3M Young Scientist Lab

Classroom Activity | Grades 6-8

Cushion It!

GUIDING QUESTION

What happens during a collision and how can the force of the impact be reduced?

LEARNING OBJECTIVES

Students will be able to:

- demonstrate the protection that cushion (bubble) wrap offers.
- investigate different protection designs.
- identify variables that affect the capacity of a sugar cube to survive a collision.

OVERVIEW

Collisions are a part of everyday life. Some are wanted (baseball and bat), some are unwanted (car crash), while others are unavoidable (stubbing one's toe). There is a great deal of basic science involved with collisions and in this lesson. Students will investigate some of this science as well as practice and develop their inquiry skills.

NEXT GENERATION SCIENCE STANDARDS

- PS2.A: Forces and Motion
  - For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
  - The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

- PS3.B: Conservation of Energy and Energy Transfer
  - When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5).
- PS3.C: Relationship Between Energy and Forces
  - When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)
- ETS1.A: Defining and Delimiting an Engineering Problem
  - The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ETS1-1)(secondary to MS-PS3-3)
- ETS1.B: Developing Possible Solutions
  - A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) (secondary to MS-PS1-6)
  - Models of all kinds are important for testing solutions. (MS-ETS1-4)
- ETS1.C: Optimizing the Design Solution
  - Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process- that is, some of the characteristics may be incorporated into the new design. (MS-ETS1-3)(secondary to MS-PS1-6)
  - The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)(secondary to MS-PS1-6)

LESSON TIME FRAME

Three 45-minute sessions:

- One session to engage students and introduce the activity.
- One session for students to carry out the investigation.
- One session to discuss and summarize their findings.

BACKGROUND INFORMATION

The study of collisions is a fundamental topic in science. Collisions are part of the broader physics: domain of mechanics → conservation laws → conservation of momentum → collisions. Momentum is a useful construct that is defined as the product of a particle's mass times its velocity. A baseball moving through the air has a given amount of momentum associated with it; the more massive the ball, the more momentum it has, and the faster

the ball is traveling, the more momentum it has. In addition to magnitude, momentum has a direction of travel associated with it. Momentum in one direction is different from momentum in another direction. When the batter hits the ball with a bat, the ball suddenly changes speed and direction, and hence the momentum of the ball suddenly changes. This sudden change in momentum is referred to as an impulse. Another common example of an impulse is a car crash. The mass of the car and its occupants traveling at a given speed is suddenly brought to a stop

One way to reduce the damaging effects of a large impulse is to either reduce the impact force (not swing the bat as hard) or to extend the time or distance of the collision. In a car crash with the momentum at a given value, the way to reduce the effect of the collision is to extend the time of the collision by increasing the distance over which the object suddenly comes to rest. This is how an airbag in a car cushions the effect of a sudden collision. The use of an airbag extends the time it takes to stop a person's body from its initial speed by increasing the distance over which the collision occurs. A secondary safety feature airbags provide is to distribute the large force of the impact over a larger surface area, reducing the maximum pressure on the body.

The generic term for any item or material that reduces the damaging effect of a sudden impulse is 'cushioning material.' Padding is a common material found in sports equipment, shipping supplies, and vehicle interiors. A popular type of cushioning material used to protect delicate items during shipping is cushioning wrap.

MATERIALS

Teacher Materials/Prep

- Home Connection Resource
- Blackboard or chart paper
- Paper towel tube
- Several sugar cubes
- D-cell battery
- Several trash cans for cleanup
- Print copies of Cushion It! Student Capture Sheet
- Print copies and cut out
    - Six Word Story Summary Student Capture Sheet
- It would be useful to practice the steps the students will conduct in this activity beforehand. See number 3 under the "Explore" section of these lessons. See also Figures 1, 2, and 3 for graphical representations of the materials and how they are used.

Figure 1:

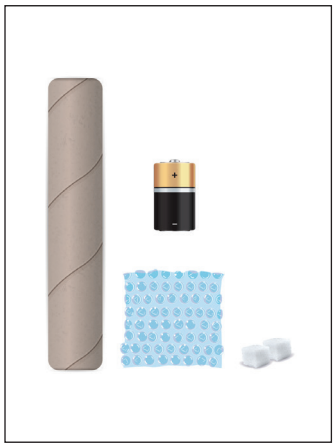


Figure 2:

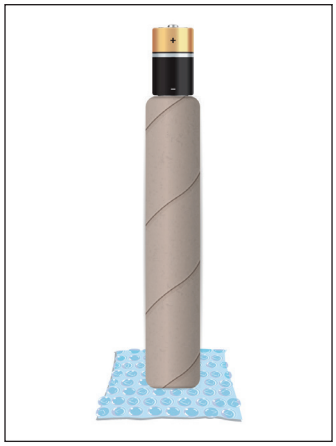
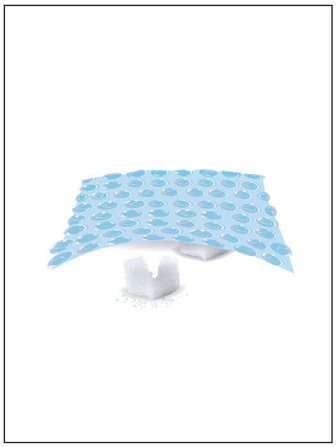


Figure 3:



Materials per Student Group

- Battery*
- Paper towel tube (empty)
- Supply of sugar cubes
- Sheet of cushion (bubble) wrap**
- Writing paper, a few sheets
- Scissors
- Ruler (optional)
- Paper towels
- Science notebook
- Pencil
- Cushion It! Student Capture Sheet
- Six Word Summary Student Capture Sheet (one per student)

*You might choose to provide standard (non-alkaline) batteries to some groups and alkaline types to other groups. Alkaline batteries are noticeably heavier and will produce a greater impulse, and therefore more damage, than standard batteries. Don't let students know about this variable ahead of time.

**This investigation works best if the cushion wrap has small air bubbles, as opposed to large bubbles that are fun and easy to pop. Each group needs a sheet approximately 12" x 24" that they can cut into smaller squares.

CLASSROOM ACTIVITY

Day 1

Engage

1. Hand a tennis ball to a student and ask them to gently toss the ball to you. Once you've caught the ball, ask students to tell you what's happened to the energy that was in the moving ball now that you've caught and stopped it from moving. This nature of the ensuing discussion will depend on students' understanding of force, motion, energy, and other mechanical-related science concepts. Note the nature of their replies so you can tailor the lesson to an appropriate level.
2. As the discussion progresses, have students think of the tennis ball as a car with people inside and your hand as a tree or similar solid immovable object that stops the car/tennis ball suddenly. Encourage students to draw comparisons between the two situations and look for their appreciation of the sudden change in motion when a moving car hits a tree. If the concept of an 'airbag' is brought up, probe for understanding of how airbags help protect passengers in cars.

***Teacher Note:** You could introduce the concept of 'momentum' and 'impulse' and related concepts mentioned in the 'Background for Teachers' section at this point if it seems appropriate for your students.

3. Display a section of cushion (bubble) wrap and ask students what they know about materials like this. Relate their ideas and comments to your earlier discussion about the role of airbags in cars. Inquire as to what experience students have had using cushion wrap. Tell students that they are going to practice and develop their inquiry skills by conducting an investigation into the protective properties of cushion wrap.

Day 2

Explore

1. Write the following prompt on the board: What is the most effective way to use cushion wrap to protect a sugar cube from a potentially damaging collision?
2. Show students a sugar cube and a D-cell battery. Ask if they think the battery could crush the sugar cube and proceed to do so by placing the sugar cube on a table, desk, or other hard surface and hitting the sugar cube with the bottom of the battery. No need to totally destroy the cube; use just enough force to crack it into several pieces.
3. To continue, hold the battery two centimeters above the sugar cube and ask students to predict what they think will happen to the sugar cube when you simply drop the battery on the cube. After some brief discussion, drop the battery; the cube should not shatter. Raise the battery to 5 cm then 10 cm and ask for a prediction each time, but do not drop the battery either time. Bring out the section of cushion (bubble) wrap again and ask students if they think it could be used to prevent the cube from being crushed. Accept a few responses without comment and tell students they are now going to work in groups to investigate how best to protect a sugar cube from being crushed.
4. Explain to students that since there were differing predictions about crushing the sugar cube from different heights, it would be best if every group dropped their battery from the same height. Briefly discuss or review the importance of controlling variables in an investigation and the need to vary only the dependent variable – which in this case is going to be the method of protecting the sugar cube, not the height of the battery drop.
5. Show students a paper towel tube and demonstrate how to place the tube over a sugar cube, hold the battery at the top of the tube, and let the battery fall through the tube onto the sugar cube. The tube visually reinforces for students that if each group does the drop this way, the drop height will be standardized among all groups. Go ahead and demonstrate this so students can see that dropping the battery from this height does indeed crush an unprotected sugar cube. Also show the sheet of cushion (bubble) wrap and suggest that they can cut it into smaller pieces with scissors. Tell students they can also use plain writing paper in their design if they like. (You might find that some groups might add a layer of writing paper between layers of cushion wrap for added protection.)

6. Optional side-concepts to include with this lesson:
    a. **Defining operationally:** If you have time and want to have your students delve into a subtle but important facet of scientific investigations, bring up the problem of just what do we mean when we say the sugar cube was, or was not, destroyed or damaged in the collision with the battery. Is the cube unharmed if just a few grains of sugar fall off but the cube still maintains its cubical shape? How big of a piece of the cube needs to break off if we are to say the cube was not protected by the cushion wrap? As you discuss this issue with your students, you will no doubt be able to apply challenges like this to other situations. For example, how heavy is a backpack that is considered "too heavy?" When does music become "too loud?" If you allow your students to go this route, you might find some interesting debates occurring within groups about "did the cube survive this particular collision?"
    b. **Repeated trials:** If you tried this test yourself, you might have discovered that you got different results when you repeated the same initial conditions. There is a fair amount of variability in this design. Is a small bubble directly over the center of a cube? Did the battery hit the layer of cushion wrap at a slight angle? Was there a residual grain of sugar from a previous trial under the new cube? In order to minimize the effect of such hidden variables, it is customary to duplicate the same conditions with several trials and look at the results statistically; that is the average of the results in this case. Students could repeat each condition (e.g. one layer of cushion below the cube and two layers above the cube, each separated by a piece of paper) three times and settle on the outcome that occurred in two of the three trials.
    c. **Limited resources:** You can add a level of challenge to this investigation if you require or force limits on the amount of cushion wrap groups use in their protection designs. One way to do this would be to assign a "cost" to a given amount of cushion wrap. For example, each square cm of wrap could cost each team ten cents. Teams would be required to keep track of the cost of each protection design and would try to keep costs down.
7. Now that students know the challenge and have seen the materials available to them, pass out one copy of the Cushion It! Student Capture Sheet to each group. Let them work in groups to design a protection system before they receive the actual materials. This step does not need to take long nor do the groups need to develop a written plan since this investigation relies somewhat on trial and error. They may use the caption sheet to take notes, draw designs, etc. if needed.
8. Once you feel the groups are ready, distribute the materials, assist as needed, and let the testing begin. You will find that the crushed sugar cubes and used pieces of cushion wrap make quite a mess, so be prepared with a workable cleanup system.

9. After the groups have gathered their data and cleaned up their materials, suggest that each group briefly meet together to discuss their results and prepare a summary conclusion they can report to the whole class on their Cushion It! Student Capture Sheet.

Day 3

Explain

1. Convene students together as a class to discuss and share individual group's conclusions. How did they answer the question? What were some of the issues with this particular design for the investigation? How could it be improved? Is there a way all the groups could graphically display a summary of the results?
2. This would be a good opportunity to review and discuss the role variables play in a scientific investigation. As students suggest variables they discovered and recognized, list them on the board or chart paper. Relevant variables for this investigation could include the number of layers of wrap above and below the sugar cube, adding paper between layers of wrap, small changes in the height of the drop of the battery, did all groups have the same type/weight of battery, the surface on which the testing was done (desk, floor, carpet), to name some of the more apparent.

Extend

1. You might want your students to modify this investigation by comparing different types of cushioning material like foam, newspaper, cloth, etc. Tying this back to variables is very appropriate and reinforcing for students.
2. If students have not discovered that the surface on which they conducted their collision tests was a significant variable in this investigation, this would be a good opportunity to extend this lesson. If the surface "gives" at all, the sugar cube can withstand a greater impulse before being destroyed. The reason this happens is because a surface that gives and is not as rigid allows the impulse to be spread out in time and distance. Car manufactures make use of this principle by designing frames of cars to crumple in a collision, allowing brief but potentially life-saving additional time for the occupants to decelerate from the car's speed down to no speed. Students could try this investigation on various surfaces: cardboard, a hard floor, rugs, wood supported above the floor, etc.
3. You could engage students in a discussion about real-world applications of some of the science principles in this lesson. Why do people bend their knees when they jump off of a stool and land on a hard surface? Why does it help when pounding a nail into a vertical board if someone pushes against the board in the opposite direction? Why does a football player prefer to tackle a lighter player rather than a heavier player? Why are people generally safer in larger cars as opposed to smaller cars?

Evaluate
Teacher Note: Have students answer the following questions on a piece of paper or in their science journal.

1. How does cushion wrap protect a sugar cube from a collision with a battery?
2. Which protection design provided the most protection and which provided the least protection for the sugar cube?
3. What were some variables that seemed to affect the outcome of your investigation with the sugar cubes?

TEACHER SCORING KEY FOR EVALUATE

1. Cushion wrap seems to spread out the blow from the battery over a bigger area and provide some extra distance for the battery to slow down before it comes to a rest.
2. Answers will vary. The most damage to the sugar cube occurred when there was no cushion wrap involved.
3. We found that these variables affected how the sugar cube survived the collisions: how much cushion wrap we used, if the cushion wrap was on top of or below the sugar cube, if we separated the layers of cushion wrap with paper or not, and the height we dropped the battery from (we lifted it way out of the tube several times).

REFLECTION

Students will reflect on their learning by completing the Six Word Story summary. Print off the Six Word Story Summary Student Capture Sheet, cut them out, and distribute one to each student. Alternatively, students may create this reflection activity in their science journal:

SIX WORD STORY SUMMARY

Exit Ticket:

Summarize your learning in **six** words.

_____ _____ _____ _____ _____ _____

Design Thoughts/Notes/Drawings

Results

Summary/Conclusion: What worked best? What did not work? Why?

SIX WORD STORY SUMMARY

Exit Ticket:

Summarize your learning in **six** words.

_____ _____ _____ _____ _____ _____

Exit Ticket:

Summarize your learning in **six** words.

_____ _____ _____ _____ _____ _____

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_____ _____ _____ _____ _____ _____

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_____ _____ _____ _____ _____ _____

HOME CONNECTIONS

Parent Background Information:

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distance over which the object suddenly comes to rest. This is how an airbag in a car cushions the effect of a sudden collision. The use of an airbag extends the time it takes to stop a person's body from its initial speed by increasing the distance over which the collision occurs. A secondary safety feature airbags provide is to distribute the large force of the impact over a larger surface area, reducing the maximum pressure on the body.

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Activities to do with your young scientist:

1. **Share:** Your young scientist could share the results and findings of the cushioning investigation they did at school for this lesson.
2. **Short investigation:** The "give" of a surface has an effect on the response of an object colliding with that surface. Use a ball (hard rubber or tennis work well) to test the "give" of various surfaces around the house: wood floor, different types of rugs, concrete, etc.
3. **Research:** You and your young scientist could use the Internet to research the science of collisions with these websites:

- Seatbelts
    - http://hyperphysics.phy-astr.gsu.edu/hbase/seatb.html#cc1
- Truck Collisions
    - http://hyperphysics.phy-astr.gsu.edu/hbase/truckc.html
- Airbags and Seatbelts
    - http://hyperphysics.phy-astr.gsu.edu/hbase/seatb2.html#cc2
- The Effect of Collision Time
    - http://www.physicsclassroom.com/class/momentum/U4l1c.cfm#rebound

4. **Activity:** Use cushion (bubble) wrap to pad and protect an item you plan to ship using a package delivery system.