Lab Handout

Lab 19. Impulse and Materials: Which Material Is Most Likely to Provide the Best Protection for a Phone That Has Been Dropped?

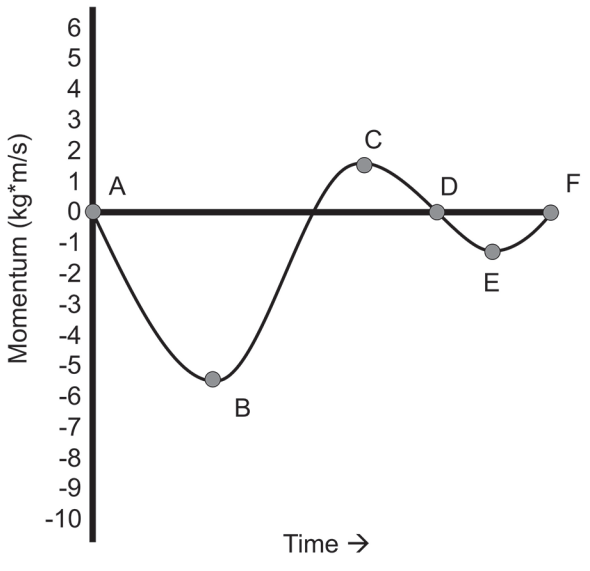
Introduction

People throughout the United States use personal electronic devices. On any given day, a person might use a cell phone, smartwatch, laptop computer, or tablet in a number of different settings. Unfortunately, people often damage these devices by accidently dropping them or knocking them off a table. Most consumers, however, do not want to replace any of these devices on a regular basis because they tend to be expensive. This is one reason why so many people use a case to protect their different personal electronic devices. Many different companies sell cases that are designed to prevent phones, tablets, or laptops from breaking when they are dropped or knocked off a table.

When a person drops a cell phone, the force of gravity causes the phone to accelerate toward the ground at −9.8 m/s^2. Any object with a velocity has momentum, and as an object accelerates during free fall, its momentum increases. Upon reaching the ground, the ground exerts an upward, normal force that causes the momentum of the object to change. Figure L19.1 is an example of a momentum versus time graph for a cell phone that falls toward and then strikes the ground, bouncing upward once, and then coming to rest. Point A in the graph corresponds to the cell phone falling out of a person's hand. Between points B and C, the cell phone is hitting the ground, with the ground exerting a force on the cell phone, causing it to bounce back up. In other words, the segment of the graph between points B and C corresponds to the collision between the phone and the ground. At point D, the cell phone has reached the highest point of its bounce, and then at point E, the cell phone hits the ground and finally comes to rest at point F. The segment of the graph between E and F corresponds to the second collision between the phone and the ground.

FIGURE L19.1

Momentum versus time graph for a falling cell phone



Cell phones tend to break easily when dropped because they are made out of lightweight materials, such as glass, aluminum, and plastic, which have a relatively low breaking

point. The breaking point of a material is the maximum amount of force that it can absorb before it deforms. Companies make cell phones out of these materials because it allows the companies to make phones that are thin and light so they are easy to carry around. Unfortunately, a phone that is thin and light is also fragile.

Protective cases help alleviate this design trade-off. Protective phone cases tend to be made from a material that has two important characteristics. First, the material must be able to minimize the force that acts on the phone during a collision. This is important because the change of momentum associated with a phone in free fall suddenly hitting the ground is a vector that acts in the direction of the net force exerted on it. Second, the material must be able to maximize the time of the collision. This characteristic is important to consider because any change in momentum happens over a specific time interval. Your goal in this investigation is to use this information to identify a suitable material for a new protective cell phone case.

Your Task

Use what you know about momentum, impulses, the relationship between structure and function, and scale, proportional relationships, and vector quantities to design and carry out an investigation to compare how different materials change the momentum of an object during a collision.

The guiding question for this investigation is, ***Which material is most likely to provide the best protection for a phone that has been dropped?***

Materials

You may use any of the following materials during your investigation:

- Safety glasses or goggles (required)
- Dynamics cart
- Dynamics track
- Force sensor
- Sensor interface
- Computer, tablet, or graphing calculator with data collection and analysis software
- Foam block
- Plastic block
- Rubber block
- Wooden block
- Metal block

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Keep fingers and toes out of the way of moving objects.

3. Wash hands with soap and water after completing the lab.

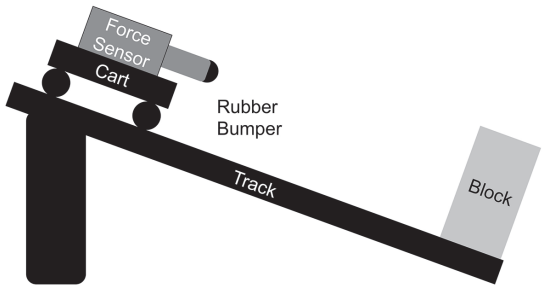
Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to investigate how different materials change the momentum of an object during a collision. Figure L19.2 shows how you can attach a force sensor to a cart and then roll it down a frictionless track on an incline. The end of the force sensor should collide with the material you are testing at the end of the track. Starting the cart at the same point on the track for each test will allow you to control for the momentum of the cart prior to the collision with the block. Before you can begin to design your investigation using this equipment, however, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

FIGURE L19.2

One way to examine the change in momentum of the cart after a collision with a specific material



To determine *what type of data you need to collect,* think about the following questions:

- How might changes in the structure of a cell phone case affect the function of the case?
- What are the components of this system and how do they interact?
- How can you describe the components of the system quantitatively?
- How do you quantify a change in momentum?
- What measurements do you need to make?
- What will be the independent variable and the dependent variable for your experiment?

To determine *how you will collect the data,* think about the following questions:

- What other variables do you need to measure or control?
- What scale or scales should you use when you take your measurements?
- Which quantities are vectors, and which quantities are scalars?
- For any vector quantities, which directions are positive and which directions are negative?

- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What type of calculations will you need to make?
- What types of comparisons will be useful?
- How could you use mathematics to document a difference between materials?
- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

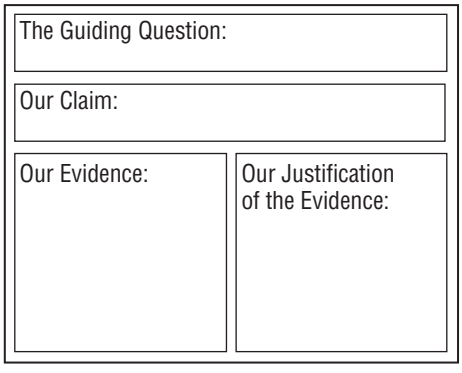
- how the culture of science, societal needs, and current events influence the work of scientists; and
- the nature and role of experiments in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L19.3.

FIGURE L19.3

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your

group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!