MSET Demonstration Package
Dynamic Impact

Mentis Sciences Education Toolkit Vision and Development History

Located in the historic Mill District of downtown Manchester, Mentis Sciences is an engineering firm which provides advanced material design and manufacturing capabilities to Department of Defense customers. Mentis specializes in the design, development and testing of advanced composite materials with a goal of providing unique flexibility, rapid development and prototyping for various composite applications.

Mentis Sciences, Inc. was founded in 1996 by John F. Dignam, following more than thirty years of service at the Army Materials Research Lab, where he served as the Director of Missile Materials. John F. Dignam spent most of his lifetime promoting national security and developing the most effective material systems to aid in countering global threats. He founded Mentis Sciences to continue promoting innovation, expertise, and emerging materials and manufacturing technologies, that will enhance U.S. security and promote economic growth.

His legacy continues under the strong and visionary leadership of John J. Dignam, who brings unique and innovative technical expertise to solving some of the nation's most daunting engineering challenges. The core values of ethics, integrity, community service, and commitment to excellence instilled by John F. Dignam live on with John J. Dignam and the Mentis team, and are apparent in every aspect of the company's structure, personality, and operations.

Mentis Sciences Internship Program recruits local high school students in good academic standing who reside in the HUBZone area of Manchester, NH. Successful youth with good attitudes and high motivation to work and learn have come through various avenues including non-traditional avenues like the Manchester Police Athletic League, The Salvation Army, and Manchester's Office of Youth Services.

Mentis makes a serious commitment of its resources to support the internship program by providing short courses in STEM related disciplines, student engineering activities and mentoring activities. In result of these courses, Mentis Sciences started to see a gap in STEM education. Biology and Life Science concepts were often the focus of science in the classroom, technology often included a smartphone app and engineering was nonexistent. Our interns and every student deserve to be introduced to STEM concepts with tools and resources that allow them to experience concepts hands-on and in a collaborative environment.

With this vision for our students, Mentis transferred skills used in their own manufacturing facility every day, and descaled the concepts and tests into one integrated unit. Mentis has developed an integrated STEM toolkit that configures to complete 40 STEM tests. With limited lab space and budgets for lab testing equipment being tight, the Mentis Sciences Engineering Toolkit (MSET) departs from the high cost limited functionality of current educational testing systems.

The MSET offers a unique view into the world of material testing and physical science. Data indicates the MSET Program increased student participation in the classroom, interest in STEM careers and opportunities for females in STEM. Students develop a deep understanding in STEM, engineering and physical science concepts.

In many ways, the internship program and new shared vision has provided Mentis employees a new sense of purpose in their work. Mentis is now expanding their vision for the MSET program, beyond their own interns and are offering the MSETs STEM educational opportunities to other schools and educational partners in their community and around the United States.

Mentis believes that every student, no matter their upbringing or education status, should have the opportunity to learn, pursue their dreams and have the high-quality resources to so. This enrichment MSET program has proven to be beneficial, providing life-changing experiences for interns, students, as well as Mentis employees. We are excited to share it with you.

Dynamic Impact Introduction

In this unit students will explore the dynamic properties of materials and systems under free fall, impact, and rebound. Students will apply basic physics principles of Kinetic and Potential Energy and how different materials are applied in engineering practice. Students will synthesize data to evaluate impact force, duration, and damping coefficients of different materials and systems as they relate to how a body in free fall comes to rest. In the end of the unit students will apply concepts in an inquiry-based project where they design a system to bring a falling body to rest.

The materials in this section have been created and organized to assist teachers in the design of lessons that use the MSET equipment and applied inquiry-based projects that are aligned with the Next Generation Science Standards, as well as the Massachusetts Science and Technology/Engineering Curriculum Framework.

Teachers

Teachers should review the Understanding by Design unit plan with particular attention to the Essential Questions students will be expected to answer by the conclusion of the unit. Throughout the lessons and experiences teachers should assess students' progress toward their capacity answering the essential questions. Finally, teachers should use the rubric to assess students' comprehension and application of the foundational principles associate with the lesson, experiment and materials covered in the unit.

Students

It is assumed that students participating in this unit will have experience in the following areas:

1. Possess basic algebra skills including manipulation of equations to solve for unknowns
2. Convert between imperial and SI units
3. Possess basic physics background and be familiar with conservation of energy, potential and kinetic energy, gravity, and kinematic equations
4. Ability to generate plots based on data obtained through experimentation and analysis
5. Interpret plots to draw conclusions about the physical process they represent

Table of Contents

UbD Chart – Dynamic Impact

<table>
<tr><th colspan="3">Desired Results</th></tr>
<tr>
<td rowspan="6">STANDARDS/ESTABLISHED GOALS

<u>Next Generation Science Standards</u>

Engineering Design:
HS-ETs1-2: Design a solution to a complex real world problem by breaking it down in to smaller, more manageable problems that can be solved through engineering.

HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints in interactions within and between systems relevant to the problem.

Forces and Interactions:
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.

K-PS2-1: Plan and conduct and investigation to compare the effects of different strengths or different directions of pushes or pulls on the motion of an object,

K-PS2-2: Analyze data to determine if a design solution works as intended to change the speed or direction of and object with a push or pull</td>
<td colspan="2">Transfer</td>
</tr>
<tr><td colspan="2">Students will be able to independently use their learning of impact force, impact durations, kinetic and potential energy, and Newton's 2nd Law to make decisions about material use when designing a structure, vehicle, etc.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr>
<td>UNDERSTANDINGS
Students will understand that…
1. As mass and acceleration of an object change, so does the force of an object on another object or surface.
2. The longer the impact duration, the less force on an object.
3. Kinetic and potential energy can affect the velocity of an object, which can affect acceleration and therefore force.</td>
<td>ESSENTIAL QUESTIONS

1. How does kinetic and potential energy affect force when one object is dropped and collides with another?
2. How can the impact duration of a collision be minimized and therefore create less force on an object or surface?
3. How are mass, acceleration, and force related to one another according to Newton's Second Law?
4. How can calculating and understanding impact duration and force help in designing structures, vehicles, etc?</td>
</tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr>
<td>Students will know…
● Newton's Second Law (F = m•a)
● The definitions of mass, acceleration, force, and velocity.
● Definitions of potential and kinetic energy
● How to use the following formulas to find kinetic energy and potential energy, $KE = ½mv^2$ and $PE = mgh$
● How to use the following formula to calculate impact duration, $\Delta t = t_f - t_f$</td>
<td>Students will be skilled at…
● Apply mathematical computations to mathematical model(s) to calculate various outcomes
● Interpret graphs to draw conclusions
● Use computer software to collect data and model hydrostatic pressure on an object
● Apply the scientific method in an experiment</td>
</tr>
</table>

HS-PS2-3 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during collision. **<u>Massachusetts State Standards</u>** Technology and Engineering: HS-ETS1-4. Use a computer simulation to model the impact of a proposed solution to a complex real-world problem that has numerous criteria and constraints on the interactions HS-ETS3-4(MA). Use a model to illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure. Analyze situations that involve these forces and justify the selection of materials for the given situation based on their properties. Introductory Physics: HS-PS2-1. Analyze data to support the claim that Newton's second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force. HS-PS2-3. Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. HS-PS2-10 (MA). Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and		

acceleration for an object moving in one dimension in various situations. HS-PS3-1. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.		

Stage 3 – Learning Plan

Summary of Key Learning Events and Instruction

See outline of Dynamic Impact experiment summary included.

Evidence

Assessment Evidence

PERFORMANCE TASK(S):

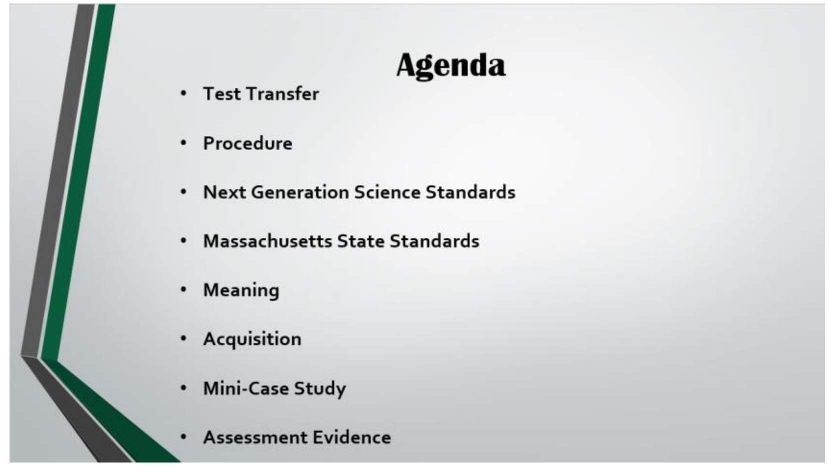
1. Students will use the MSET device to conduct an experiment to measure force and impact duration as an object falls into a variety of foam structures while considering potential and kinetic energy. The MSET device will be used to plot force and impact duration, and students will use these values to determine the highest and lowest impact force as well as calculate the velocity of the object.

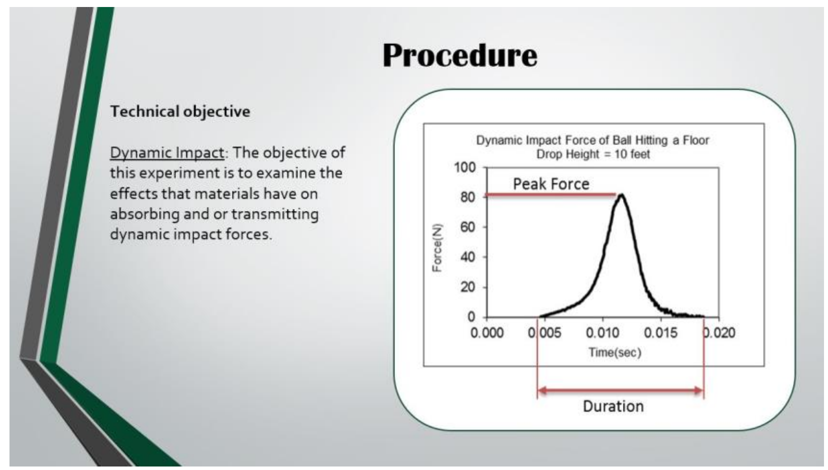
2. As a final performance assessment, students will complete the Inquiry-Based Mini-Project (see page 26), where they will calculate impact duration for a falling object as it hits foam pieces. Students will need to calculate potential and kinetic energy and the height of the object after impact using various foam combinations and then provide a rationale for their decision about what combination of foam structures would result in the maximum height for the object. The students will use the MSET and mathematical calculations to make decisions and to provide an explanation of their solution. Student understanding will be evaluated using the mini-project rubric (see page 32).

OTHER EVIDENCE:

The essential questions will be used as an entrance/exit slip to determine growth in understanding.

PowerPoint Template for Instruction – Dynamic Impact





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Procedure

Approach

Dynamic Impact: In this experiment a mass will be dropped onto three target samples each made of a different material. The magnitude and time duration of the impact force will be recorded. Figure 1 shows how the force varies as a function of time as a surface is impacted. The mass of the falling object (carriage, load cell, and impact load nose) will be constant for all tests. Additionally, the drop height will be held constant for all tests to ensure that each test has the same impact energy.

Standards/Established Goals

Next Generation Science Standards

Engineering Design:

- HS-ETS1-2: Design a solution to a complex real world problem by breaking it down in to smaller, more manageable problems that can be solved through engineering
- HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem

Forces and Interactions:

- HS-PS2-1 Analyze data to support the claim that Newton's second law of motion
- HS-PS2-3 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during collision
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- K-PS2-2: Analyze data to determine if a design solution works as intended to change the speed or direction of and object with a push or pull

Standards/Established Goals

Massachusetts State Standards

Technology and Engineering:

- HS-ETS1-4: Computer simulation to propose a real-world solution
- HS-ETS3-4(MA): Illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure.

Introductory Physics:

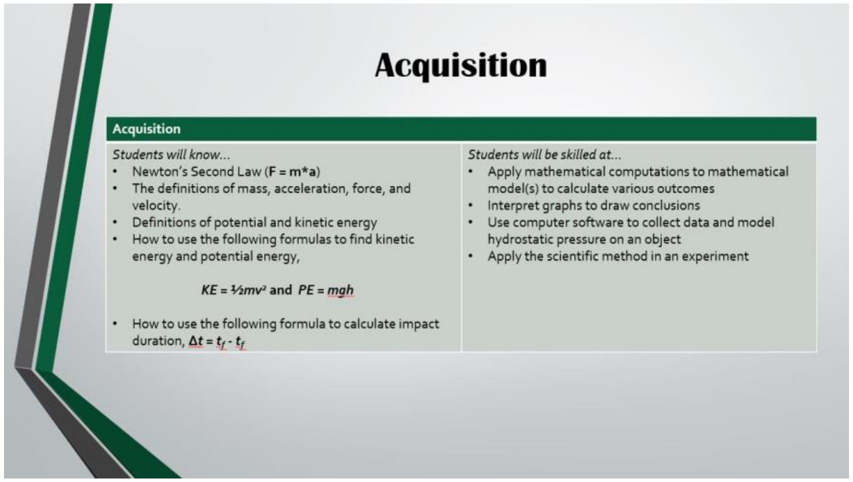
- HS-PS2-1: Analyze data to support Newton's second law of motion
- HS-PS2-3: Apply scientific principles of motion and momentum to design, evaluate, and refine a device
- HS-PS2-10 (MA): Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and acceleration for an object moving in one dimension

Introductory Physics:

- HS-PS3-1:Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system

Meaning

Meaning	
UNDERSTANDINGS: *Students will understand that...* 1. As mass and acceleration of an object change, so does the force of an object on another object or surface. 2. The longer the impact duration, the less force on an object. 3. Kinetic and potential energy can affect the velocity of an object, which can affect acceleration and therefore force.	ESSENTIAL QUESTIONS: 1. How does kinetic and potential energy affect force when one object is dropped and collides with another? 2. How can the impact duration of a collision be minimized and therefore create less force on an object or surface? 3. How are mass, acceleration, and force related to one another according to Newton's Second Law? 4. How can calculating and understanding impact duration and force help in designing structures, vehicles, etc?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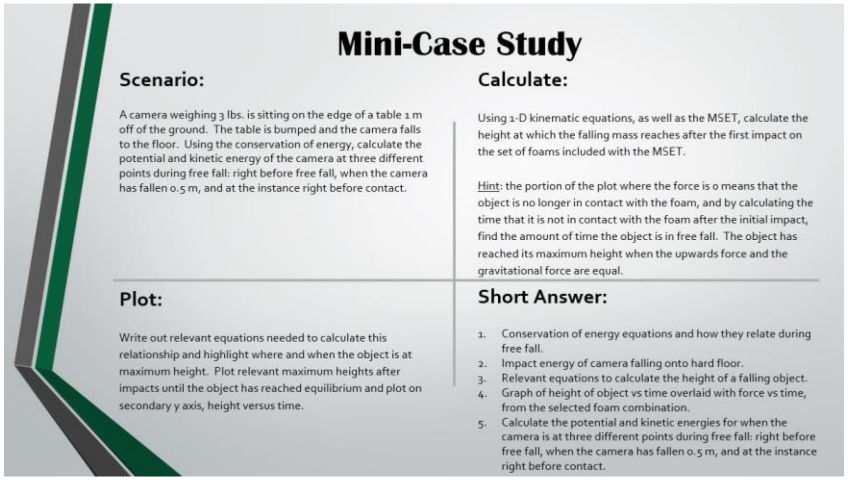
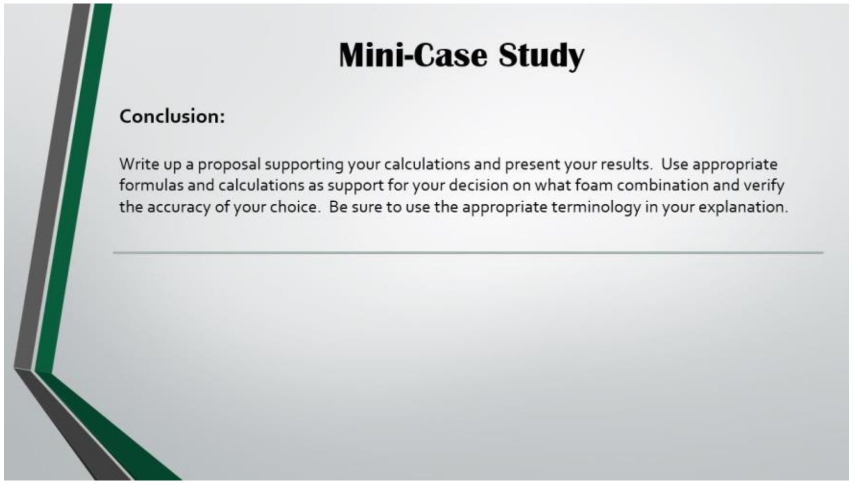
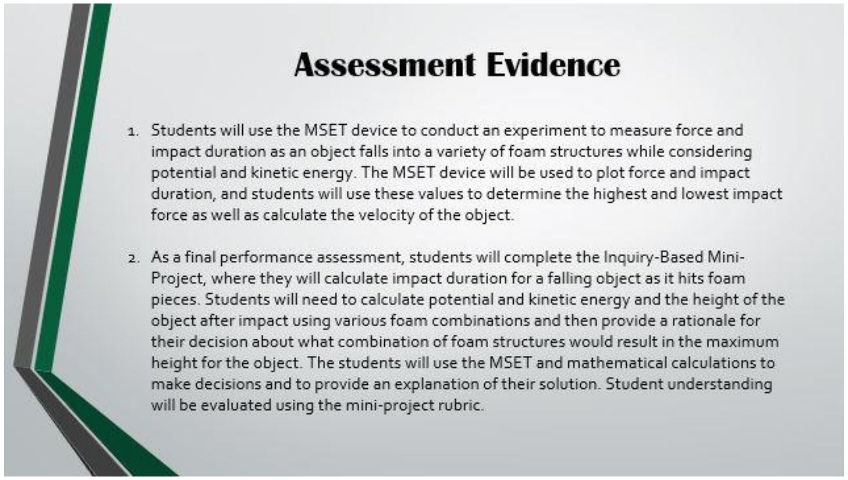

Mini-Case Study
Scenario:
A camera weighing 3 lbs. is sitting on the edge of a table 1 m off of the ground. The table is bumped and the camera falls to the floor. Using the conservation of energy, calculate the potential and kinetic energy of the camera at three different points during free fall: right before free fall, when the camera has fallen 0.5 m, and at the instance right before contact.
Calculate:
Using 1-D kinematic equations, as well as the MSET, calculate the height at which the falling mass reaches after the first impact on the set of foams included with the MSET.
Hint: the portion of the plot where the force is 0 means that the object is no longer in contact with the foam, and by calculating the time that it is not in contact with the foam after the initial impact, find the amount of time the object is in free fall. The object has reached its maximum height when the upwards force and the gravitational force are equal.
Plot:
Write out relevant equations needed to calculate this relationship and highlight where and when the object is at maximum height. Plot relevant maximum heights after impacts until the object has reached equilibrium and plot on secondary y axis, height versus time.
Short Answer:
1. Conservation of energy equations and how they relate during free fall.
2. Impact energy of camera falling onto hard floor.
3. Relevant equations to calculate the height of a falling object.
4. Graph of height of object vs time overlaid with force vs time, from the selected foam combination.
5. Calculate the potential and kinetic energies for when the camera is at three different points during free fall: right before free fall, when the camera has fallen 0.5 m, and at the instance right before contact.


Mini-Case Study
Conclusion:
Write up a proposal supporting your calculations and present your results. Use appropriate formulas and calculations as support for your decision on what foam combination and verify the accuracy of your choice. Be sure to use the appropriate terminology in your explanation.


Assessment Evidence
1. Students will use the MSET device to conduct an experiment to measure force and impact duration as an object falls into a variety of foam structures while considering potential and kinetic energy. The MSET device will be used to plot force and impact duration, and students will use these values to determine the highest and lowest impact force as well as calculate the velocity of the object.
2. As a final performance assessment, students will complete the Inquiry-Based Mini-Project, where they will calculate impact duration for a falling object as it hits foam pieces. Students will need to calculate potential and kinetic energy and the height of the object after impact using various foam combinations and then provide a rationale for their decision about what combination of foam structures would result in the maximum height for the object. The students will use the MSET and mathematical calculations to make decisions and to provide an explanation of their solution. Student understanding will be evaluated using the mini-project rubric.

MSET Experiment Procedure – Dynamic Impact

Technical objective

The objective of this experiment is to examine the effects that materials have on absorbing and or transmitting dynamic impact forces.

Background

When 2 objects (or 1 object and an immovable surface) impact they impart a force on each other until they come to rest. Newton's Second Law, as shown in Equation #1, states the force is equal to mass times acceleration. If the objects do not shatter during impact, mass is constant, the force imparted on the objects is proportional to the acceleration. Additionally, acceleration is related to velocity (or change in velocity) and is inversely proportional to distance and/or time. This means that a longer duration impact will impart less force on the object. Also, larger deflections (distance) during the impact will impart less force on the object.

$$F = m \cdot a \qquad \text{Eq. (1)}$$

Consider the case of a steel ball being dropped on a concrete floor. Both materials are very stiff and as a result will not deform very much. Because of this the time duration of the impact is short, acceleration is high, and force imparted on each object is high. Consider the same ball being dropped onto a foam pad. In this case the foam is not stiff and is able to deform considerably. Because of this the time duration of the impact is long, acceleration decreases slowly as the ball comes to rest and rebounds; is proportional to the energy absorbed by the foam; thus the force imparted on the object is low. This is the concept behind the use of crumple zones in automobiles. In a collision the crumple zones collapse which extends the duration of the impact and decreases the impact force and reduces the acceleration of the occupants.

The above example uses the assumption that the energy of the impact is constant for both cases (steel on concrete and steel on foam). For this experiment the energy will be held constant. There are two different types of energy to consider: Kinetic Energy and Potential Energy. The impact energy is a result of Kinetic Energy (KE) which is given by Equation #2 which has components of the object mass and velocity. Since we are assuming that mass is constant for each of the two situations described above the energy of the impact is directly related to the velocity just before impact.

$$KE = \frac{1}{2}mv^2 \qquad \text{Eq. (2)}$$

Where:
KE = Kinetic Energy
m = mass (of the ball)
v = velocity (of the ball just before impact)

The law of conservation of energy states that energy cannot be created nor destroyed in an isolated system. This gives rise to the concept of Potential Energy (PE) as given by Equation #3. Potential Energy is the resulting energy of an object in a force field. For our example of the falling ball the Potential Energy the force field is due to gravity and the magnitude of energy has components of mass, gravitational acceleration, and the initial height of the ball above the impact surface. The height and mass of the ball prior to being dropped have a potential energy “PE” defined in equation #1.

$$PE = mgh \qquad \text{Eq. (3)}$$

Where:

m = Mass of the ball
g = Gravitational constant = 9.8 m/s^2
h = Height when released

Since energy is conserved, the velocity just before impact can be determined by setting Equation #2 equal to Equation #3 (KE=PE). If mass and gravity are constant, then the velocity just before impact only depends on the height of the ball above the impact surface.

Approach

In this experiment a mass will be dropped onto three target samples each made of a different material. The magnitude and time duration of the impact force will be recorded. Figure 1 shows how the force varies as a function of time as a surface is impacted. The mass of the falling object (carriage, load cell, and impact load nose) will be constant for all tests. Additionally, the drop height will be held constant for all tests to ensure that each test has the same impact energy.

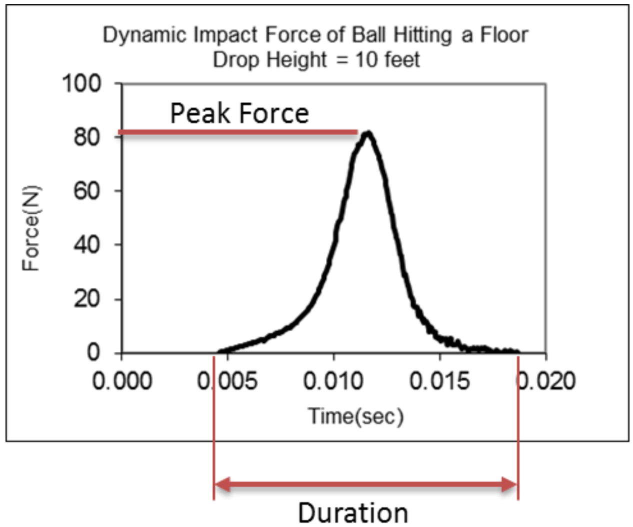
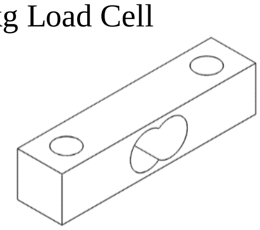
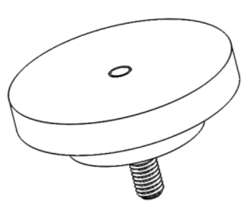
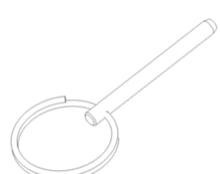
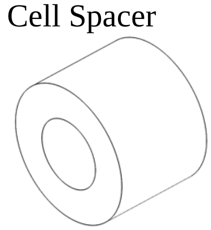
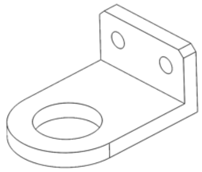
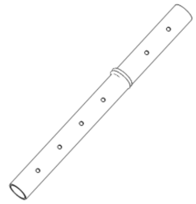
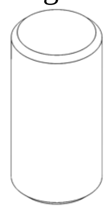
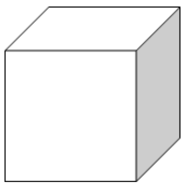
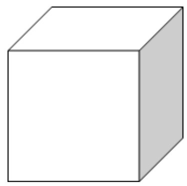
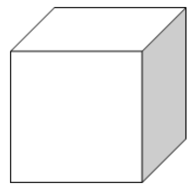
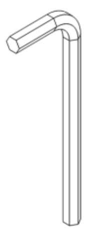


Figure 1-Force imparted on target during impact event

<u>Experiment Setup</u>

1. Gather the following components:

5/8" Thumbscrew x2 	5kg Load Cell 	Load Cell Bolt 
Impact Target 	Retaining Pin 	Load Cell Spacer 

Impact Tube Mount 	Impact Tube 	Impact Slug 
Soft Foam 	Medium Foam 	Firm Foam 
4mm Hex Wrench 		

2. Attach the tower to the base plate as shown in the Quick Setup Guide.
3. If a load cell is attached to the carriage, remove it with the provided 4mm hex wrench.

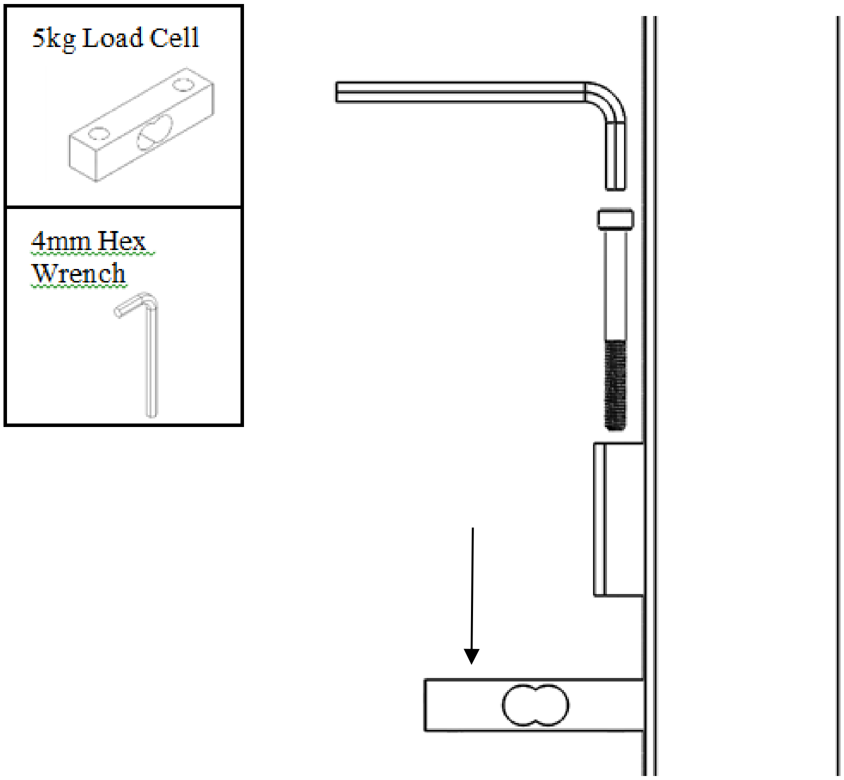


Figure 2: Removal of Load Cell from Carriage

4. Attach the Impact Tube Mount to the tower using the two 5/8" long thumbscrews as shown in Figure 3.
5. Thread the impact target onto the load cell.
6. Attach the 5kg load cell to the base plate using the load cell bolt and the load cell spacer. Ensure the arrow on the load cell is pointed downwards. Refer to Figure 4.

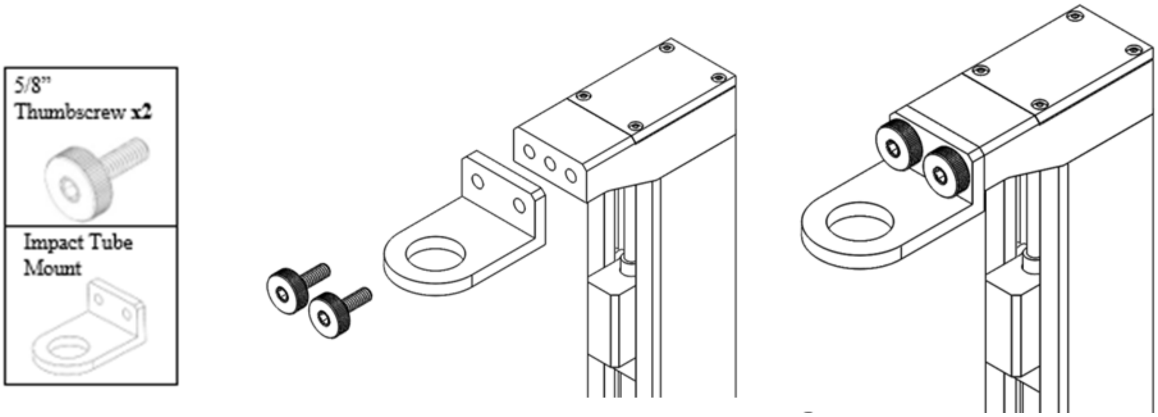


Figure 3: Placement of Impact Tube Mount

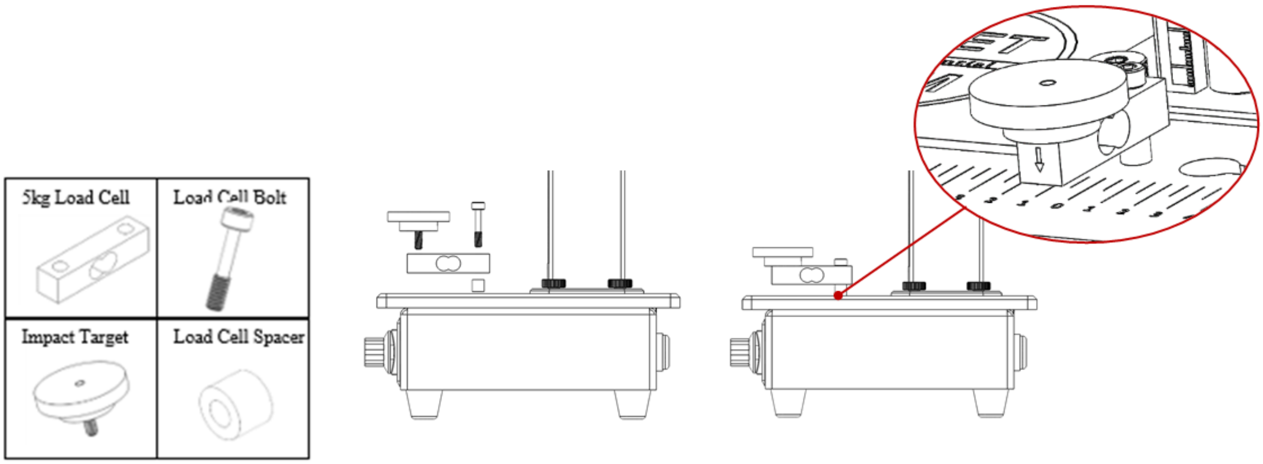


Figure 4: Placement of Load Cell with Impact Target

7. Plug the load cell into port 1 at the back of the SIM.

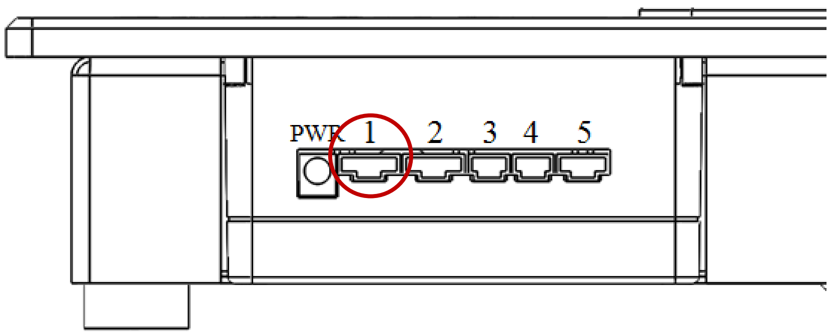


Figure 5: Port 1 on SIM

8. Lower the impact tube assembly onto the impact tube mount. Adjust the rubber collar such that the bottom of the tube sits approximately 2” from the impact target. Refer to Figure 6.

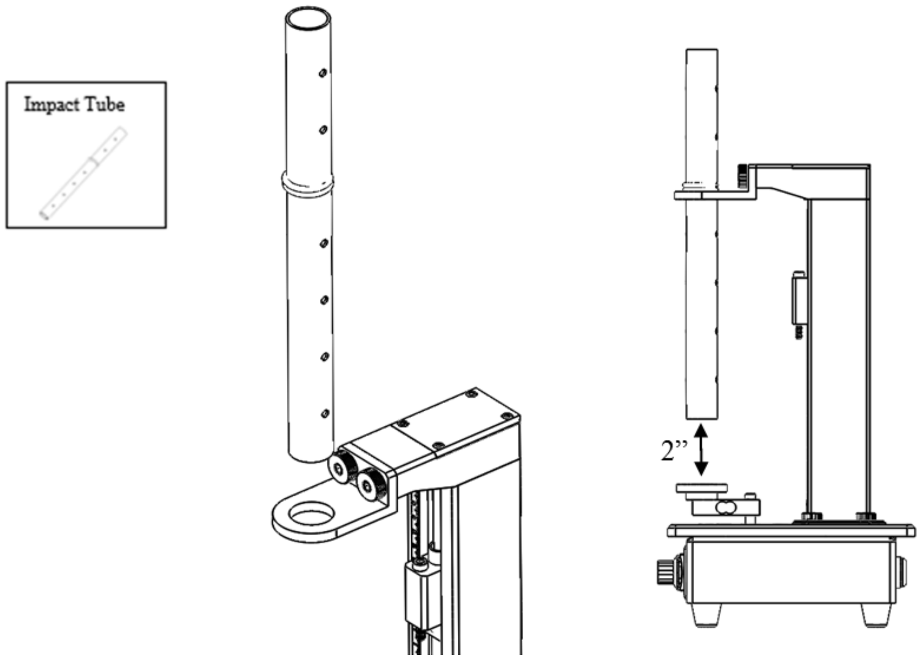
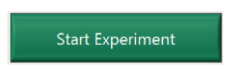


Figure 6: Placement of Impact Tube

Experimental Procedure

1. In the MSET software, click “Dynamic Impact” then 

to launch the dynamic impact experiment.

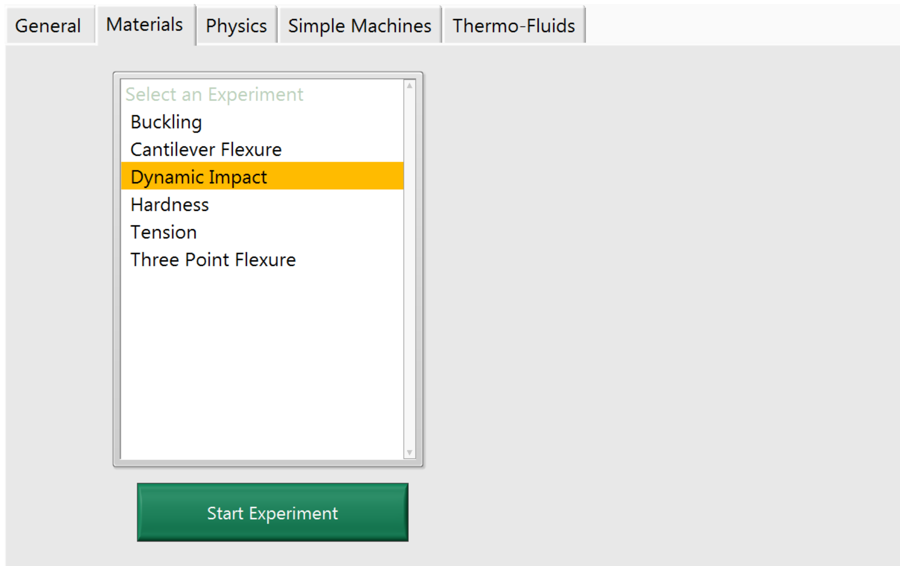


Figure 7: Location of Dynamic Impact Experiment

2. Select the 5 kg load cell from the menu options.

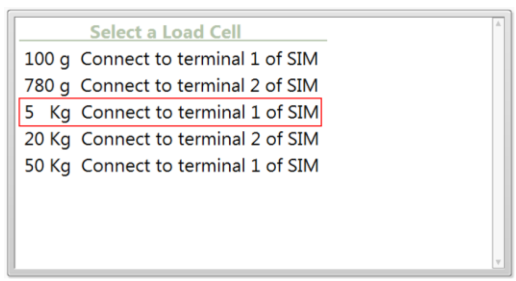
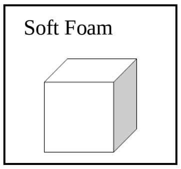


Figure 8. Load Cell Options

3. Place the soft foam on the impact target as shown in Figure 9.



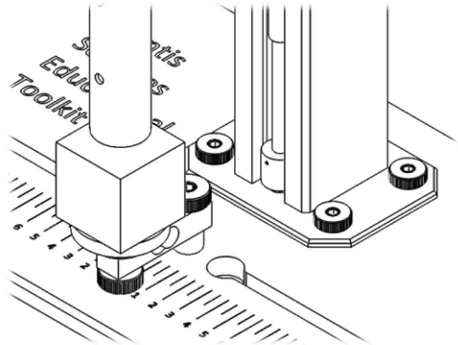


Figure 9: Placement of Impact Sample

4. If the impact tube makes contact with the sample, adjust the tube until there is a slight gap.

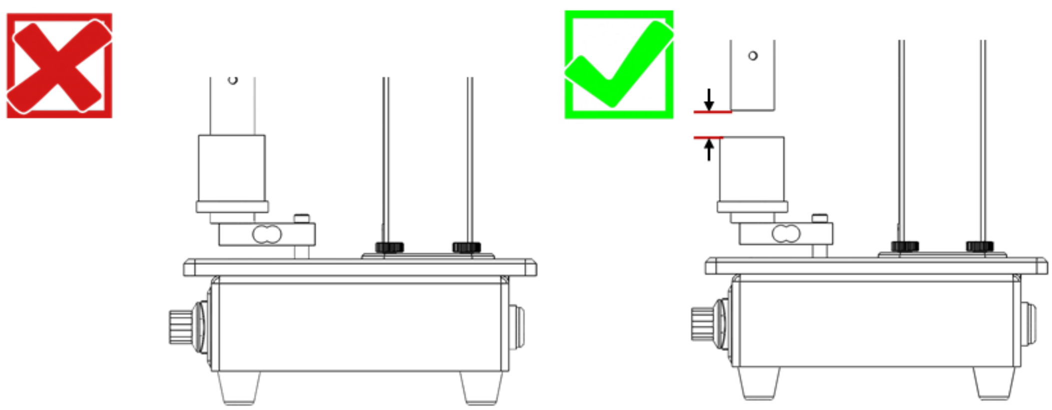


Figure 10: Incorrect vs. Correct Tube Height

5. Insert the retaining pin into the hole just below the tube mount on the impact tube.
6. Carefully drop the impact slug into the tube such that is rests on the pin.

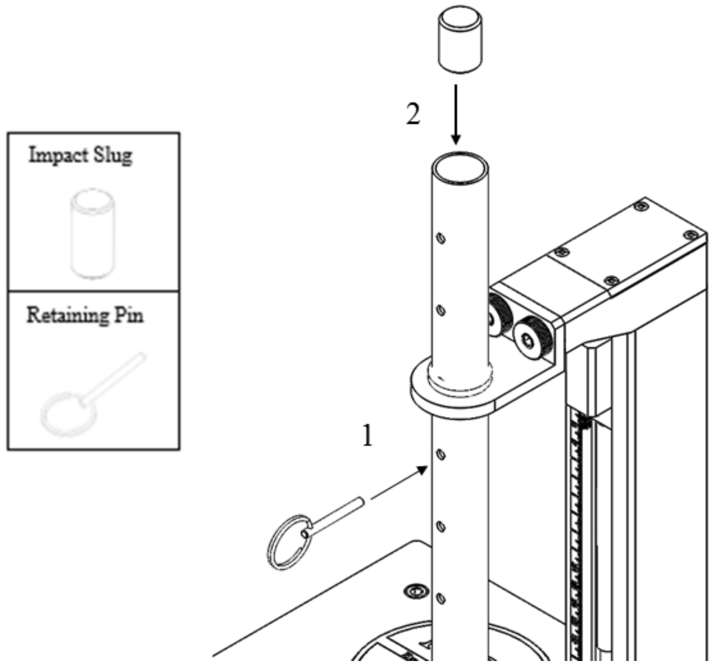
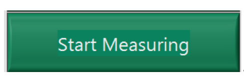
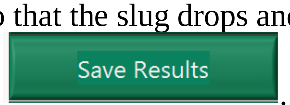
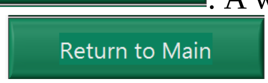
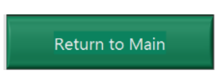


Figure 11: Placement of Impact Slug

7. On the MSET program, click 

.
8. While using one hand to hold the tube steady, use the other to remove the retaining pin so that the slug drops and lands on the impact sample.
9. Press 

. A window will pop up notifying the user that data will be saved once 

is pressed at the end of the experiment.
10. Record the duration of the first impact (the largest peak) in Table 1.
11. To retrieve the impact slug, lift up on the impact tube.
12. Replace the soft foam with the medium foam and repeat steps 5-10. Do this again for the firm foam.
13. When finished, click 

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Data Analysis

1. Retrieve the data collected in the previous section by navigating to the C: drive then MSET >Materials. Import this data into a data processing program like Microsoft Excel. Plot each data set. Record the peak force and duration of first impact for all samples in the table below. Use Eq. (4) to calculate the impact duration.
   a. To calculate the impact duration:
      i. On the plot, click the point where the force starts to initially increase. This is the start time, called t_s.
      ii. The force curve will then increase to a peak, and return back to zero, click the point where it first returns back to zero. This is the final time, t_f.
      iii. These times are in milliseconds. The impact duration is the difference of these values. The impact duration is called "Δt". It's calculated as follows:

$$\Delta t = t_f - t_s \qquad \text{Eq. (4)}$$

Table 1: Peak forces and impact durations

Sample Type	Peak Force (N)	Impact Duration (msec)
Soft		
Medium		
Firm		

2. Which material produced the highest impact force? The lowest?

3. If a sample was halfway between the firm and medium foam what force vs time plot would you expect? Show plot in Figure 12.

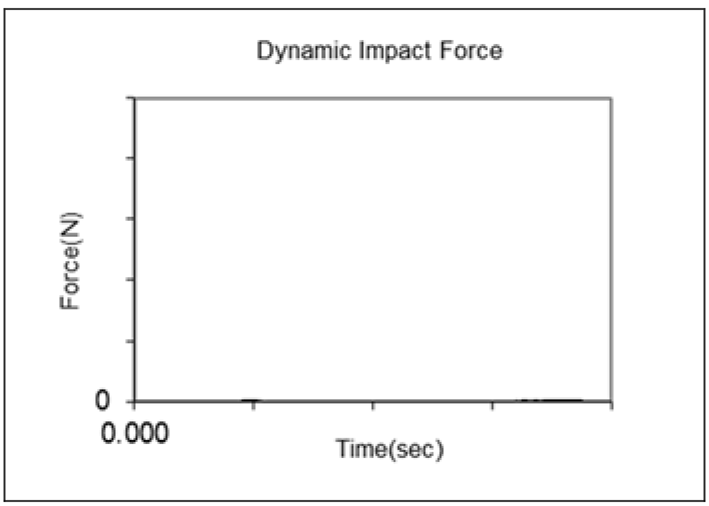


Figure 12 - Expected Force vs Time plot for Firm/Medium Foam

4. Using Equations 2 and 3 calculate the carriage velocity just before impact. Hint: assume the kinetic energy equals the potential energy.

Why does the impact slug not bounce back up to the initial height of the drop? Explain in terms of energy conservation. Hint: is there anywhere else for the potential energy to go?

MSET – DYNAMIC IMPACT

Purpose

Examine the effects of impacting materials of different composition, and how the impact force varies as a function of event duration.

Impacts

Dynamic impacts are a common result of daily activities. As an example, a person walking or running experiences dynamic forces to their body. The weight of the person, and type of footwear worn, will effect the magnitude of force generated.

Theory

The amount of potential energy "PE", that an object of mass "M" has is a function of height "H", and gravitational constant "G".

[illegible] = [illegible]

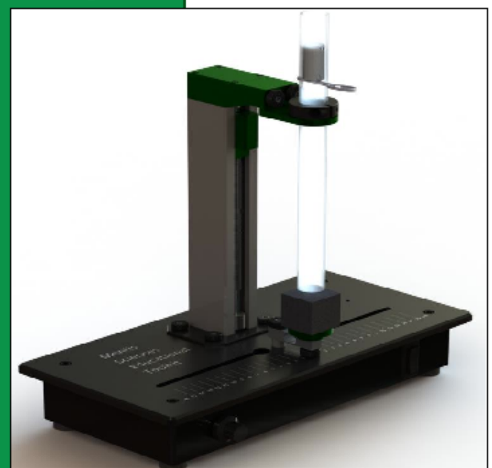
As it falls, the height decreases, and velocity "V" increases. The potential energy is converted to kinetic energy "KE".

[illegible] = √2[illegible]

The force of impact "F" is defined by Newton's second law with "A" being the deceleration.

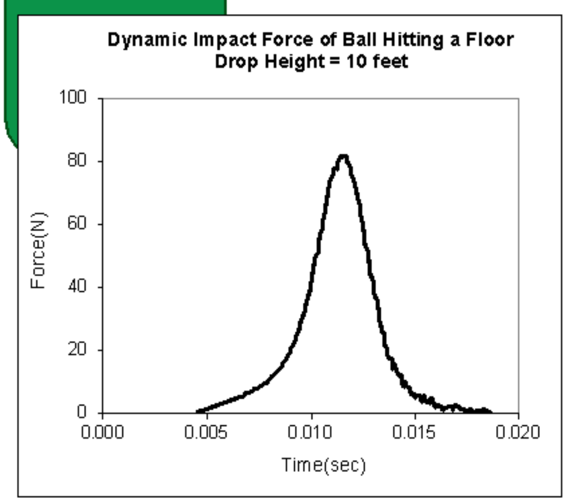
[illegible] = [illegible]

Setup



Results

A number of materials with various energy absorbing characteristics will be measured and compared to each other. The impact magnitude and duration time will be compared. Energy absorption of each will be calculated and compared to the kinetic energy.



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Inquiry-Based Mini Project – Dynamic Impact

A camera weighing 3 pounds is sitting on the edge of a table, 1 meter off of the ground. The table is bumped and the camera falls to the floor. Using the conservation of energy, calculate the potential and kinetic energy of the camera at three different points during free fall: right before free fall, when the camera has fallen 0.5 m, and at the instance right before contact.
Using 1-D kinematic equations, as well as the MSET, calculate the height at which the falling mass reaches after the first impact on the set of foams included with the MSET. Hint: the portion of the plot where the force is 0 means that the object is no longer in contact with the foam, and by calculating the time that it is not in contact with the foam after the initial impact, find the amount of time the object is in free fall. The object has reached its maximum height when the upwards force and the gravitational force are equal. Write out relevant equations needed to calculate this relationship and highlight where and when the object is at maximum height. Plot relevant maximum heights after impacts until the object has reached equilibrium and plot on secondary y axis, height versus time.

Provide incorporate the following concepts in your answer:

1.) Conservation of energy equations and how they relate during free fall.

2.) Impact energy of camera falling onto hard floor.

3.) Relevant equations to calculate the height of a falling object.

4.) Graph of height of object vs time overlaid with force vs time, from the selected foam combination.

5.) Calculate the potential and kinetic energies for when the camera is at three different points during free fall: right before free fall, when the camera has fallen 0.5 m, and at the instance right before contact.

Write up a proposal supporting your calculations and present your results. Use appropriate formulas and calculations as support for your decision on what foam combination and verify the accuracy of your choice. Be sure to use the appropriate terminology in your explanation.

Teacher Solution Key – Dynamic Impact

1.) Relevant equations:

$$KE = \frac{1}{2}mv^2$$

Where KE=Kinetic Energy, m=Mass, and v=Velocity

$$PE = mgh$$

Where PE=Potential Energy, g=Constant gravitational acceleration, and h=Height of object

$$v = vo + \sqrt{2ad}$$

Where v=Final velocity, vo=Initial velocity, a=Acceleration, and d=Distance (displacement)

$$t = \frac{-vo \pm \sqrt{vo + 2ad}}{a}$$

Where t=Time

$$\Delta t = t_f - t_i$$

Where Δt =Change in time, t_f =Final time, and t_i =Initial time

$$d = v_i t + \frac{1}{2}at^2$$

Where d=Displacement, v_i =Initial velocity, and t=Time

$$E = ma_g h$$

Where E=Impact energy, h=Height that object fell from, and a_g =Acceleration due to gravity

Given:

Mass of camera=3lbs
Height of table=1m

2.) Impact energy of camera falling onto hard wood floor.

$$E = (1.36kg)\left(9.81\,{}^{m}/_{s^2}\right)(1.00m) = 13.3J$$

3.) Height at which the falling mass reaches after initial impact on each of the foam samples:

$$\Delta t = 207.47 - 112.03 = \frac{95.44}{2} = 47.7msec = 0.0477sec$$
$$d = (0.00\,{}^{m}/_{s})(0.0477s) + \frac{1}{2}\left(9.81\,{}^{m}/_{s^2}\right)(0.0477^2 s) = 11.2mm$$

Soft foam=11.1mm

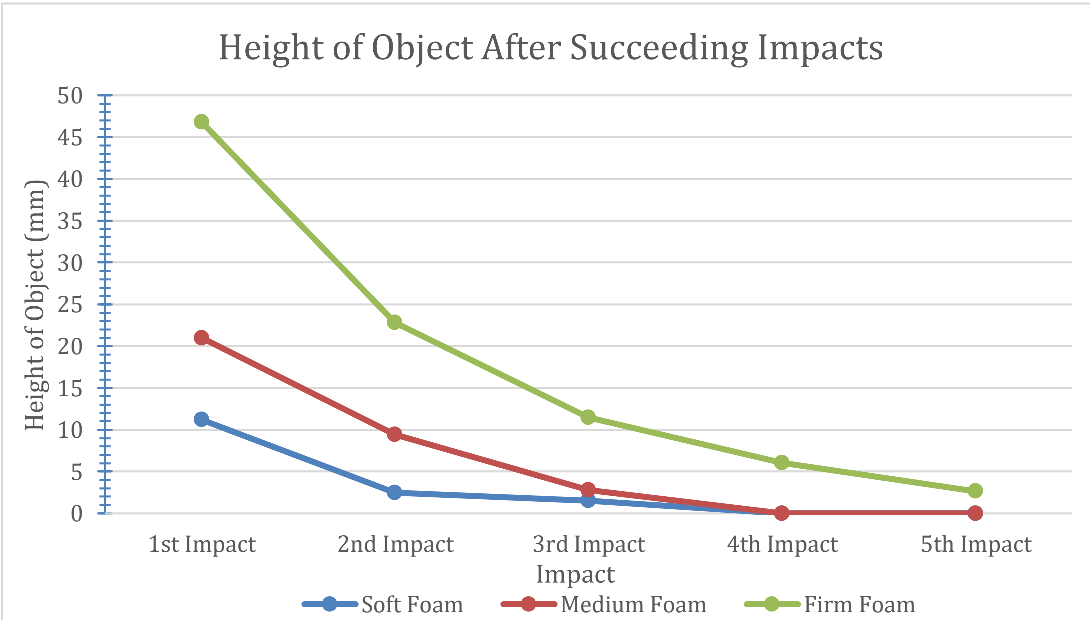
$$\Delta t = 227.85 - 97.05 = \frac{130.8}{2} = 65.4msec = 0.0654sec$$
$$d = (0.00\,{}^{m}/_{s})(0.0654s) + \frac{1}{2}\left(9.8\,{}^{m}/_{s^2}\right)(0.0654^2 s) = 21.0mm$$

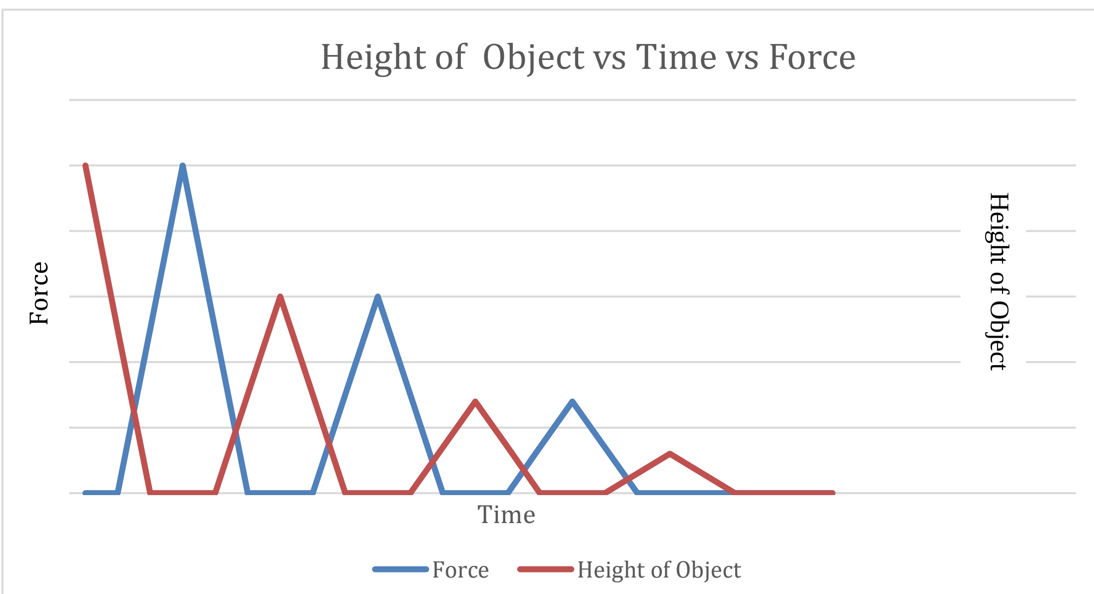
Medium foam=21.0mm

$$\Delta t = 278.48 - 82.98 = \frac{195.5}{2} = 97.8msec = 0.0978sec$$
$$d = (0.00\,{}^{m}/_{s})(0.0978s) + \frac{1}{2}\left(9.8\,{}^{m}/_{s^2}\right)(0.0978^2 s) = 46.9mm$$

Firm foam=46.9mm

4.) Graph of height of object after succeeding impacts with different foam samples and object vs time overlaid with force vs time





5.) Potential and kinetic energies for when the camera is at three different points during free fall

Potential Energy of camera:

Before fall=13.3J

$$PE = (1.36kg)\left(9.81\,{}^{m}/_{s^2}\right)(1.00m) = 13.3J$$

When camera has fallen 0.5m=6.67J

$$PE = (1.36kg)\left(9.81\,{}^{m}/_{s^2}\right)(0.50m) = 6.67J$$

Instant right before contact=0.00J

$$PE = (1.36kg)\left(9.81\,{}^{m}/_{s^2}\right)(0.00m) = 0.00J$$

Kinetic Energy of camera:

Before fall=0.00J

$$KE = \frac{1}{2}(1.36kg)(0.00\,{}^{m}/_{s})^2 = 0.00J$$

When camera has fallen 0.5m=6.67J

$$v = \sqrt{(0.00\,{}^{m}/_{s})^2 + 2\left(9.81\,{}^{m}/_{s^2}\right)(0.50m)} = 3.13\,{}^{m}/_{s}$$

$$KE = \frac{1}{2}(1.36kg)(3.13\,{}^{m}/_{s})^2 = 6.66J$$

Instant right before contact=13.3J

$$v^2 = (0.00\,{}^{m}/_{s})^2 + 2\left(9.81\,{}^{m}/_{s^2}\right)(1.00m) = 4.43\,{}^{m}/_{s}$$

$$KE = \frac{1}{2}(1.36kg)(4.43\,{}^{m}/_{s})^2 = 13.3J$$

The kinetic and potential energy of an object varies depending on its position and movement. These two measurements are based on different physical properties, but there are times when they both equal one another. For example, when a given object, such as a camera, has fallen exactly half of its possible path of travel, the kinetic and potential energies are equal. The object has lost half of its potential energy by falling half of the distance, and the object has gained half of its kinetic energy.

The potential energy formula depends the most on the objects height. The other two variables in the equation, the mass and the gravitational acceleration, are constant for the object. This means that the change in height is the main factor in calculating an objects potential energy.

The kinetic energy formula is prioritized around the objects velocity. Again, since the mass is always constant, given no sheering or flaking, so the velocity is the main determining factor of an objects kinetic energy. Since energy is conserved, the velocity just before impact can be determined by setting the kinetic energy equal to the potential energy. If mass and gravity are constant then the velocity just before impact only depends on the height of the ball above the impact surface.

The foam compound needed to send an object upwards one inch would need to have a total air time of around 50.8 msec.

Inquiry Based Mini Project Rubric – Dynamic Impact

	3	2	1	0	Score
Proper Use of Equipment	Used the MSET to collect impact duration and force data accurately	Struggled with using the MSET and getting accurate data. Was able to use it with some assistance.	Even at the end of the experiment, struggled with the used of the MSET and could not accurately collect data using the equipment.	Didn't use the MSET	
Accuracy of Use of Terminology	Used all the terms accurately including, impact duration, impact force, acceleration, potential energy, and kinetic energy	May have used all of the terms but one or two were not used accurately.	Used some of the terms but not all of them or the terms were used but not used accurately.	Didn't use any of the terms in the explanation of the design	
Rationale for Solution	Provided a detailed rationale for the choices made in their solution. Explanation included a connection to Newton's Laws of Motion as well as how impact duration and acceleration can affect the force inflicted on an object. Potential and kinetic energy are also used in the explanation and rationale.	Provided a rationale for their solution, but could only briefly connect Newton's Laws, impact duration, acceleration, potential and kinetic energy, and force on an object.	Provided a rationale, but their explanation was lacking connections to Newton's Laws, impact duration, acceleration, potential and kinetic energy, and force on an object.	Didn't provide a rationale for their solution	
Use of Mathematical Computations	Used the given formula to calculate impact duration, kinetic, and potential energy accurately. Calculations were used to explain choices made about design.	May have used the given formulas to calculate impact duration, kinetic, and potential energy accurately, however could not use it to explain choices made about design.	Attempted to use the given formulas to calculate impact duration, kinetic, and potential energy but included some miscalculations.	Did not use the given formula for calculations.	