Berkeley Engineers and Mentors

Feeling Eggsellent

Target Grade: Elementary/Middle
Author: Chelsea Yang
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Brief Overview

In this lesson, mentees will apply the engineering design process and general concepts of force/impact to build structures to protect eggs that are dropped from a certain height.

Main Teaching Goals

- Understanding concepts of **force** and **impact**
    - Applying understanding in trying to reduce force and impact
        - Force - something that changes the motion of an object
        - Impact - when objects forcibly come into contact with each other
- Understanding how different materials respond to force/impact
- Applying the **engineering design process**
    - Engineering design process - series of steps that engineers take in order to arrive at solutions
    - How can students improve their designs if their eggs break?
    - How can students minimize the amount of materials that they use?
- (optional) Understanding **air resistance** and how it can be utilized to reduce impact on the egg drop device
    - Air resistance - frictional force that air exerts on a moving object

Careers and Applications

Though we may not need to protect eggs very often in the real world, applications of design to reduce force and impact are still numerous. Mechanical engineers must take into account materials and design when designing new vehicles. Not only safety, but aesthetics, production and material costs, and weight must also be considered.

Another obvious application of impact engineering is in the design and construction of sports equipment, such as tennis rackets, footballs, etc. Sports equipment must be designed to last through many collisions (as is their purpose).

Some less obvious applications come in the form of cushioning devices, which are also

designed to reduce or stop impact. Cushioning devices such as pillows and mattresses must be both comfortable and able to reduce the strain on the human spine and neck. Shoes, especially running shoes/tennis shoes must cushion athletes feet and reduce impact on joints. Many other things that students may encounter in daily life (chairs, sofas, phone cases, chip bags, drink bottles) must be engineered to resist damage in the case of collisions!

In this design challenge, students should also consider how their device will react upon landing. These considerations were important in the design of the Mars Rover; NASA scientists designing the rover had to consider how it would withstand the heat and impact of landing on Mars!

Agenda

- Module 0: Get Wrecked (5-10 min)
- Introduction (5-10 min)
- Building!! Round 1 (15-20 min)
- Testing (5-10 min)
- Building!!! Round 2 (15-20 min)
- Testing (10-15 min)

Module 0: Get Wrecked

Introduction

This mini-module will introduce mentees to the concepts of collision/force/impact and how they could possibly reduce them.

These concepts can also be used to relate this lesson back to the marble roller coasters lesson. Concepts such as kinetic energy and potential energy can be brought back (Where does the egg drop device have the most kinetic energy? Where does it have the most potential energy?) The relationship between kinetic energy, momentum, and mass can also be examined.

Teaching Goals

1. **Shock** on an object can be reduced through the use of shock absorbing materials and through a slower speed of descent.
    a. **Shock**: sudden change in acceleration.
2. Relationship between acceleration and impact force
    a. **Impact Force**: force applied when two or more bodies collide, usually over a short period of time.
    b. **Force**: something that changes the motion of an object

Background for Mentors

Background for this module and background for the egg drop have been combined! Refer to the background for mentors in the next module.

Materials

- Ziploc bags (3 per group)
- Pita chips (1 bag per group of 10)
- Layer of paper towels (Roughly 4 sheets per group)

Procedure

1. Give the mentees chips. Each mentee should place their chip into a ziploc bag. Tell them to simply drop the chip.
    a. The crackers should NOT break. The students should pick the chips back up (if not broken).
2. This time, have the mentees throw the chips at the ground.
    a. This time they SHOULD break.
    b. Ask the mentees: why did the pita chip break the second time?
        i. This should be pretty intuitive for the students.
3. THIS time, lay a layer of paper towel down. Have the mentees throw the crackers at the ground again (the chip should land on the paper towel).
    a. The paper towel layer should be decently thick (~3-5 layers of paper towel) in order to properly cushion the pita chip.
    b. Hopefully, the chip will NOT break or at least break less.
    c. Ask the mentees: why didn't the chip break this time? (Or why did they break less).
        i. This should also be intuitive!
        ii. Lead into the ways to reduce shock on objects (intro)!

Additional Notes for Mentors

The mentees might be tempted to throw their chip even harder the second time, but this works better when they throw with around the same amount of strength as the first time.
This module might be too simple for students in higher grades. If the site leader wishes to, they could go right into the introduction and have a longer period for building and testing. Remember to focus on the "why" of this module!!

Introduction

Start off by asking about the first module with questions like: When was the chip easy to break? When was it hard to break? Why? What do the mentees think would break a fall? If a mentee was falling, what would they want beneath them? This can lead into a discussion of how different material properties are important in designing something that will protect an egg.

Next, discuss how design can also help in reducing the impact force on the egg. Bring up examples of reducing impact in daily life: cushioned shoes, mattresses, airbags in cars, etc. A useful example to lead into the discussion of impact force is the following thought experiment: What happens when someone jumps out of a plane with nothing on? Now what happens when you add a parachute? Obviously, the parachute is the better option, but you can segway into how slowing the descent of the egg drop device can protect the egg.

The main ways that the students can protect their eggs are to reduce the speed that the egg drops at or to reduce the impact that the egg feels with cushioning. These two modes of protection were paralleled in module 0 (throwing versus dropping and throwing on the floor versus throwing onto the paper towels).

Module 1: Design Challenge! Let's drop it

Introduction

The mentees will begin to build and test their egg drop devices.

Teaching Goals

1. Materials and design can help lessen the impact on the egg
    a. Different materials may be better or worse at reducing shock on an egg
        i. **Shock**: sudden change in acceleration
    b. Different designs can help slow down descent and reduce impact force
        i. **Impact force**: force applied when two or more bodies collide, usually over a short period of time.
        ii. (optional) Different designs can increase air resistance and slow the descent of the device
            1. **Air resistance**: friction exerted by air on a falling object.
2. Understanding and applying the **engineering design process**
    a. Engineering design process: a series of steps that engineers use to solve problems

Background for Mentors

Impact and Shock

Shock or impact is a large amount of force applied to an object over a short interval of time. The expression for **impulse** can be derived from Newton's second law:

$$F_{average} = ma_{average} = m\frac{\Delta v}{\Delta t}$$

If both sides of the equation are then multiplied by Δt, the resulting equation is F*Δt = m*Δv. The value F*Δt is defined as the impulse. Since m*Δv = Δp (momentum), this means that **impulse = change in momentum**. This is known as the impulse-momentum theorem. This can also be described by the following:

In a collision, an object experiences a force for a specific amount of time that results in a change in momentum. The result of the force acting for the given amount of time is that the object's mass either speeds up or slows down (or changes direction). The impulse experienced by the object equals the change in momentum of the object. (physicsclassroom.com)

How can this be related to the egg drop lesson? As the egg drop device hits the ground, it experiences a force as it hits the ground; this results in a change in momentum, or impulse. The goal of the egg drop is to reduce the impulse on the egg. As shown by the equation above, impulse can be reduced by reducing the speed of the drop/increasing the amount of time it takes to drop the egg.

How can the descent of the egg be slowed down? This can be related back to the concept of air resistance/drag force! **Air resistance**, or **drag force**, is the frictional force that air exerts against a moving object. Air resistance can be increased by increasing the cross sectional area of the falling object.

Students can increase the air resistance felt by their egg drop devices by adding components such as parachutes or sails(as shown in Figure 3).

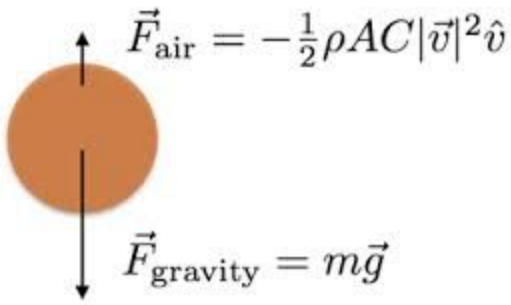


Figure 1: Air resistance free body diagram(wired.com)

Shock Absorption

Another way to reduce the force on the egg is to use shock absorbers. Shock absorbers are materials that are able to decrease the amplitude (strength) of a shock energy's wave. This is a process known as damping. The energy of the shock wave is usually converted into heat.

Possible shock absorbers for this lesson are: cotton balls, styrofoam packing peanuts (these are actually used as shock absorbers during the shipping process), and balled paper.

Engineering design process

The engineering design process is an iterative process that consists of a series of steps that are followed in order to come up with a solution to a problem. It's important to allow the students to come up with their own plans and to refine them as they go!

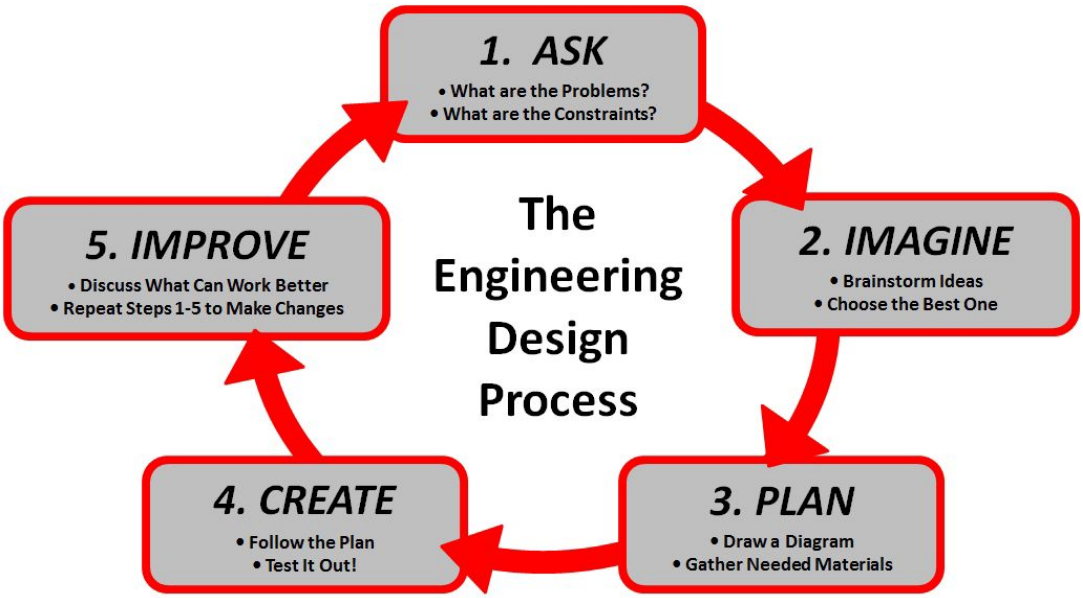


Figure 2: Engineering Design Process (washoeschools.net)

Materials

- Masking tape (2 rolls per class)
- Paper (copy paper) (2 sheets per student)
- Cardboard (2 sheets per class)
- Rubber bands (1 per student)
- Egg carton (1 per class)
- Eggs (2 per group)
- Practice Eggs (Easter Eggs with pennies inside)
- Plastic bags (grocery bags) (~5 per class)
- Styrofoam packing peanuts (1 ziploc per class)
- Popsicle sticks (2 per student)
- String (1 roll per class)
- Scissors
- Ziploc bags (~1 per 2 students)
- Balloons (3 per class)
- Toilet paper (1 roll per class)
- Pricing table (~1 per 2 students)
- Prizes (egg stickers)
- Materials from home*

Procedure Have the mentees form groups of 3 or 4.

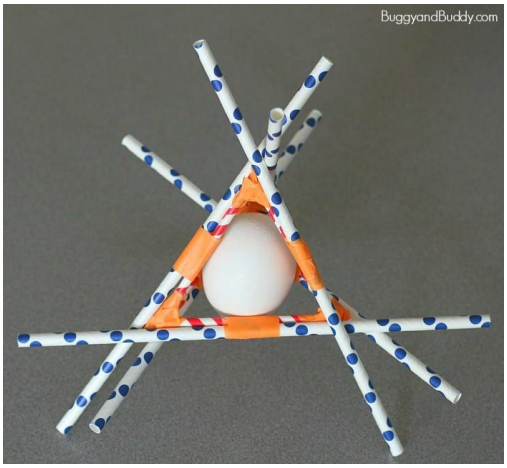
1. Have either the mentors or mentees keep track of how much of each material their group

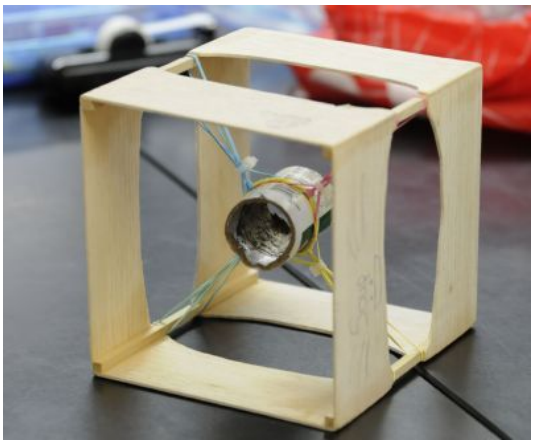
is using (OPTIONAL: see notes below).
2. Time to build! (15-20 min)
3. Test the designs by dropping them roughly 1 story (throw into the air if no balcony available).
    a. Use the test eggs in the first round of testing to test how quickly the egg drop devices fall/how they hold up after being dropped.
    b. When using real eggs, place the egg into a ziploc bag and squeeze out all the air before placing into the device in order to reduce clean up!
4. Repair/build again (15-20 min)
5. Test the designs again!
    a. This time with real eggs!
6. Competition mode:
    a. Whichever student drops the egg from the highest height without it breaking wins!
    b. The egg drop device that used the least amount of materials and lasted the longest can also get a prize if your site is calculating costs!
    c. For older sites, it may be a good idea to restrict the amount of materials that students can use in order to build their egg drop device.
    d. If you end early, try adding these extra challenges:
        i. (for more advanced sites or if the egg drop devices are working well) Test the students egg drop devices with both a real egg and a test egg(double the weight) to see if the egg still survives.
        ii. Challenge the students to take materials OFF of their current egg drop devices and see if the egg is still protected!
        iii. (for younger sites) Vote on the most aesthetically pleasing egg drop device!
        iv. Challenge students to make parachutes for their egg drop devices after taking materials off.

Additional Notes for Mentors

- May get kind of messy!
    - Eggs should be put into ziploc bags and the air should be squeezed out before being placed into devices in order to minimize getting egg everywhere.
- Older mentee adjustments:
    - Higher drops, if possible
    - More restricted amount of materials
        - Used included tables to help the students keep track of what they used in their egg drop device! At the end of the lesson, see which group of students used the least amount of materials to protect their eggs.
- I wanted to include more “interesting” materials but I don’t want to put a huge load on the logistics team, so feel free to bring things that you think would be interesting from home!
    - Some examples:
        - Mythbusters did an egg drop challenge with an orange and latex gloves as materials! (https://www.youtube.com/watch?v=ZOMW3hplSpI)

    - Sponges
    - Toilet paper rolls
    - Wire
    - Cotton balls
- Examples of egg drop designs:





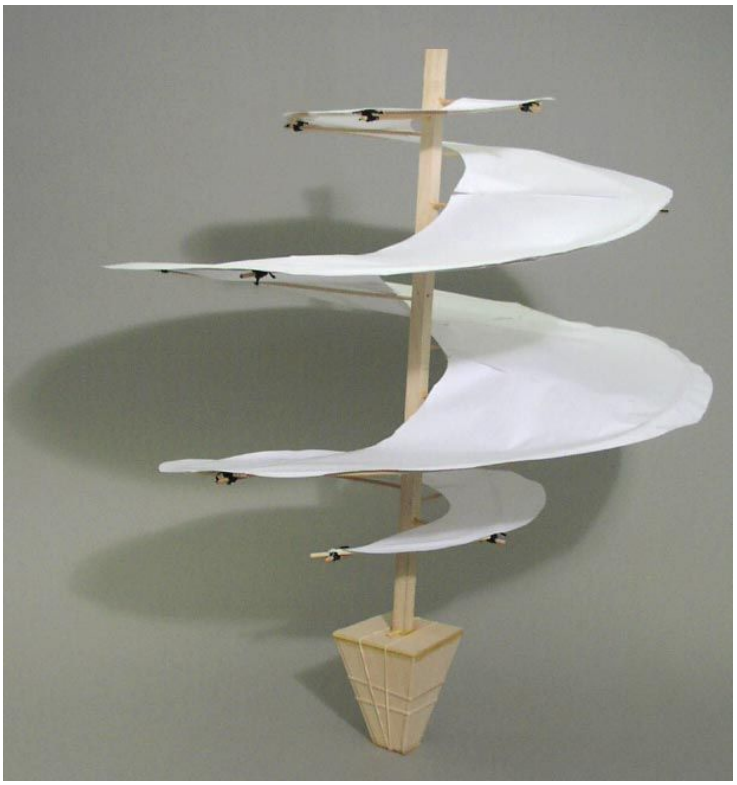


Figure 3: Example egg drop device designs (buggyandbuddy.com, Propublicbono.org, zizidesignideas.com)

Material	Straws (1 straw)	Popsicle sticks (1 stick)	Paper (1 sheet)	Cup (1 cup)	Card Board (1 sheet)	Twine (1 foot)	Bag (1 bag)	Rubber Band (1 band)	Packing peanuts (1 peanut)	Toilet paper (1 square)
# used										

Figure 4: Example material record table

Conclusion

Have a brief discussion on what worked and what didn't work. How can this be applied to real life? (refer to introduction)

Recap the teaching goals of the lesson: how reducing the speed at which the egg drop device falls reduces the impact force on the egg and how to use the engineering design process can improve the egg drop device.

References

- Important Mechanical Properites, University of Warwick https://warwick.ac.uk/fac/sci/wmg/globalcontent/courses/ebm/mant/materials/properties_of_materials/
- Impulse Force, Hyperphysics http://hyperphysics.phy-astr.gsu.edu/hbase/impulse.html
- Momentum and Impulse Connection, https://www.physicsclassroom.com/class/momentum/Lesson-1/Momentum-and-Impulse-Connection
- Air resistance, Physicsclassroom https://www.physicsclassroom.com/mmedia/newtlaws/sd.cfm

Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Copy paper	2 sheets per student	$24	Amazon
Plastic bags	~10 bags per site	$8.45 per 100	Amazon
Twine	1 roll per site	$4 per roll	Amazon
Rubber bands	~50 per site	$6 for 500	Amazon
Styrofoam cups	~14 per site	$9.39 for 100	Amazon
Eggs	1 carton per site	~4	Safeway
Test eggs	~5 per site	$0	BEAM

Masking tape	2 rolls per site	$0	BEAM
Popsicle sticks	~30 per site	$0	BEAM
Pita chips	1 bag per 10 students	$14 for 24 bags	Amazon
Paper towels	Couple of sheets per site	$0	Get some from the school bathroom on site
balloons	5 per site	$6.48 for 100	Amazon
Toilet paper	1 roll per site	$16 per 24 rolls	Amazon
Straws	10 per site	$8 for 200	Amazon
Packing peanuts	1 gallon bag per site	$12.95 for 25 gallons	Amazon
Prize: egg stickers	20 per site	$11 for 500 stickers	Amazon