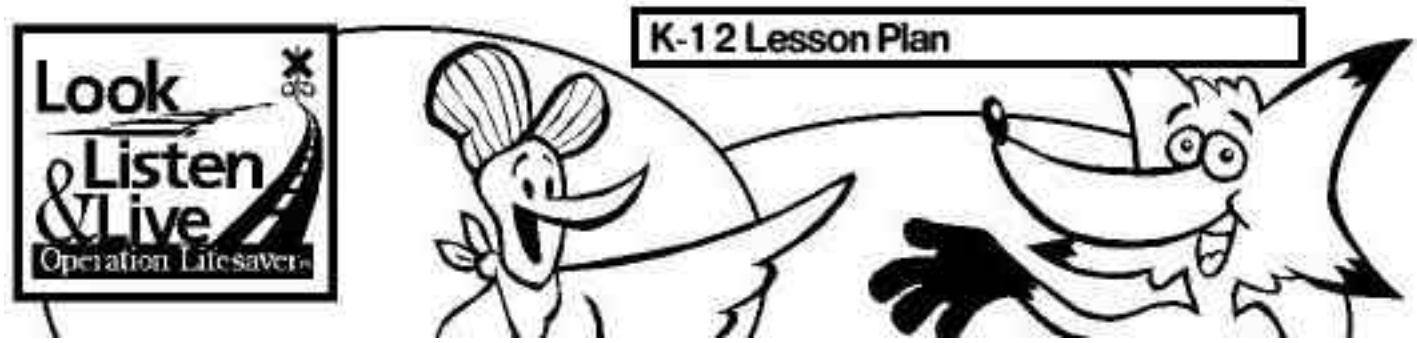

TRAIN VS. CAR: WHO WINS?

Grade: Ninth Grade

Subjects:

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SAFETY MESSAGE:

- You have no frame of reference to determine train distance and speed.

OVERVIEW

This lesson incorporates science concepts of mass, weight, velocity and forces to determine what happens when a train hits a car. Students conduct an experiment using easily accessible materials (grapes, aluminum foil and a weight) and then analyze the results. The language arts component can be expanded for use in a health/ safety or language arts curriculum. In such cases, students would do the experiment without the math problems.

SUGGESTED TIME ALLOWANCE

One or two 40-50 minute class periods

OBJECTIVES

Students will be able to:

- Understand the effects of collisions between objects of large and small mass.
- Analyze the results of a collision.
- Express observations in different forms through discussion and

writing.
- Utilize group problem-solving skills within the parameters of an experiment.
- Extrapolate the connection between the experiment and safety messages presented.

National Academic Content Standards addressed by this lesson.

MATERIALS

Per student:

- Experiment sheet

Per group:

- 1.3 grams or 15 cm x 8 cm of aluminum foil (Note: You may need to adjust the size of the piece of aluminum foil since different brands of foil vary considerably.)
- 3-4 red grapes (or suitable "squishable" substitute)

For the class:

- 5 kg (or 11 lb) weight, unbreakable (a 10-lb. weight from a weight room can be used; adjust ratios accordingly)

VOCABULARY

Mass, weight, velocity

PROCEDURES

TEACHER PREPARATION:

Review background information on driving and *Die Hard Teacher's Guide*. Also, determine if you will be using the math problems as part of this lesson. If so, review the problems and their solutions.

MOTIVATION:

Provide students some real-life examples of the effects of force and mass: *How many of you have ever seen a car after a terrible car crash? A house that has been crushed by a tree that has fallen? If necessary, review force, mass and velocity with your students.*

Today we're going to simulate the effect of a train hitting a car in order to determine what happens.

ACTIVITY:

1. Lead in to the activity, explaining the experiment that students will conduct. The experiment simulates a train hitting a car at 12 mph (weight dropped from a height of 7 feet). You need to place something to cushion the fall and deaden the noise when you drop the weight on the car (e.g., cushion, carpet scrap, etc.) Also use paper towels to absorb the juice from the crushed grapes.
    - Weigh a piece of aluminum foil equal to 1.3 grams. You can have the students weigh the foil or give them the weight of the foil to record on their data sheet.
    - Make the foil into a "car" and place grapes into the car.
    - Write a scenario about the car and the people in it.
    - Have students take their cars to the grade crossing (Place where weight is dropped).
    - Drop the weight on the cars and have students clean up the crash.
    - Write an incident report and conclusion.
    - Discuss the results of the experiment.
    - Do the calculations to prove the forces involved.
    - Do the five math problems, if instructed. (Note: Eliminate any or all problems, depending on students' abilities and focus of class.)
2. Review formulas with students: Review momentum formula with students M = m x v. Also go over the velocity and distance formulas. d = r x t and d = 1/2 a x t2.
3. Have student groups of 2-4 use the Collision Experiment Data Sheet to complete the experiment. Students should come up with their calculations and then write their conclusions. To calculate speed of the falling weight use this equation: d = 1/2 a x t2 where a is acceleration due to gravity (32 ft/sec2

or 9.8 m/sec2) and d is height weight dropped from. t for 7 ft is .66 sec and for 10 ft is .79 sec. To find final velocity, d = (vf - vi)/2 x t. vf is 21.2 ft/sec for 7 feet and 25.3 ft/sec. Convert to mph by dividing by 1.46 and you get 14.5 mph and 17.0 mph respectively. You can do these calculations for any height.

4. Have students write an incident report, as if they were a police officer on the scene of the crash just witnessed. Have them interview members of the class who serve as the witnesses and write the details of what happened.
5. Discuss the results of the experiment in connection with safety messages. *Why are these messages important?* Consider the following train facts during discussion:
    - Most locomotives weigh 125-225 tons, depending on the size of the locomotive.
    - Weights of freight cars vary from 30-50 tons when empty to 80-100 tons or more when loaded.
    - The ratio of an average freight train (8000 tons) to an automobile is about 4000:1.
    - Trains use a mechanical air brake system and the air must be to each car before the brakes are applied and the train begins to stop. This takes several seconds, so a train will travel several hundred feet before full braking occurs. This is the reason that it takes a considerable distance (up to 1 1/2 miles) for a freight train to stop.
    - When lights begin flashing at a crossing, the train will be at the crossing about 20 seconds later.
    - Use the Laws of Momentum to illustrate to students the forces involved. Example: An 8,000 ton train traveling at 50 mph would have a momentum of 400,000 tons mph. For a car to have the same momentum, it would have to travel 200,000 mph. This is completely impossible and is 265 times the speed of sound.

CONCLUSION:

Have students present their incident reports. In language arts classes, expand on the writing and discussion by including the newspaper article activity detailed in the extensions to this lesson.

HIGHER ORDER THINKING

To assure students are using critical thinking skills, present questions such as this at appropriate places within the lesson: *Why is it difficult to determine the distance and speed of an approaching train? (no frame of reference) What analogies can you make to other circumstances in life? (e.g., a shooting star, an airplane coming in for a landing, etc.)*

ASSESSMENT

- Discussion about the experiment (Understand the effects of collisions between objects of large and small mass.)
- Data sheet and written reports (Analyze the results of a collision.)
- Incident report and scenario (Express observations in different forms through discussion and writing.)
- Teacher observation and group completion of experiment and written work (Utilize group problem solving skills within the parameters of an experiment.)
- Discussion after experiment (Extrapolate the connection between the experiment and safety messages presented.)

EXTENSIONS

Science/Math: Have students devise a similar experiment.

Social Studies: Have students interview local police to obtain information about real crashes that have occurred in their neighborhood, then present their findings to the class.

Language Arts: Have students play reporter and write a newspaper article that details the incident they "witnessed" during their experiment, as if it were real. The point of view of the survivors should be included in the article.

TEACHER RESOURCES

Solutions to math problems
Background information on driving
Die Hard If You're Dumb video
Die Hard teacher's guide
Die Hard video clips (Quicktime Required):

- Vehicles Crash with Train
- Three Areas of Railroad Safety
- Trespassing Facts
- Judging Train Speed

Video utilization tips for *Die Hard If You're Dumb*

NATIONAL ACADEMIC CONTENT STANDARDS

These standards are provided by the Mid-continent Regional Educational Laboratory (McREL) online publication, Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education. <http://www.mcrel.org/standards-benchmarks/>

The following standards are addressed by the activities of this lesson:

Language Arts
Level IV: High School (Gr. 9-12)
Standard 1: Demonstrates competence in the general skills and strategies of the writing process
Benchmarks:

- Writes compositions that fulfill different purposes (e.g., to reflect, to analyze, to persuade)
- Writes fictional, biographical, autobiographical and observational narrative compositions (e.g., narrates a sequence of events; evaluates the significance of the incident; provides a specific setting for scenes and incidents; provides supporting descriptive detail, etc.)

Life Skills: Thinking and Reasoning
Level IV: High School (Gr. 9-12)
Standard 4: Understands and applies basic principles of hypothesis testing and scientific inquiry
Benchmark: Presents alternative explanations and conclusions to one's own experiments and those of others

Mathematics
Level IV: High School (Gr. 9-12)
Standard 1: Uses a variety of strategies in the problem-solving process
Benchmark: Uses formal mathematical language and notation to represent ideas, to demonstrate relationships within and among representation systems, and to formulate generalizations

Standard 3: Uses basic and advanced procedures while performing the processes of computation
Benchmarks:

- Adds, subtracts, multiplies, divides and simplifies rational expressions
- Uses a variety of operations (e.g., finding a reciprocal, raising to a power, taking a root, taking a logarithm) on expressions containing real numbers

Science
Level IV: High School (Gr. 9-12)
Standard 12: Understands motion and the principles that explain it
Benchmark: Knows that laws of motion can be used to determine the effects of forces on the motion of objects

Standard 15: Understands the nature of scientific inquiry
Benchmark: Designs and conducts scientific investigations by formulating testable hypotheses, identifying and clarifying the method, controls and variables; organizing and displaying data; revising methods and explanations; presenting the results; and receiving critical response from others

To see related standards for your state, search Achieve's Clearinghouse: < http://www.achieve.org/achieve/achievestart.nsf/Search?OpenForm>

COLLISION EXPERIMENT DATA SHEET

Name_____

Objective: To observe the effect of collision of objects of unequal masses.

Procedure:

1. Obtain a sheet of aluminum foil.
2. Make it a rectangle about 15 cm by 8 cm.
3. Record its mass.
4. Make the foil into the shape of a closed container, i.e. car.
5. Obtain 2 or 3 red grapes and place them in the container.
6. Tightly close the container.
7. Write a short essay on a separate piece of paper about the “car” and the “people” (grapes) in it.
8. Your “car” will be in a collision as instructed by your teacher.
9. Clean up after the accident.
10. On the same paper as your essay, write the results of the collision.
11. Write a conclusion for this experiment.

Data:

Mass of Car _____ Mass of Weight Used _____

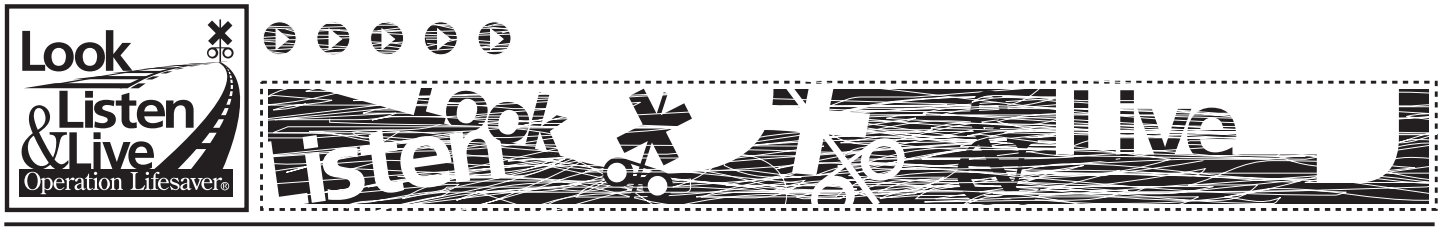
Ratio of Weight / Car _____

Calculations:

1. Find the velocity of the weight when it hit your car.

2. The mass of a train to a car is about 4000:1. How did your “car” compare to the mass of the weight?

Conclusion:



Solve the Following Problems: (Show work on separate paper)

1. The weight ratio of a freight train to a car is 4000:1. Using this ratio, what weight of aluminum can would be crushed by a person weighing 150 lbs.?

2. Find the momentum of a 6500 ton train traveling at 40 mph. If a 2-ton car had the same momentum as the train, what would the velocity of the car be? How many times the speed of sound is this?

3. Trains are equipped with air brakes, which apply from the locomotive to the end of the train car by car. This process averages about 12 seconds plus 4 seconds for the engineer to apply the brakes. How far does the train travel if it is going 50 mph (74 ft/sec) before the brakes are applied and the train begins to slow down and stop?

4. A car of 4000 lbs is struck by a train traveling at 45 mph. If the train weight is 12,000 tons, what is the velocity of both train and car after impact? Assume the car becomes attached to the locomotive.

5. A motorist stops at a railroad crossing because the lights are flashing. The train is 500 feet away and going 45 mph. The motorist is in a hurry and after waiting 4 seconds decides to cross the tracks. If his car accelerates at 5 ft/sec^2 and the distance he must travel to clear the track is 50 ft, is a 911 call necessary. (Support your answer mathematically.)

Formulas Needed:

Momentum = mass x velocity

Distance = velocity x time

Distance = 1/2 acceleration x (time)^2

Speed of sound is 750 mph

To convert mph to ft/sec, multiply mph by 1.46.

PROBLEM SOLUTIONS

1. Use ratio 4000/1 = 150 lbs/lb x = 0.0375 lbs x 16 oz/lb = 0.6 oz (About a third the mass of an average empty aluminum pop can.)

2. M = mass x velocity Mtrain = 6500 tons x 40 mph = 260,000 tons mph.

   Therefore 260,000 tons mph = 2 tons x v car

   V car = 130,000 mph Divide by speed of sound (1090 ft/sec or 747 mph) =174 times greater than speed of sound.

3. Distance = velocity x time
   Distance = 74 ft/sec x 16 sec = 1184 ft. (3 3/4+ football fields)

4. Momentum before collision = momentum after collision
   12,000 tons x 45 mph = 12,002 tons x velocity after velocity after = 44.99 mph

5. Train Distance = velocity x time 500 ft = 65.7 ft/sec x t
   t = 7.6 sec for train to reach crossing.
   Car Distance = 1/2 a x t^2 50 ft x 2 = 5 ft/sec^2 x t^2
   t^2 = 20 sec^2 t = 4.4 sec to travel 50 ft
   4.4 sec + 4 sec wait time = 8.4 sec
   Call 911 as train reached crossing .8 sec before car.