STEM Explore, Discover, Apply (STEM EDA) is designed as a three course progression through STEM (science, technology, engineering, and mathematics) topics. Students begin by exploring STEM concepts (STEM Explore, 6th grade), then transition to discovering fundamental concepts (STEM Discover, 7th grade), followed by the application of the concepts (STEM Apply, 8th grade). Throughout each course in the sequence, the engineering design process guides the students through the design and implementation of the projects and concepts.

STEM EDA engages middle school students through a series of hands-on projects that help improve their problem-solving and critical-thinking skills. All projects seamlessly integrate the engineering design process which allows students to creatively explore STEM through design.

This multi-grade level curricula utilizes liberal arts disciplines to provide meaning and depth to the content. Through STEM EDA, students develop invaluable skills focusing on leadership, team-building, creativity, and communication.

STEM EDA’s modular nature provides ultimate flexibility to schools. Teachers can implement the curricula as a standalone elective course, insert specific modules into an existing class, or provide the modules as an after school program.

Goals of Course

- Foster excitement for STEM
- Develop a level of exploration in middle school students through STEM projects
- Provide a context for the engineering design process through “classic” STEM projects
- Drive towards fundamental concepts (at the grade appropriate level) through STEM experiences
There is an energy here that is very contagious!

My students are motivated and excited to come to school and work on this module.

Students who were unmotivated and uninvolved are now key players in their small groups and have found an interest in academics they didn’t think they had.

-Middle School Teacher

A Few Things You Will Notice

The stop sign indicates the end of a section and is a good/suggested stopping place. This symbol is visible in both the student edition and the teacher manual.

Cyber Pop Outs connect the STEM topic to the cyber world.

This material is based upon work supported by the U.S. Department of Homeland Security under Grant Award Number, 2013-PD-127-000001, Modification #2. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.
The process contains overarching themes as well as defined steps. Use the process as a quick reference throughout the module.

- **Iteration** – Revisiting steps provides the opportunity to improve upon designs.
- **Communication** – Within a design team, communication is essential to reach an agreement on a solution.
- **Teamwork** – Group cooperation provides diverse perspectives and help in accomplishing goals.
- **Creativity** – STEM and liberal arts disciplines are integrated to encourage unique solutions.
- **Imagination** – Opportunity to apply creative thoughts during development offers unlimited options.
### Materials List

All materials can be purchased at your local Superstore or Discount Department Store unless otherwise mentioned.

#### Per Class

<table>
<thead>
<tr>
<th>Materials</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scissors</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>Markers</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>Rulers</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>Calculators</td>
<td>School Supplies or Office</td>
</tr>
</tbody>
</table>

#### Per Team

<table>
<thead>
<tr>
<th>Materials</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Cotton Balls</td>
<td>Pharmacy or Cosmetics</td>
</tr>
<tr>
<td>60 Centimeters of tape</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>5 Rubber bands</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>5 Paper clips</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>1 Sheet of cardstock</td>
<td>School Supplies or Office</td>
</tr>
<tr>
<td>2 Foam cups <em>(minimum 8.5oz.)</em></td>
<td>Grocery</td>
</tr>
<tr>
<td>2 Foam bowls</td>
<td>Grocery</td>
</tr>
<tr>
<td>1 Meter of toilet paper</td>
<td>Grocery</td>
</tr>
<tr>
<td>30 Straws</td>
<td>Grocery</td>
</tr>
<tr>
<td>1 Large egg <em>(purchased near Egg Drop test date)</em></td>
<td>Grocery</td>
</tr>
<tr>
<td>40 Centimeters of twine</td>
<td>Crafts or Hardware</td>
</tr>
<tr>
<td>1 Plastic egg <em>(to be used as a substitute for the real egg during construction)</em></td>
<td>Seasonal</td>
</tr>
<tr>
<td>Fill to make the plastic egg weigh 60g <em>(marble, sand, sugar, salt, etc)</em></td>
<td></td>
</tr>
<tr>
<td>Scale to weigh plastic egg with filler</td>
<td><strong>Additional materials may be provided at the teacher's discretion</strong></td>
</tr>
</tbody>
</table>

*Can be purchased online from Amazon.com or similar site*
Let’s jump right in! For this class, we will build vessels that will hold real eggs. The goal is to design the vessel so the egg will survive a fall from a specified height.

**SECTION 1: BUILDING VESSELS**

Materials for Each Team

- 25 Cotton balls
- 60 Centimeters of tape
- 5 Rubber bands
- 5 Paper clips
- 1 Sheet of cardstock
- 2 Foam cups (minimum 8.5 ounces)
- 2 Foam bowls
- 1 Meter of toilet paper
- 30 Straws
- 1 Large egg (purchased near Egg Drop test date)
- 40 Centimeters of twine
- 1 Plastic egg (to be used as a substitute for the real egg during construction)
- Filler to make the plastic egg weigh 60 grams (marble, sand, sugar, salt, etc.)
- Scale to weigh plastic egg with filler

**Additional materials may be provided at the teacher’s discretion.**

Construction Tools and Other Supplies

- Scissors
- Markers
- Rulers
- Calculator

**A VESSEL... WHAT IS THAT?**

A vessel is a container for holding something. In our case, that “something” is an egg!
Restrictions

- You are ONLY allowed to use the materials listed in the materials section and any other materials provided by your teacher. Construction tools are not included in the allowed materials.
- Your vessel must fit within a 30 cm x 30 cm x 30 cm box. If the vessel is too large, you will have to remove some materials, making it fit within the dimensions.
- You cannot put any adhesive material (e.g., tape) directly on the egg.
- You cannot alter the egg’s state in any manner (e.g., boil the egg, paint the egg, etc.).
- You ONLY have the time in this class to build your vessels. The drop WILL occur during the next class.
- You must be able to insert the real egg into your vessel without taking apart any portion of your vessel. For example, if you take out any cotton balls when putting the real egg into your vessel, the cotton balls will have to remain out of the vessel. Access to the egg is essential!

Additional Notes

- Plastic eggs will be provided to guide in the design of your vessel.
- Filler such as a marble, sand, sugar, salt, etc. will be placed inside the plastic egg to simulate the weight of the real egg. You may include the plastic egg and the filler in your final design.
- Large eggs will be used.
- Real eggs will be provided by your teacher on the day of the drop. Keep in mind when designing the vessels you will need to replace your fake egg with a real egg. In other words, do not permanently enclose the fake egg in your vessel.
- Be creative!
Now it is time to test the vessels. We will go to a specified location and drop each vessel from a given height. Before we do any testing, let's look at each other's designs.

Each team must present their vessel design in front of the class. Use the following questions to guide your presentations. Presentations will be about three minutes each. Take ten minutes to answer the questions and prepare to present.

Describe your vessel design (e.g., materials used, shapes, size, method of building, etc.).

Why did you choose the design?

What do you think is the weakest part of the design?

How might the egg crack?
During the Vessel Testing

Be sure to **pay close attention** to what happens as the vessels are dropped and make contact with the ground. Use the questions below to record what you observe during the testing of your vessel.

Did your egg survive the fall?  

If your egg survived, how did your vessel design keep the egg from cracking?  

If your egg cracked, what part of the vessel failed?  

What are three things you would change/improve on your vessel design even if your egg survived?  

1.  
2.  
3.  

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SECTION 3: ENGINEERING DESIGN PROCESS

**What is the Engineering Design Process?**

The engineering design process is a methodical process used by real engineers to aid in design.

**THE PROCESS CONSISTS OF THE SEVEN STEPS:**

1. Identify the Problem
2. Research the Problem
3. Brainstorm Solutions
4. Choose a Solution
5. Create and Develop a Prototype
6. Test and Evaluate the Prototype
7. Improve and Redesign

**WHAT IS A PROTOTYPE?**

A prototype is the initial full-scale design created or constructed to serve a functional purpose.
How do you think following each step of the engineering design process can help us with the design of our vessels?

Circle the steps in the process that you used for your design.

What step did you start with for your vessel design?

Do you think you were prepared to start where you did?

If you were not ready, it is okay! Since Step 7 is “Improve & Redesign” and the process is iterative, we can redesign our vessels starting at Step 1!
The process contains overarching themes as well as defined steps!

- Iteration
- Communication
- Teamwork
- Creativity
- Imagination

WHAT DOES ITERATION MEAN?
Iteration means the process involves repetition.

Why do you think **iteration** is important to the design process? ____________________________

Why do you think **communication** is important to the design process? ________________________

Why do you think **teamwork** is important to the design process? ____________________________

Why do you think **creativity** is important to the design process? ____________________________

Why do you think **imagination** is important to the design process? ____________________________
You are going to become very familiar with the engineering design process. The process will guide you throughout all the projects in this course. Instead of only talking about the engineering design process, let’s put it to practice. Now, you will experience the process first hand. Let’s try the egg drop project again, starting at Step 1 of the engineering design process!

What is the first step?

Before engineers begin any design project, they must first understand what they are trying to accomplish. To understand, they must define exactly what the problem is. Once the problem is identified, they can always refer back to the problem statement to ensure they are staying on course while trying to solve the problem.

Why do you think it is good to clearly identify the problem at the beginning of design?

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Before identifying the problem, look back at the project instructions. You will build vessels that will hold real eggs. The goal is to design the vessel so the egg will survive a fall from a specified height. You can refer back to the first few pages of the workbook for materials, construction tools, restrictions, and additional notes on the project.

Now that you reviewed the project instructions, start identifying the problem! Use these first few questions to help you identify the problem.

What do you have to design?

What are you trying to accomplish with the project?

What restraints do you have?

Write a sentence or two that identifies the problem.
Why do you think anyone would want to drop an egg off a building in hopes that it would not break? How often do you think an egg is dropped off a building? Probably not very often, but what if the egg symbolizes something else? Many times engineers perform experiments with objects that represent other things. This way they can visualize what will happen in the real scenario. Our egg dropping from the building can represent a variety of scenarios.

What do you think the egg drop represents? ____________________________________________

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The egg could represent a stuntman jumping from a building. In movies, there are people that have to perform dangerous stunts for the actors. They have to safely do things like walk through fire, drive cars fast, and even jump out of buildings.

The stuntman should test out his safety gear. By making smaller models of his gear (the vessel), he can use the egg to represent himself in the jump from the building.

Re-identify the problem with this new context for the egg drop. Remember the process is iterative.

Write a few sentences that identify the problem. ____________________________________________

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Now that the problem is defined, move to the next step in the engineering design process. You must **research the problem**. In order to create a successful design, you must research the factors that influence the success or failure of the design. As a class, you will explore some fundamental concepts that affect the design of your vessels.

**What is making the vessel fall?**
*Why does the vessel not just float in the air after we release it?*
*What causes it to fall towards the ground?*
*Any ideas? It falls because of gravity!*
*What is gravity?*

Wait, so what is gravity? Try to explain gravity in your own words. 

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It is time to do research on gravity! Many times engineers, scientists, and others try to get as much information as they can on a topic to fully understand it. Reading articles is a good way to perform research and build a better understanding.

Your teacher will give you an encyclopedia article or an internet source on gravity. Spend the next ___ minutes reading the article. Highlight information that will help you understand these concepts. When time is up, everyone will share what they read with the class. Use the given lines to help organize your thoughts.

List three things you learned from the article(s) that impact/relate to your vessels.

**Topic: Gravity**

1. 
   
2. 
   
3. 

Learn from your classmates! Use the lines provided to list information that your classmates learned from the articles that you may have missed.

1. 
   
2. 
   
3. 

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Isaac Newton, a famous scientist, developed the law of gravity. Newton knew from Galileo, also a famous scientist, that as objects fall to the ground, they typically hit the ground at the same time. He wanted to know why this happened.

Why do you think the two objects hit the ground at the same time? ________________

After experimentation, Newton discovered that objects hit the ground at the same time due to the same force acting on both objects. He noted that this happened every time for objects within a vacuum.

Falling objects not in a vacuum can be affected by the air and other outside forces. However, for our vessels, these outside forces will be so small that we can ignore them!

**WHAT IS A VACUUM?**

Does that mean objects are in a vacuum cleaner?

No, a vacuum is space entirely void of matter (e.g., no air, dust, or any other particles).

**Try It Yourself**

Pick up two dissimilar items (items that are not the same) and drop them from the same height (waist high is fine) and see which hits the ground first. Be sure to hold the objects directly parallel with the ground and release them at the exact same time.

What happened? They should have hit the ground at the very same time! Neat, right?! Remember, two very different objects fall at the same rate and hit the ground at the same time. Newton discovered that the objects fell at the same rate due to the same force acting on the objects.

He called this force gravity, which we have defined earlier as a force that is responsible for interactions between objects (in our case, the falling objects and the ground). Through experimentation, Newton was able to quantify (find a number for) the force. He found that objects fell at a rate of 9.81 meters per second per second.
Okay, that is weird, meters per second per second? What does that mean? Look at it part by part. What are meters per second and what is that measuring?

Speed, but not really speed! Generally we say speed, but when we have a direction associated with the speed, the scientific term is velocity! Velocity is distance per time with direction.

Meters per second identifies how fast an object is moving. It measures the distance an object travels over the time it took to travel the measured distance.

Velocity per second measures how fast the velocity is changing. Think about it like this…

**Velocity Example**

When adults drive a car, they travel at a certain velocity. They might travel 50 miles per hour; however, when they start driving, they are not immediately going 50 miles per hour. Drivers have to accelerate (increase) their velocity to get up to 50 miles per hour. They see this acceleration by the needle on the speedometer (dial that tells the driver how fast they are going) in the dashboard of the car. The velocity at which the dial moves is showing the velocity of the car per time or more generally, distance per time per time (i.e., meters per second per second).

Okay, so how does this car example apply to falling objects?

Well, Newton observed that the distance per second per second, also known as acceleration, is constant for falling objects at a rate of 9.81 meters per second per second, which is written $9.81 \text{ m/s}^2$. He called this constant rate the *gravitational acceleration*, because the force of gravity pulls the objects towards the earth at that rate. We can use the gravitational acceleration to better understand the behavior of our falling vessels.

However, Newton did not stop there. He did not just discover the acceleration of a falling object due to gravity, but he wanted to fully understand this idea of gravity and acceleration. Newton performed even more experiments and found guiding principles for objects in motion. These principles are called *Newton's Laws of Motion*. 
Before continuing our discussion on Newton’s Laws of Motion, it is time to do a little more research on the concepts Newton had to research himself!

Your teacher will give you an encyclopedia article or an internet source on mass versus weight, then you will get an article on motion. Spend the next _____ minutes reading the first article provided by your teacher. Highlight information that will help you understand these concepts. When time is up, everyone will share what they read with the class. Use the given lines to help organize your thoughts.

List three things you learned from the article(s) that impact/relate to your vessels.

**Topic: Mass vs. Weight**

1. 

2. 

3. 

Learn from your classmates! Use the lines provided to list information that your classmates learned from the articles that you may have missed.

1. 

2. 

3. 

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Now, spend the next _____ minutes on the article about motion.

List three things you learned from the article(s) that impact/relate to your vessels.

**Topic: Motion**

1. ____________________________________________________
2. ____________________________________________________
3. ____________________________________________________

Learn from your classmates! Use the lines provided to list information that your classmates learned from the articles that you may have missed.

1. ____________________________________________________
2. ____________________________________________________
3. ____________________________________________________
Newton actually developed three laws of motion, but we will look more specifically at the second law.

**Newton’s Second Law of Motion**

**states:** Acceleration of a body depends on the amount of force acting upon it as well as the mass of the body.

Newton developed a mathematical expression that represents this idea. The expression shows that the force (F) acting on a body is equal to the mass (m) of the body multiplied by the acceleration (a) of the body.

\[ F = m \times a \]

How do you think we can apply this information to our project?  

We can use this information to determine the amount of force acting on our vessels as they hit the ground.
For this module we focus on protecting the fragile egg inside your vessel. We could also consider the information on our computers and the information we share as fragile and in need of protection. Did you know there are some simple practices you can do at home to keep your PC safe and your data protected?

Many laptops and computers already have protective software installed. A quick check of your computer can help you uncover just how vulnerable you actually are to outside intrusion.

Just like your egg, keeping your data safe from outside forces is extremely important. Watch this short video then write a checklist, persuasive paragraph, or list of questions you can present to your parents to assess how healthy or safe your personal computer is.

https://www.youtube.com/watch?v=U4lweHnf71E

It is time to go deeper into the idea of \( F = m \times a \). This expression is saying the force acting on an object can be found by multiplying the acceleration of the object by the mass of object.

What is the object in this project? ____________________________

Do you know what the acceleration of the object is? ____________________________

If so, what is the acceleration ____________________________

What about the mass? We do not know the mass yet, but can you find it? ______________

How can you find the mass? ____________________________

Great! So after you finish building your prototype vessels, you can calculate the force acting on them when they hit the ground.

How does the force affect this project when the vessels hit the ground? Does that force mean anything?

How do you think force relates to your vessel design? ____________________________

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______________________________

If the acceleration is constant at 9.81 m/s\(^2\), then the smaller the mass of the vessel, the ______________ the force will be.

**Try It Out**

\[ F = m \times a \]

If \( m = 100 \text{ kilograms (kg)} \) and \( a = 9.81 \text{ m/s}^2 \) then

\[ F = (100 \text{ kg}) \times (9.81 \text{ m/s}^2) = 981 \text{ kg x m/s}^2 \]

But if \( m = 10 \text{ kg} \) and \( a = 9.81 \text{ m/s}^2 \) then

\[ F = (10 \text{ kg}) \times (9.81 \text{ m/s}^2) = 98.1 \text{ N} \]

**FORCE**

A unit of force in the metric system is a kg x m/s\(^2\), which is called a Newton after Isaac Newton. It is usually represented as N.
How does the mass of the vessel affect the design? ____________________________

Our vessels must be designed to withstand the force acting on them when they hit the ground. How can we combat the force acting on the vessels so the egg inside each vessel does not crack? Any ideas? ____________________________

When the vessel hits the ground, the force acting on the body multiplied by the distance the body moves after impact is the energy released by the vessel. The energy can be directed through the vessels so the vessel takes the brunt of the force and the egg inside remains unaffected. How does this happen? How can we design our vessels to absorb the energy and leave the egg unharmed? You can use materials that help in the process of dissipating (scattering) the energy away from the egg. What sort of materials do you think will do that?

Think about a car. Cars are designed to do the exact same thing you want your vessels to do. Cars are designed to withstand impact while keeping the person/people inside safe.

How do cars withstand impact and keep passengers safe? ____________________________

How can this apply to our vessels? What materials will help the egg withstand the impact?
Now that you have researched the problem and explored the various factors that affect the design of your vessel, it is time to brainstorm possible solutions.

**SECTION 6: BRAINSTORMING SOLUTIONS**

What is brainstorming? Does that mean there is a thunderstorm inside your brain?! NO! Brainstorming is a technique that engineers and others use to develop a list of possible solutions to a problem.

**RULES FOR BRAINSTORMING:**

- No idea is a bad idea
- Do not criticize each other’s ideas
- Build on each other’s ideas
- Be creative

Why do you think these rules are important? Pick one of the rules for brainstorming and write why you think it is important.

It is time to practice brainstorming! As a class, think of possible ways you can help keep the environment safe and healthy. Take ______ minutes to write your ideas in the space below.

Then everyone will share their ideas with the class.
Since you have such a good foundation in the research, you will have the additional challenge of creating your vessel with less material than the first time around! The new materials list is as follows, and the same construction tools, restrictions, and additional notes apply.

### Materials for Each Team

- 15 Straws
- 30 centimeters of tape
- 15 cotton balls
- 1 foam cup
- 1 foam bowl
- 1 plastic egg (used as a substitute for the real egg during construction)
- 1 meter of toilet paper
- 1 sheet of cardstock
- 5 paper clips
- 5 rubber bands
- 30 centimeters of twine
- 60 grams of filler weight inside plastic egg (to simulate weight of the real egg)

As a team, begin brainstorming ideas for the new vessel design. Remember, no idea is a bad idea; do not criticize each other’s ideas; try to build on each other’s ideas; and be creative! Ideas can be improved versions of your first vessel design or completely new designs. Use the following pages to brainstorm.
Brainstorm Idea 1

Materials to use: __________________________________________
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Description of design: __________________________________________
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How does this design reflect the research in Step 2? ______________
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On the next page, sketch a picture of your design. Use the grid lines on the engineering paper to help form the drawing.
Brainstorm Idea 2

Materials to use: __________________________________________
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Description of design: __________________________________________
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How does this design reflect the research in Step 2? __________________________
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On the next page, sketch a picture of your design. Use the grid lines on the engineering paper to help form the drawing.
Brainstorm Idea 3

Materials to use: ____________________________________________________________
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Description of design: ______________________________________________________
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How does this design reflect the research in Step 2? ____________________________
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On the next page, sketch a picture of your design. Use the grid lines on the engineering paper to help form the drawing.
Brainstorm Idea 4

Materials to use: ____________________________________________________________
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Description of design: _______________________________________________________ 
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How does this design reflect the research in Step 2? _____________________________
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On the next page, sketch a picture of your design. Use the grid lines on the engineering paper to help form the drawing.
Brainstorm Idea 5

Materials to use: ________________________________________________

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Description of design: ____________________________________________

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How does this design reflect the research in Step 2? ___________________

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On the next page, sketch a picture of your design. Use the grid lines on the engineering paper to help form the drawing.
Each design team should now have brainstormed at least five ideas. It is time to choose the actual design solution.

How do you begin to choose the final design solution? You need to look over the brainstormed ideas and determine the best one, keeping in mind the best idea might be a combination of your brainstormed ideas.

First, look back at your brainstormed ideas. Choose your top three that you feel will provide the best vessel. Remember the research in Step 2 to help you choose the top three.

Top three brainstorm ideas: ____________________________________________

Each team will weigh the pros and cons of their top three ideas. Look at each one individually and list the features that are positive and the features that are negative. This process will help in determining the best design.

WHAT ARE PROS AND CONS?
Pros are the positive (good) features.
Cons are the negative (bad) features.
### Brainstorm Idea # ______

**Pros:**
List the strengths of this design.

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**Cons:**
List the weaknesses of this design.

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How does this design neglect (not include) the research in Step 2?

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Do you think the egg will survive in this vessel? ____________________________
Brainstorm Idea # ______

**Pros:**
List the strengths of this design.

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**Cons:**
List the weaknesses of this design.

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How does this design incorporate (include) the research in Step 2?

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Do you think the egg will survive in this vessel? _____________________________
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Looking at the pros and cons of the top three design ideas, it is time to decide which design will be the actual vessel used in the experiment.

Analyze the pros and cons list. Look at the strengths and weaknesses of each design. Is there a combination of the designs that provides a better vessel?

Use the space below to finalize your vessel design.

Materials to use: 

<table>
<thead>
<tr>
<th>Material 1</th>
<th>Material 2</th>
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Description of design: 

How has your design changed throughout the brainstorming process? 

On the next page, sketch a picture of your final design. Use the gridlines on the engineering paper to help form the drawing.
SECTION 8: CREATING & DEVELOPING A PROTOTYPE

It is time to start building our prototypes! Remember, a prototype is the initial full-scale design created or constructed to serve a functional purpose.

As you are building your prototype over the next few days, you might want to revisit some of the earlier steps in the design process. You may need to go back to the brainstorming phase and develop a new design idea. That is okay. The next few pages in this workbook are left open for you to sketch, make notes, and document the process of creating and developing your vessel prototype.

Notes:

________________________________________________________________________
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Create & Develop a Prototype
Thinking Space

Additional Notes

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Take a break from the engineering design process and do some creative writing. You know the context for the egg drop is a stuntman falling from a building; use your creative writing skills to tell a story about your stuntman.

Use the following questions to guide your story. Write down your initial thoughts. Afterwards you will put these thoughts together to create a story!

Why is the stuntman falling? ________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

What is the atmosphere like around the stuntman (e.g., is the building on fire; are there a lot of people around him; etc.)? ________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

How does the stuntman feel as he falls? ____________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

How will the safety apparatus (your vessel) save the stuntman from getting hurt? Describe your vessel in terms of it being a safety apparatus. _______________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

CREATIVE ELEMENT
Stuntman Story

Use the following lines to write your story about the stuntman. Remember to use complete sentences and proper grammar.
It is almost time to test and evaluate your prototype vessels. Before you test the vessels, you can determine the force that will act on the vessels when they hit the ground.

Remember from Step 2, the class found out that the force acting on the vessel is equal to the mass of the vessel multiplied by the acceleration.

What was the acceleration? ____________________________________

You should note that units are very important. You need to use the same type of units throughout your calculations. In metric (or SI units) the acceleration due to gravity is 9.81 m/s², but what is that value in non-SI units (English units)?

9.81 m/s² converts to 32.2 ft/s²

If you are converting your calculations into English units, then you want to use the acceleration due to gravity as 32.2 ft/s². However, base your calculation on SI units. You want to measure the mass of your vessel in terms of kilograms.
Each group should measure the mass of their vessels. What is the mass of your vessel without the real egg? Be sure to take the plastic egg out of the vessel when you measure the vessel's mass if you are not planning to keep the plastic egg in the vessel during the drop.

- What is the mass of the vessel without the real egg? _____________________________
- What is the mass of the real egg? _____________________________
- What is the mass of the vessel with the egg? _____________________________

The units of force are Newtons (N). A Newton breaks down to be a kg x m/s², however, our mass is in grams (g). We need to convert the mass of our vessel and egg into kilograms (kg). Use the space below to convert the mass of your egg from grams to kilograms.

Mass of vessel with egg in kilograms = _____________________________

Now that the mass has been determined, calculate the amount of force the vessel will receive when it hits the ground. Use the space below to make your calculation. Remember force (kg x m/s²) in SI units is called a Newton and is represented as N.

Force = _____________________________
Presentations

Each group must present their vessel to the class. Take a few minutes to plan your presentation. Each presentation will last approximately three to five minutes.

Use the reasons from Step 4: Brainstorm Solutions and any adjustments made in Step 5: Choose a Solution to describe your design.

Explain to the class why you chose the design, including how it incorporates the information from Step 2: Research the Problem.

Discuss how a stuntman would be safe in your design.

Describe what you feel is the weakest part of the design.

What is the force that will be exerted on the vessel at impact?
Before testing your vessel, discuss velocity and how you can find your vessel’s velocity (speed) as it falls.

Remember, acceleration is constant at 9.81 m/s², which is a measure of how fast the velocity of the vessel falls. Remember, velocity is measured by the distance that the falling object travels divided by the time it travels that distance in a certain direction.

\[ \text{Velocity} = \frac{\text{distance traveled}}{\text{time}} \]

So how can you determine the velocity of your vessels? You can measure the time it takes to fall from the specified height. Divide the height by the time and you will get the speed (distance per time) of your falling vessels.

What is the direction of your falling vessel? _______________________________________

Each group will calculate the velocity of their falling vessels. On the next page is a sheet that will guide you through this calculation.

Remember, the process of design is never finished! There is always room for improvements to your design. For example, developers are quickly releasing multiple cell phone versions each year because they are constantly learning how to better the designs. Hence, evaluating the performance of your vessel is crucial.

During the testing, in addition to timing how long it takes your vessel to fall, be sure to pay close attention to what happens as the vessels are dropped and make contact with the ground.
SECTION 11: TESTING AND EVALUATING THE PROTOTYPE

What was your vessel’s velocity? Calculate your answer in the box below. Remember velocity has units of distance per time (in SI meters per second of m/s).

\[
v = \frac{\text{distance traveled}}{\text{time to travel distance}}
\]

Velocity =

Did your egg survive the fall? 

If your egg survived, how did your vessel design keep the egg from cracking?

If your egg cracked, what part of the vessel failed?
SECTION 12: IMPROVING & REDESIGNING

It is important to take some time to reflect on the project. Looking at what happened during the testing and evaluation phase will help in improving and redesigning the vessels and understanding the concepts showcased throughout the project. Each team will share their thoughts on the project with the class.

Did your vessel have a higher or lower impact force compared to other teams? ____________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
How did force affect the outcome of the falling vessels? ______________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
If your egg did not survive, why do you think it cracked? _________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
If your egg survived, why do you think it did not crack? _________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
What are two things you would change/improve on your vessel design even if your egg survived?

1. 

2. 

How did the engineering design process help in designing your vessel? 