**What does Packaging Design have to do with Math?**

**Lesson Plan**

**Video:** <https://youtu.be/Ud4_chYvm2k>

**Teacher Note:** Please preview the entire video and pre-work the solutions in order to anticipate students’ needs, misconceptions and resources unique to your classroom.

You will also need to determine the background knowledge of your students regarding the following topics, and decide the best method for providing that background in order to support the conceptual understanding of the mathematics shown in the video.

* + Gravity
	+ Impact
	+ Velocity
	+ Force
	+ Metric units
	+ US Customary Units

**Common Core Mathematical Content Standards**

* 5.MD Convert like measurement units within a given measurement system.
* 6.EE.2 Write, read and evaluate expressions in which letters stand for numbers.

**Common Core Mathematical Practice Standards**

1. Make sense of problems and persevere in solving them.

2. Reason abstractly and quantitatively

6. Attend to precision

**Company Information**

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**Summary**

How annoying is it when you open a package and the item inside is broken? Very! Package design engineers use mathematics and physics to help them determine the best way to get the package to you safely, and securely while taking into account cost and environmental impact. In this video students will begin the design process by calculating the impact velocity and impact force of a dropped object.

**Pre-Activity Discussion:**

* Discuss/review the process of converting between customary and metric units
* Vocabulary
	+ Impact Velocity
	+ Impact Forces
	+ Newton

**Differentiation:**

* Unit analysis could be used when solving the problems posed.
* Students may also benefit by working with others as part of a partner/group investigation.

**Part 1: (0:00 – 1:09)**

BREAK 1

* Have students brainstorm all the things to consider when designing packaging for an object, including what measurements they would need to know like weight of the object and height from which the object would be dropped.
* How would/could mathematics play a role in those considerations?
	+ One idea that will be expanded on in part 2 and 3 is how to determine the amount and density of cushion needed around the packaged object.
	+ The density of the cushion depends on the predicted impact velocity and the force of the impact.
	+ So, finding the impact velocity and force of impact is necessary to calculate at the beginning of the design process.
* Have students use part one of student handout to document their discussion.
* Share ideas whole group.
* Some possible solutions are shared in the video at the start of part 2.

**Part 2: (1:14 – 1:55)**

 BREAK 2

* In order to determine the amount and type of cushioning in our package design, we first need to know both the impact velocity and force created when the object is dropped.
* Problem posed:
	+ *What is the impact velocity of an object weighing 25 pounds and falling* ***4.5*** *feet?*
* Information given in the video.
	+ Formula for Impact Velocity = $\sqrt{2gh}$ (g = acceleration due to gravity and h = height)
	+ Weight of object = 25 lb.
	+ Height from which the object is dropped **= 4.5 feet** **\* Note that there is a typo in the video for this measurement at 1 min 50 sec and 2 min 6 sec. The answer shown in part 3 is correct**
	+ Acceleration due to gravity (g) = 384.4 inches per second squared.
	+ Note that units are not the same in the height and weight information given and the units that were used for gravity. This was done so that a conversion would be necessary in the calculations.
	+ **Students will also find the impact velocity in meters per second squared after Part 3.**
* Students should use their handout to record their problem solving methods.
* Before showing Part 3 have students share their answers and methods.
* Discuss any errors or misconceptions in student thinking and calculations.

**Part 3: (****2:00 – 2:35)**

 BREAK 3

* Remember - The density of the cushion depends on the predicted impact velocity and the force of the impact. We have the impact velocity in customary units, but now we need to find both the velocity and the force of the impact in metric units.
* Force is measured in a unit called a Newton
* Problem posed:
	+ *What is the impact velocity in metric units?*
		- Conversion factor needed 1 foot = 0.3048 meters
	+ *What is the impact force of the 25 lb. object?*
* Information given in the video
	+ Force = mass x acceleration
	+ Acceleration due to gravity in metric units (g) = 9.8 meters per second squared
	+ 1 pound = 0.454 kg
* Students should use their handout to record their problem solving methods.
* Before showing Part 4 have students share their answers and methods.
* Discuss any errors or misconceptions in student thinking and calculations.

**Part 4: (2:30 – 3:29)**.

* Answer to part 3 is shown
* Discuss with students why packaging design engineers must also consider cost and environmental impact during their design process.

**Extension:**

* How do package design engineers determine which material to use for which object they package? Investigate different types of cushioning material, it’s effectiveness, cost and environmental impact. Make a recommendation based on your research.
* Investigate the external packaging used by manufacturers. How is the external packaging designed? How does the corrugated box the object is in add to the security of the object? What are the thickness, and stability options for corrugated boxes?
* Have students design an effective packaging solution for a random breakable object, given specific perimeters. Have students run experiments to determine which package design was most effective. Is there a second option for packaging that would be more cost effective?

**Student Handout - *What Does Packaging Design have to do with Math?***

Name(s):

**Pre-Video Discussion:**  *Notes on important background information.*

**Break 1:**

1. Brainstorm all the things to consider when designing packaging for an object.

2. What math would you have to figure out as you work on package design?

**Break 2:**

3. What is the impact velocity of an object weighing 25 pounds and falling **4.5** feet?

 (show your solution methods and label your solution)

**Break 3:**

4. If we want our measurements to be in metric units. What would the impact velocity be in meters per second? (hint: 1 foot = 0.3048 meters)

*5*. What is the impact force of the 25 lb. object in Newtons?

**ANSWER KEY – What does Packaging Design have to do with Math?**

**Break 1:**

1. Brainstorm all the things to consider when designing packaging for an object.

 Answers vary

2. What math would you have to figure out as you work on package design?

 Answers vary

**Break 2:**

3. What is the impact velocity of an object weighing 25 pounds and falling **4.5** feet?

 (show your solution methods)

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V = $\sqrt{2\*386.4\* 54}$

 V = 204.28 in/sec

**Break 3:**

4. If we want our measurements to be in metric units. What would the impact velocity be in meters per second?

 V = $\sqrt{2\*9.8\*1.3716}$

 V = 5.1849 m/sec

*5*. What is the impact force of the 25 lb. object in Newtons?

 25 lb = 11.35 kg

 Force = 11.35 kg \* 9.8 meters per sec squared

 Force of impact = 111. 23 Newtons