Lab Handout

Lab 13. Kinetic Energy

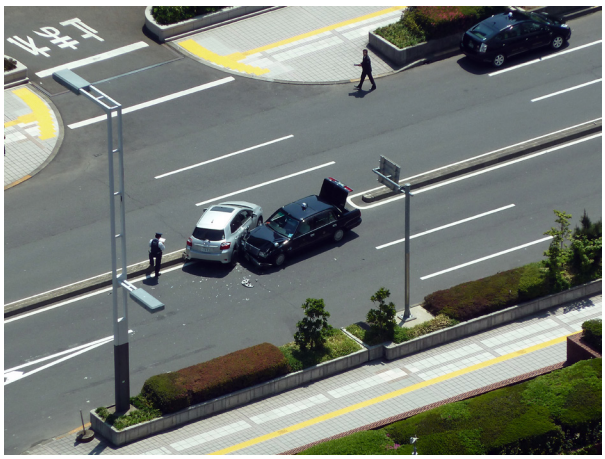
How Do the Mass and Velocity of an Object Affect Its Kinetic Energy?

Introduction

When law enforcement officials investigate car crashes (see Figure L13.1), it can sometimes be difficult to determine who is at fault and what laws were broken, especially when there is no footage of the crash. To re-create the crash scene, investigators use physics concepts to determine the specifics of a crash, including the speed and direction (together, the velocity) in which a car was traveling and when the driver attempted to stop. These figures can then be used to help determine who is at fault in a crash and the laws that person broke.

FIGURE L13.1

A police officer investigates a crash scene.



You already know that energy is conserved and transferred within and between systems, not created or destroyed. This is also true in car crashes. A traveling car has a certain amount of kinetic energy, and when that car hits another car or a different object, some of that energy is transformed into heat or sound, but most is used to do the work that deforms the car or object it crashes into. So, when cars collide, the transfer of their kinetic energy is responsible for the resulting damage. The damage done to the cars can be used, along with other pieces of evidence, to determine the velocity of the car.

In this investigation, you will be applying the same physics concepts to determine the mass or velocity of an object that has been dropped onto an inelastic surface (one that does not return to the same shape after impact). You will be creating a collision between a ball of variable mass and a large container of flour to investigate this relationship.

Your Task

Use what you know about force and motion, patterns, and causal relationships to design and carry out an investigation that will allow you to create a mathematical model explaining the relationship between mass, velocity, and force of impact.

The guiding question of this investigation is, **How do the mass and velocity of an object affect its kinetic energy?**

Materials

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

- Large plastic container filled with flour
- Racquetball with slit
- Funnel
- Rice or beans
- Meterstick
- Ruler
- String
- Stopwatch
- Electronic or triple beam balance
- Excel, graphing calculator, or other mathematical software (optional)
- Safety glasses or goggles

Safety Precautions

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

1. Wear sanitized indirectly vented chemical-splash safety goggles during lab setup, hands-on activity, and takedown.
2. Never put consumables in your mouth.
3. Sweep up flour off the floor to avoid a slip or fall hazard.
4. Do not throw objects.
5. Wash hands with soap and water after completing the lab activity.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in developing your mathematical model is to design and carry out an investigation to determine how mass and velocity affect the kinetic energy of the variable-mass ball. Because the kinetic energy of the ball will deform the flour surface during an impact, the extent of this deformation can be used to determine the kinetic energy of the ball at impact.

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

- What information do you need to create your mathematical model?
- What measurements will you take during your investigation?
- How will you determine the velocity of the ball?
- In what way will you vary the mass of the ball, if at all?
- How will you know how much kinetic energy has been absorbed by the flour surface?

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

- What equipment will you need to collect the data you need?

- 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 the data you collect?
- How will you organize your data?

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

- What type of calculations will you need to make?
- What type of table or graph could you create to help make sense of your data?

Once you have carried out your investigations, your group will need to use the data you collected to develop a mathematical model that can be used to help explain the relationship between the mass of an object, the velocity of the object, and the kinetic energy of the object. You should be able to use your mathematical model to predict any one of the three values when given the other two. For example, if given the kinetic energy measurement and the object's mass, you should be able to use your mathematical model to determine the velocity of the object at impact.

The last step in this investigation is to test your mathematical model. To accomplish this goal, you can predict the kinetic energy measurement of a ball with a given mass and velocity. If you are able to use your mathematical model to make accurate predictions about the object's mass, velocity, and kinetic energy, you will be able to generate the evidence you need to convince others that the mathematical model you developed is valid.

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

- the importance of identifying cause and effect;
- how scientists often need to track how energy moves into, out of, and within a system;
- the difference between laws and theories in science; and
- how scientists must use imagination and creativity when developing models and explanations.

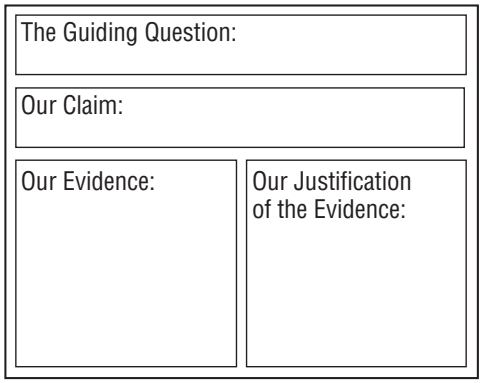
Initial Argument

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 L13.2.

FIGURE L13.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member 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 arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?
- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did your group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

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 most acceptable and valid answer to the research question!

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 and valid!