THE GREAT EGG DROP CHALLENGE

PROTECTION FROM IMPACT DAMAGE

"Experience is the teacher of all things." — Julius Caesar

Ever wonder what happens when two objects collide? Welcome to the Great Egg Drop Challenge! Your mission, should you choose to accept it, is to design a protection system to get a raw egg safely to the ground from a free fall of 7 feet high onto a flat, hard surface, such as concrete, tile, or laminate.

Use materials you have on hand, and get as creative as you like! Here are three potential categories for your egg protection system:

1) **Containers**–such as a cardboard box, plastic or styrofoam container, plus a padding system… paper towels, crumpled paper, pop corn, rubber bands, peanuts, the sky's the limit.

2) "**Outside the Box**"–build your own protection system around your egg… maybe with balloons and straws, crumpled paper and string… get creative!

3) "**Parachute / Glider**"–the strategy for this category is to lower the impact velocity to reduce the collision damage. You'll probably still need some padding… and a longer space to test, like your driveway, or a parking lot.

How does this relate to real life? Bicycle helmets are designed to protect your head from damage if you fall off your bike. Cars have multiple strategies to protect their occupants from serious physical harm in the case of an accident, with airbags, plus crumple zones that absorb much of the impact damage.

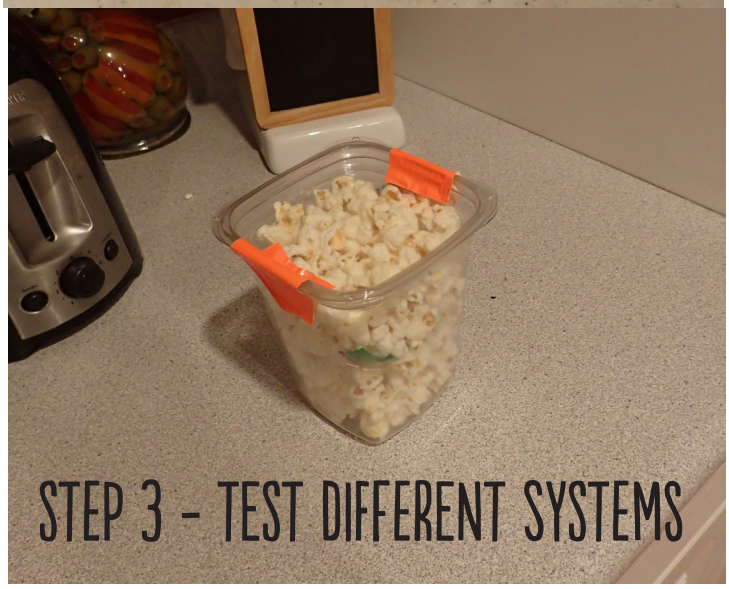
Lesson Objectives

- Learn about **potential energy**, **kinetic energy**, and how objects behave when dropped from various heights
- Learn about **conservation of energy**, and **conservation of momentum**
- **Identify two key factors that control the amount of impact damage**
- Learn about **elastic** and **inelastic** collisions
- Experiment with designing and building various "**packaging systems**" to protect the egg from breaking from a specific height. What works? What doesn't?
- Develop **test standards** to compare different systems, for example: how many feet high the package can be dropped from and **not break the egg**.

Materials Needed

- A few **raw eggs**
- **Recommended**: a couple **hard boiled eggs** for use as test dummies (good for testing until they crack - then they can be eaten)
- **HIGHLY Recommended**: Plastic **ziplock** sandwich bags (bag your raw or hard boiled eggs first to *minimize the clean-up needed when the eggs break*… plus you may be able to salvage the eggs to make scrambled eggs afterwards!)

THE GREAT EGG DROP CHALLENGE
MATERIAL SYSTEM SUGGESTIONS



Packaging material system suggestions — the sky's the limit — use your imagination. You can do this experiment several different times, and set different constraints on materials to be used for each. Have fun with this!

Some potential outer frameworks:

- Plastic straws & tape
- Plastic food container with lid
- Cardboard box
- Large ziplock plastic bag
- Part of a plastic bottle, plastic wrap & tape
- Masking tape and/or duct tape to seal your system

Potential cushioning materials:

- Balloons & string
- Sponges
- Cotton balls
- Pop corn
- Styrofoam
- Insulation foam board
- Crumpled paper
- Shredded paper
- Bubble wrap
- Rubber bands & tape (& carrier of some sort, such as single egg carton cell, small inner box, etc.)
- Plastic grocery bags, wadded up
- Cotton quilt batting remnants
- Foam remnant
- Aluminum foil
- Anything else you can think of that you have around the house and are willing to donate to the experiment

Testing –

- Recommended **drop height** is 7 feet from bottom of container to the ground. **You may need an adult to help you with this.** If you can, record video to share, or snap some photos.
- **Ground conditions**–must be a hard, flat surface, such as concrete, black top, tile, laminate... NOT CARPET, padding, pillow, or grass, etc.
- **Take pictures**! (and video if possible) to share. Look at your egg. What does the fracture look like (if it breaks?) Info on how to share your photos is provided at the end!

THE GREAT EGG DROP CHALLENGE

EGG FRACTURE PATTERNS & POTENTIAL TEST DUMMIES

LEFT: **A successful test**–no cracks in your egg!

Want to do lots of tests, with minimal mess? Try using a **test dummy** as a substitute for a raw egg. To be useful, your "test dummy" needs to behave like the real deal.

In the photos below, I tested (and broke) a **raw egg**, and compared the fractures from the raw egg with the fracture pattern on a **hard boiled egg**. You see the same characteristic fracture pattern, so a **hard boiled egg is a good test substitute** for checking out your packaging system (and you can easily eat it afterwards!)

SUCCESSFUL TEST - NO CRACKS!

UNSUCCESSFUL TEST OF RAW EGG–SEE THE RING OF CRACKS AROUND THE IMPACT?

SUCCESSFUL TEST DUMMY... THIS HARD BOILED EGG CRACKED ON IMPACT... SHOWING THE SAME CHARACTERISTIC RING OF CRACKS AS THE RAW EGG!

This **hard boiled egg** shows the same **fracture pattern** as the **raw egg** when dropped unprotected from a 7-foot height. This means a hard boiled egg makes a **good test dummy** for evaulating the damage that a raw egg would see. **Same weight, same shell fracture toughness**... just not as much mess because the egg is solid.

WHAT CAUSES ALL THE MESS?
WHAT'S THE KEY FACTOR IN A COLLISION?

Okay, so you can stop now if you want... but isn't this fun? Don't you *want* to learn more?

Can you make some guesses about how to **increase** the amount of damage to an object? Or **decrease** it?

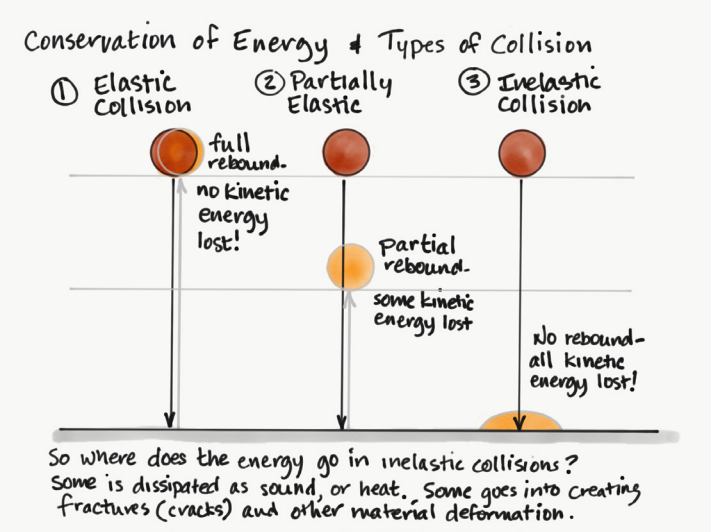
- What do you think would happen if you *increased* the **drop height**? Would the damage increase? Why?
- What do you think would happen if you *decreased* the **drop height**? Would the damage decrease? Why?
- What do you think would happen if you *changed* the **impact surface**? What if you dropped the egg onto **grass**? Or a **pillow**? Would the damage decrease? Why?
- What do you think would happen if you could make the egg **lighter**? Or **heavier**? Why?

A *guess* is called a *hypothesis* by scientists and engineers. Sounds cooler than guess, right? Engineers come up with theories, or hypotheses about how things work, then they do tests to see if they were right.

Let's say we wanted to test the effect of **drop height** and **weight** on **damage**. Can you think of some tests we could do? We're not limited to using eggs for this test... we just want to learn about collision damage.

Read on for some ideas you can try. *It will help if you have a digital scale to compare weights for this next part. But, it's not essential.*

VELOCITY AT IMPACT = THE SQUARE ROOT OF 2*G*H (H=HEIGHT OFF GROUND, G=GRAVITATIONAL CONSTANT) INCREASED HEIGHT = INCREASED VELOCITY AT IMPACT = MORE ENERGY = MORE POTENTIAL FOR DAMAGE BUT... MORE MASS ALSO INCREASES THE ENERGY AND POTENTIAL FOR DAMAGE



TYPES OF COLLISIONS

If you have a rubber bouncy ball and drop it, the ball will bounce to nearly the same height... a **mostly elastic collision**.

In a **completely inelastic collision**, there is **NO rebound**, and **all the kinetic energy is lost**. Where does all that energy go? Some of it goes into **sound** (you can hear the impact), some is dissipated as **heat**, and some goes into **material changes**, like forming cracks and new fracture surfaces... it takes energy to turn that egg into mush!

Damage is a function of momentum lost, and **momentum** = **mass** times **velocity**.

So, you can reduce the momentum of a system by reducing its **mass** (weight), or by reducing its **velocity** (speed) – or both!

For an object dropped from a vertical height, we can calculate the Potential Energy as a function of its height off the ground. Just before it hits the ground, all the potential energy is converted to kinetic energy, and we can calculate the velocity at impact as a function of the object's height, and the gravitational constant.

So, the greater the height, the greater the velocity at impact.

3 TYPES OF ELEMENTS IN A MECHANICAL SYSTEM

MASS, SPRINGS, AND DAMPERS

So how does most packaging work to protect the items inside?

There are 3 types of elements in a **mechanical** system (a *translational* system, as opposed to a *rotational* system, which is slightly different).

- **Mass** (our egg)
- **Spring** (energy storage devices)
- **Damper** (energy dissipators)

Springs are things like rubber bands–they can store energy and release it later. The force transmitted by a spring is equal to its **spring constant**, multiplied by the amount the spring **changes in length**.

Dampers dissipate energy through some sort of deformation and/or heat generation. The force transmitted by a damper is equal to the **damping coefficient** times the **velocity**, and always acts in the opposing direction... so **dampers will reduce your velocity**, too!

Cotton balls will compress when squished... energy dissipated by deformation. Most padding used in packaging can absorb the shock of impact by deforming slightly... so that shock is not passed on to the surrounding material. Bubble wrap uses pockets of air that compress when deformed... when you compress air, you generate heat. Small amounts of compression = small amounts of heat generated.

Look around you. What types of protection can you notice? Are they springs or dampers?

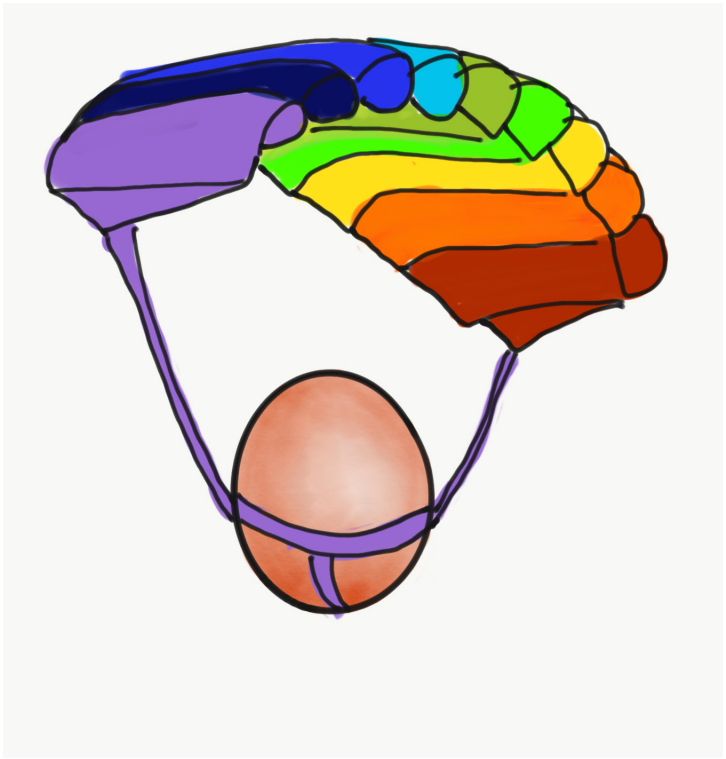
- What types of protection have you seen in packages shipped to your house?
- What types of protection are used in a bike helmet?
- Do your gym shoes have cushioning to absorb some of the shock from running and jumping? That's a type of protection, too.

Look around to get some ideas of cushioning or protection that you can use in your egg drop device. Try as many as you like. Are some better than others? What are some ways you could test this?

A) DAMAGE TO HOLLOW EGG AFTER IMPACT

B) HOLLOW EGG SHOWING HOLE IN BACK USED TO DRAIN EGG

C) DAMAGE TO RAW EGG AFTER IMPACT



REDUCING THE MASS OF YOUR SYSTEM

This isn't a valid option for our Egg Drop Challenge, but it shows the impact that reducing the mass (or weight) of your system can have.

Just for fun, I made a hole in a raw egg to remove the yolk and egg white. It was harder than I thought it would be... I had to enlarge the hole (figure b, bottom left) to get the egg out. When I dropped it, I got the characteristic ring of cracks (figure a, top left), but the cracks were not as extensive as observed for the raw egg (figure c, bottom right), or the hard boiled egg as shown on page 3.

Damage is a function of momentum lost, and momentum = **mass** times **velocity**.

In this example, the velocity was held constant, but I reduced the amount of fracture damage done to the egg shell from the fall, by first reducing the **mass** of the egg... (of course I had to damage the egg first to remove the mass!)

So, lower mass = lower momentum = less damage.

REDUCING THE (VERTICAL) VELOCITY OF YOUR SYSTEM

This IS a valid option for our Egg Drop Challenge, but you have to find a way other than reducing the drop height.

Two objects dropped from the same height will hit the ground at the same time... unless **air resistance** is a major factor due to the shape and weight of the object.

Parachutes, gliders, and paper airplanes are all examples of objects that use shape (and a little horizontal velocity) to use air currents to slow their descent.

Dampers will also act to reduce the impact velocity around your **mass** by **dissipating energy**.

SHARE PICTURES / VIDEO OF YOUR EGG DROP EXPERIMENT!

Want a chance to win a copy of my book, *Putney and the Magic eyePad?*

Visit the egg drop page on my website:

https://putneydesigns.com/egg-drop/

Scroll down to the bottom of the page where it says: **"Submit a photo or video of your experiment,"** and complete the form to the left.

Note: If you are under 13, you must have a parent or guardian submit this information on your behalf.

By submitting this information, you affirm that you have permission to submit this photo or video, and give me permission to post this on my website.

Address is only required if you want a copy of my book. I will email you if your entry is selected.

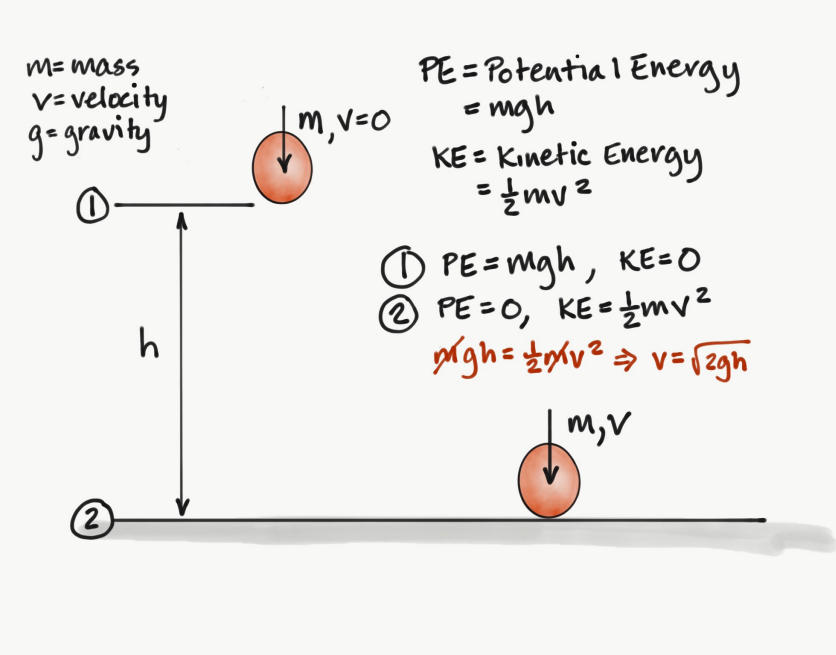
Good luck!

Five winners will be chosen from the entries submitted by June 30th, 2020.

What egg protection system will you dream up?

I can't wait to hear about your experiment!

Have fun!



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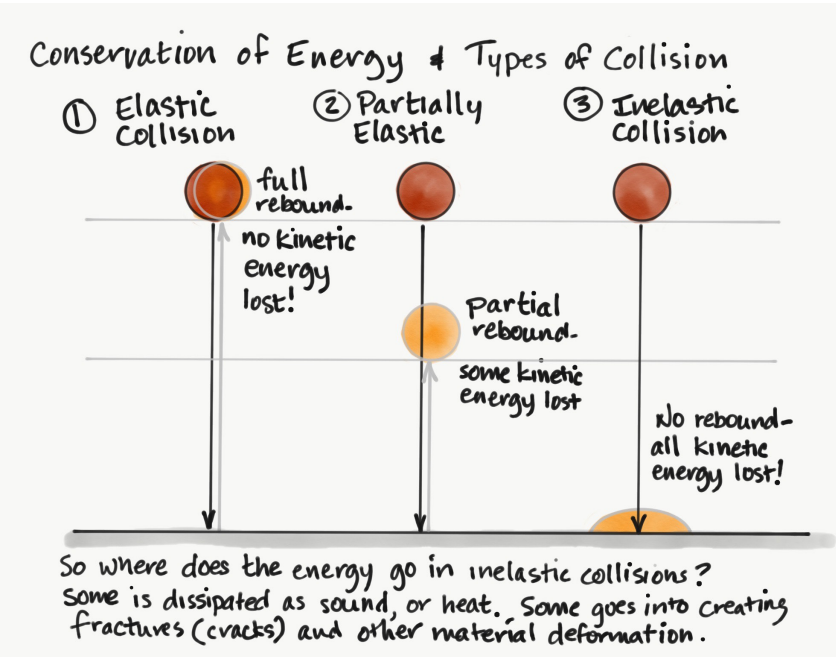

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CONSERVATION OF ENERGY

Let's talk about conservation of engergy for a moment. When we lift our egg to a height, h, above the ground, it has a **Potential Energy**, **PE=mgh** where:

m=the mass of the egg (think weight)
g=the gravitational constant (32.2 ft/s^2)
h=the height above the ground

When we release the egg, some of that potential energy is converted to **kinetic** (moving) **energy**, **KE=0.5 mv^2 where:**

v=the **velocity** of the egg (think speed)

(The superscript, 2, means that v is multiplied by itself, v^2 =v x v... in engineering equations, multiplication is implied, so mgh = m x g x h)

Just before the egg hits the ground, all the potential energy is converted to kinetic energy, so **mgh=0.5mv^2. Solving for velocity gives the square root of 2gh.**

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