Description
In this engineering-based lesson, learners design and build a device that will control the motion of a dropped ball.

Grade Levels
4-12

Duration
65 minutes

Tech Tips
Brainstorming
Material Strategies for Engineering
Prototyping
Sharing Solutions

The Tech Challenge Connections
This lesson can help Tech Challenge teams build skills that aid in crafting their solutions, such as:

- Utilize the engineering design process to create a successful prototype.
- Generate and analyze ideas that may satisfy a set of criteria and constraints.
- Work on optimization.
- Practice designing, building and modifying a device that controls movement.
- Start working on how to trigger movement.

Objectives
Students will:

- Learn how to improve a design by exploring variations through rapid prototyping.
- Practice analyzing a problem with a team.
- Practice comparing and optimizing solutions.

Standards Connections

- *3-5-ETS1-2* Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- *3-5-ETS1-3* Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
- *MS-PS2-1* Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.
- *MS-ETS1-2* Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- *MS-ETS1-3* Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Grade level modifications
Design challenges can be modified to suit younger/less experienced and older/more experienced learners. General suggestions:

1. For older students, add additional criteria to the challenge with the Challenge Cards provided. These also allow groups to work at different rates and continue to be challenged even after they are successful with one challenge. Introduce Challenge 1 and Challenge 2 at the beginning of the lesson and have them work on them simultaneously. Have different balls out for use in the challenge, or have them use the most difficult for each challenge (e.g., tennis ball for Challenge 1, whiffle ball for Challenge 2).
2. For younger or less experienced learners, have them only do one challenge in a class period so they have more time for building and iteration. Give them only one type of ball to work with (a golf ball is the best starter for Challenge 1, tennis ball for Challenge 2).

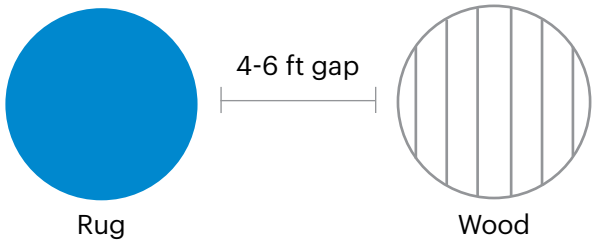
Materials

- Binder clips (60)
- Clothespins (30)
- Coffee filters (50)
- Corks (50)
- Foam sheets (30)
- Foil sheets (30)
- Paper bowls (30)
- Paper clips (100)
- Paper plates (30)
- Paper towel tubes (20)
- Pipe cleaners (100)
- Popsicle sticks/Craft sticks (100)
- Rubber bands (100)
- Straws (50)
- Twist ties (50)
- Variety of balls (3 - 4 of each: ping pong, whiffle, golf, tennis, racquet) or 1 per team if everyone is using the same type of ball

We leave tape and glue off this list on purpose. Forgoing tape and glue will allow for rapid iteration of designs. This also will allow you to recycle and reuse materials for another session.

Test Area

- 36” circular area on a soft surface (carpet, rug)
- 36” circular area on hard surface (wood, tile, linoleum, cement)
- 2 step stools (for dropping devices - optional)



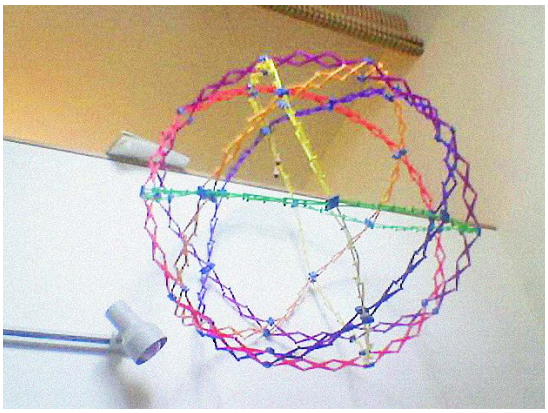
Prep

Collect, organize and set up materials. See Tech Tip: Materials Strategies for Engineering Design.

- Build a solution (or solutions) yourself, with other educators or kids you know. This will give you practice with the materials and tools to be able to anticipate student questions.
- Set up Test Area

Lesson

1. Introduce expansion and the Design Challenge. (5 minutes)
    a. Group students in teams of 2 - 4.
    b. Ask learners, "Can you think of some devices that have motion or expansion triggered by impact or another action?"
        i. Examples include: Hoberman spheres (open when mechanically pulled), parachutes (only do their job when they expand), umbrellas (super useful when expanded but can contract and be put away), airbags (only do their job when they expand), origami (uses folds to contract and convert shape) and balloons (expand with air pressure).
        ii. Suggested wording: *For some of these, the expansion is triggered by an action, such as putting up an umbrella, a car crash triggering an airbag, or air pushing open a parachute. Today we are going to use ideas like this to design a device that either triggers motion when dropped or dampens motion when dropped.*



Hoberman Sphere

2. Introduce first Design Challenge

Design Challenge 1
Build a device that causes the ball to roll off the rug after a drop.
Criteria
• Device needs to be dropped straight down by students standing on the ground or step stool. • Device must contain a ball. • Ball must roll off the carpet/rug (with or without the device).
Constraints
• Only the materials provided may be used. • Device must be built in the allotted time. • Device must be able to be carried to the Test Area. • Device cannot be built in the Test Area.

3. Allow student groups to brainstorm. See Tech Tip: Brainstorming. (5 minutes)
    a. Let students explore the materials and have them think about the attributes of different materials. Remind them they will test, revise their designs and retest!
4. Have students build, test and iterate. See Tech Tip: Prototyping. (15 minutes)
    a. For groups who are immediately successful, provide them with Challenge Cards.

5. Gather the class together to share their devices. See Tech Tip: Sharing Solutions. (10 minutes)
    a. Have each team present their device (one team at a time).
        i. *Tell us how your device was intended to work. After testing, what changes to your device did you make and why?*
        ii. Students demonstrate their devices.
        iii. Reflection: *If you had more time or materials, what would your team try next?*
    b. Transition to Design Challenge 2: *During this design challenge, we focused on how to create movement after a drop. Now that we have some experience with the materials, let's shift to designing a device that will minimize motion.*

Design Challenge 2 Build a device that keeps the ball on the wood circle.
Criteria • Device needs to be dropped straight down by students standing on the ground or step stool. • Device must contain a ball. • Device and ball must remain together.
Constraints • Only the materials provided may be used. • Device must be built in the allotted time. • Device must be able to be transported to the Test Area. • Device cannot be built in the Test Area.

6. Allow teams to brainstorm. (5 minutes)
    a. Let teams know they may modify their existing device or create a second device to complete this challenge.
7. Have students build, test and iterate. (15 minutes)
    a. Provide access to the same materials as in the previous challenge.
    b. For groups who are immediately successful, provide them with Challenge Cards.
8. Gather everyone together and share out. Aside from the last question, shareout should focus on Design Challenge 2. (10 minutes)
    a. Have teams demonstrate their device.
        i. Have teams share: Tell us how your device was intended to work.
        ii. What was the key to getting it to work?
    b. Have teams share: If you had more time or materials, what would your team try next?
        i. Did you run into any problems when testing your device?
        ii. What changes did you make to solve these problems?
        iii. Can you think of a real-world application for your design?
        iv. What did you do to complete this challenge that differed from the previous challenge?

Modify your device to work with a different type of ball.
CHALLENGE 1 OR 2

Make your device more reliable. For instance, if your device is successful 1 out of 3 times, make it work 2 out of 3 times.
CHALLENGE 1 OR 2

Create a device that will move two balls.
CHALLENGE 1

Have the ball roll to the same place every time on the rug.
CHALLENGE 1

Have two balls roll in opposite directions on the rug.
CHALLENGE 1

Drop your device from a different height.
CHALLENGE 1 OR 2

Make one device that completes both challenges.