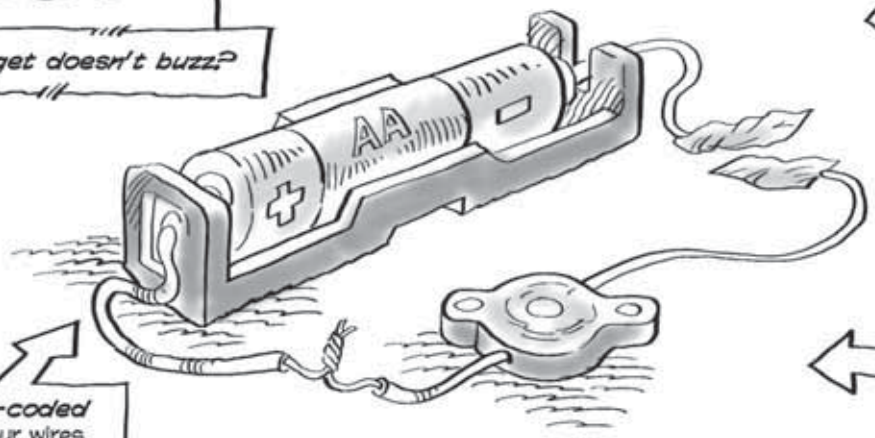


# TEST

*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.

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

# REDESIGN

1. What worked well in your game?

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

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# MAKING IT REAL:
## DRIVING HOME THE ELECTRIFYING GAMES UNIT

### 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).**