Module Overview	
For grade level(s)	Middle School-6th to 8th grade High School-9th to 12th grade
Suggested Time	MESA Period: 3-5 weeks of daily 50-60 minute sessions MESA Afterschool: 4 total sessions of 60-90 minutes each MESA Saturday: 2 Saturdays for total of 8 hours
Purpose	The purpose of this unit is to reinforce or introduce the engineering design process to MESA students, while introducing students to principles of package engineering. Students will be prepared to build an egg drop container at the end of the unit that will achieve the greatest "surviving egg to total egg" ratio at the MESA Day competition.
Objectives	At the end of this unit students will: • Know the parts of the design cycle and relate them to an egg drop project • Critically analyze packaging materials and choose appropriate materials to complete their tasks • Solve problems related to energy • Solve problems related to surface area and volume • Understand the practical applications of the design process for students and for engineers • Build a competitive egg drop container for the MESA competition
Standards Addressed (Common Core and NGSS)	**Common Core Mathematics Standards** **Grade 6** ***Expressions and Equations 6-EE*** 6c. Evaluate expressions at specific values of their variables. Include expressions that arise from formulas used in real-world problems. Perform arithmetic operations, including those involving whole-number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations). For example, use the formulas V = s3 and A = 6 s2 to find the volume and surface area of a cube with sides of length s = 1/2. **Grade 6** ***Geometry 6-G*** 2. Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths, and show that the volume is the same as would be found by multiplying the edge lengths of the prism. Apply the formulas V = l w h and V = b h to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems.

Standards Addressed (Common Core and NGSS) Cont.	4 Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems **Grade 7 *Geometry 7-G*** 6. Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms. **Grade 8 *Geometry 8-G*** 9. Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems. ***Geometry Congruence G-CO*** 7. Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent. ***Geometric Measurement and Dimension G-GMD*** 3. Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems. ***Modeling with Geometry G-MG*** 3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios. **Next Generation Science Standards (NGSS)** ***PS Physical Sciences Middle School (6-8) MS-PS2-1*** Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.] ***MS-PS2-2*** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]

Standards Addressed (Common Core and NGSS) Cont.	***PS Physical Sciences High School (9-12) HS-PS2-1*** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.] ***HS-PS2-3*** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*[Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]
Assessment	Students will be evaluated through the following methods: • Assessment worksheets • Oral presentations with rubrics • Lab reports with rubric • Project testing and evaluation
Additional Resources	Free fall and the Acceleration of Gravity http://www.physicsclassroom.com/class/1dkin/u1l5b.cfm Newton's Second Law of Motion http://www.physicsclassroom.com/Class/newtlaws/u2l3e.cfm Glenn Learning Technologies http://www.nasa.gov/centers/glenn/home/index.html Momentum and Impulse Connection http://www.physicsclassroom.com/class/momentum/u4l1b.cfm Physics Net: Typical Values of Drag Coefficient http://www.ac.wwu.edu/~vawter/PhysicsNet/Topics/Dynamics/Forces/DragCoeficientValues.html

Background

Since the helmets worn by Roman soldiers thousands of years ago, to the pads worn by modern day football players, since the creation of bubble wrap and packing peanuts, to the inclusion of air bags in automobiles, protecting people and things has been important to society. It is in the area of packaging engineering that the science of protection is practically understood and applied. Although "package engineering" itself is not considered a formal branch of engineering, it borrows from various engineering disciplines, such as mechanical engineering, materials science and engineering and even chemical engineering. It is certainly an area that will continue to be relevant, as its applications (shipping, helmets, infant car seats, sport pads, etc.) continue to "impact" us greatly today.

For some relevant and current uses of packaging engineering, one can visit the following websites:

Sealed Air corporation: the makers and patent holders of "Bubble Wrap"
http://www.sealedairprotects.com/

UPS: description of their package engineering methods
http://www.ups.com/content/us/en/bussol/browse/package-engineering.html

Bell Helmets: Manufacturer of helmets for recreational use http://www.bellhelmets.com/cycling/

Information on the manufacturing of football helmets and NFL equipment management
http://entertainment.howstuffworks.com/fb-equip.htm

Car crash simulations and explanations of the physics of accidents and protection from the Insurance Institute of Highway Safety http://www.iihs.org/

Benefit To Society

The need to protect packages and objects in general is of great importance to our society. The shipping industry (UPS, FedEx, etc.), for example, must use packaging technologies that will successfully protect the wide myriad of items that they transport throughout the world. Essentially, any company that needs to ship products would need to consider carefully which packaging products and materials to use to safely protect their commodities

Perhaps more importantly, people need similar technologies to protect them in many areas and situations. Automobiles are one example of the use of these technologies to insure the safety of vehicle passengers. From the design and construction of a car's chassis and frame, to its ability to absorb the energy of impact, and the strategic placement and function of air bags inside car cabins, package engineering informs safety in automobiles. Another example is in the area of sports, as helmets and pads are worn by athletes in football and hockey especially and are essential in minimizing injury and long term bodily damage.

Engineering Design Process/Module Content

Engineers have to create a solution to a problem. The solution must fit into the given constraints for the problem. In the MESA program, we learn to engineer solutions that can relate to real world problems. The use of the engineering design process contextualizes this problem solving approach for students.

This unit is organized around 4 steps in the engineering design process: investigate, plan, create, evaluate, and then restart the process, over and over again until a viable competition-ready project is created. The unit begins with an introductory/ice breaker activity that leads students into the challenge to be addressed.

Organization of Module/Content

Introduction

Naked Egg Drop Activity as an icebreaker.

Step 1: Investigate

- Research egg drop projects online using search engines, or can begin with this link: http://www.science-ideas.com/egg-drop-project-ideas.

- Review relevant Physics/Mathematics Concepts with students (the complexity and depth through which these concepts are covered will vary by grade level and student math/science background, and is at the discretion of the instructor):

MOMENTUM

- Momentum & Impulse PowerPoint: use one of the following presentations to provide students with a conceptual understanding of the concepts.
  http://www.engr.ucr.edu/mesa/advisors/**Momentum_and_Impulse**.ppt
  http://batesvilleinschools.com/physics/PhyNet/Mechanics/Momentum/momentum_in_a_nutshell.ppt
- Conservation of Momentum Lesson:
  http://www.physicsclassroom.com/class/momentum/u4l2b.cfm and presentation:
  https://docs.google.com/presentation/d/1ijuUa5lC7LecXckOV3npgLH-WptRwZaZ8JVKOEatm1s/edit?pli=1#slide=id.p14
  and videos showing examples of the conservation of momentum:
  http://video.pbs.org/video/1607941500/ , http://www.our-space.org/materials/states-of-matter/momentum-in-space
- Momentum/Energy Lab http://www.flinnsci.com/Documents/PRpdfs/PS10871.pdf
- Momentum & Impulse Problems: test students' conceptual understanding of concepts.
  http://tuhsphysics.ttsd.k12.or.us/Tutorial/Lessons/Imp_and_Mom.html#Solutions

ENERGY

- Kinetic & Potential Energy PowerPoint: use the presentation to provide students with a conceptual understanding of the concepts. http://education.jlab.org/jsat/**powerpoint/energy**_forms_and_changes.ppt
- Energy Problems: test students' conceptual understanding of concepts. http://webs.rps205.com/curriculum/science/files/B394F7A6B21444F4816A38A22D45D036.pdf

DRAG

- "It's a drag" lab activity
- Another Drag lab/activity: http://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_airplanes/cub_airplanes_lesson05_activity1.xml

GEOMETRY: VOLUME, SURFACE AREA

- Interactive/on-line resources for explaining basic 3D figures and surface area/volume formulas (cube and cylinder)
- http://www.learner.org/interactives/geometry/area.html
- Surface Area, Volume and Total Area discussion and problems: http://www.calculatorsoup.com/calculators/geometry-solids/geometricshapes.php
- Introduce MESA students to the engineering design process. There are many online resources to do this including: The "teach engineering" resource: http://www.teachengineering.org/engrdesignprocess.php The "science buddies" website to explain the engineering design process: http://www.sciencebuddies.org/engineering-design-process/engineering-design-process- steps.shtml
- Have students create their own design notebook: MESA students will use a journal to document the information gathering process they engaged in and any relevant information that will prepare them for designing and building their competition ready package. The journal can also follow them throughout the different steps of the project. Regular entries into the notebook/journal are an essential part of this unit/project. The "science buddies" website contains a concise explanation of a notebook/journal http://www.sciencebuddies.org/blog/2010/01/lab-notebooks.php

Step 2: Plan

- Students will apply their knowledge of drag and shock absorption to a simple version of the ultimate problem by doing the "Descent Module Activity" in the curriculum folders. Activity based on a NASA resource based on the "Pathfinder" mission. http://quest.nasa.gov/mars/teachers/tg/program3/3.1.html

- Have students use lessons from the "Descent Module Activity" to begin planning their own preliminary/model egg package.

- Egg Drop Geometry: Using knowledge of Volume and area, design preliminary shapes for your package, determine feasibility of materials in designing and building the package. Determine the Volume and Surface Area of your potential package.

- Planning – Insure information is entered on the students' "Design Notebook."

Step 3: Create

- Begin the construction of a package that will hold one egg, a model/prototype of your competition package.

- If needed, another egg container activity can be found on the RAFT website: http://www.raft.net/ideas/Egg%20Drop.pdf

- Create – Insure information is entered on the students' "Design Notebook."

Step 4: Evaluate

- Analyze the materials, process and plan used in single egg drop package for effectiveness

- Reference the MESA project rules: http://mesa.ucop.edu/mesa_day_rules/ as students prepare to potentially build their competition package.

- MESA Egg Drop Lab Report – Reflect on what you have learned and experienced to begin your Egg Drop Lab Report. Utilize the Science concepts and understanding of design to restart the design process for your Actual Package.

- Evaluation – Insure information is entered on the students' "Design Notebook."

Repeat Steps until confident you have competition-ready Egg Drop Package

The different activities and lessons in this module will be presented in the following ways

- Discussions and Concept Overviews (PowerPoint Presentations, etc.)
- Hands-on investigation of concepts
- Student Self-guided and Collaborative Work
- Demonstrations and Labs

SAMPLE PACING GUIDE

Although instructors can structure their lessons as they see fit, below is the suggested pacing guide for this module:

Activity	Approximate Time
Introduction	
Naked Egg Drop Activity Testing and discussion on results and Introduction to egg drop unit and project	**1-2 class periods**
Step 1: Investigation	**5 – 8 45 minute class periods**
Egg Drop Link – researching packaged egg drop on- line.	1 class period and/or homework assignment
Overview of Physics Concepts and Completion of Problems	4-5 class periods
Investigation Reflection/Learning Log	Homework and/or 1 class period
Step 2: Planning	**3 – 4 class periods**
NASA Light Bulb Lab	1 ½ class periods
Overview of Design Cycle/ Geometry	2 -2½ class periods
Planning - Reflection Log	Homework or ½ class period
Step 3: Create	**2 - 3 class periods**
Mini Egg Drop	1 – 2 class periods or 1 class period plus homework
Create – Reflection Log	Homework or 1 class period
Step 4: Evaluate	**3 – 6 hours of self-guided school or home work**
MESA Egg Drop Lab Report Write Up	2 – 5 hours or as much time as possible
Evaluate – Reflection Log	Homework or 1 class period