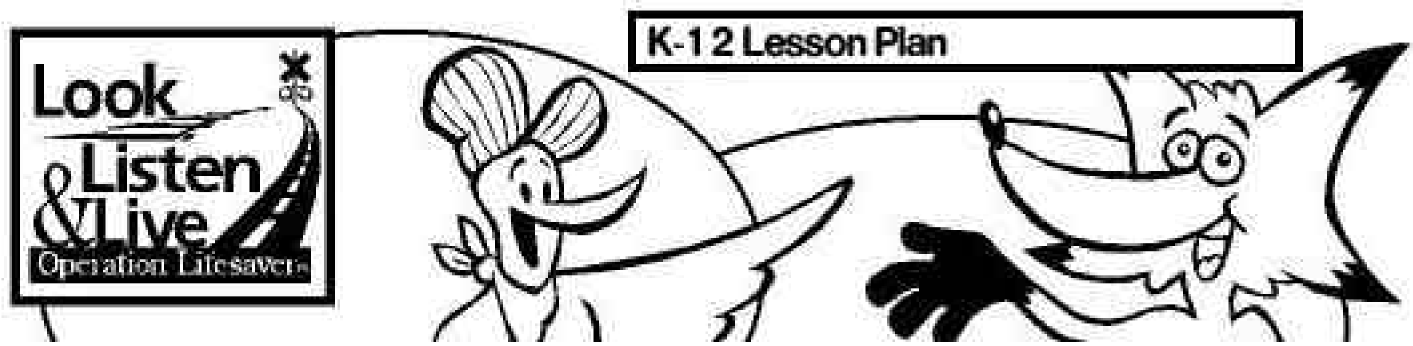

Hit and ????

Grade: Eleventh and Twelfth Grades

Subject: 

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OVERVIEW

This lesson provides three options for completing a lab experiment, depending upon the equipment available. The lab demonstrates the effects of the impact between a train and a car and illustrates the principle of momentum before and after collisions.

SUGGESTED TIME ALLOWANCE

One or two 40-50 minute class periods, depending upon version of experiment done

OBJECTIVES

Students will be able to:

- Demonstrate the effects of impact between a train and a car.
- Discuss difference between size and mass.
- Analyze change in momentum before and after collision.
- Relate the experiment to train-car incidents that can occur if safety messages are not followed.

SAFETY MESSAGE:

- If your vehicle stalls on a railroad crossing, everyone should get out of the vehicle and run in the direction of the train and away from the tracks.

National Academic Content Standards addressed by this lesson.

MATERIALS

Physics Problems Handout – one per student

Activity 1:

- 1000 gram solid weight
- Ring stand with large ring
- Facial tissue
- Scotch or masking tape
- One pea from a can of peas

Activity 2:

- Pitsco basswood CO2 cars
- CO2 cartridges with detonator
- Fish line (60 feet)
- Wooden blocks and screw eyes
- 1 box toothpicks
- 1 can of peas
- Small piece of modeling clay

Activity 3:

- Air track

VOCABULARY

Mass, velocity, speed, momentum

PROCEDURES

TEACHER PREPARATION:

Refer to the teacher's guide for solutions to physics problems. Review the difference between velocity and speed, if necessary, in order to lead discussion with students. If using an air track, test it out before use and develop the third activity more thoroughly, based upon activity #2. Refer also to the general background information about trains and railways.

MOTIVATION:

Give different-sized matchbox cars to three students. Have them come up in the front of the room and play with the cars, making sure to demonstrate collisions. Ask the rest of the class to observe what happens to the cars' positions before and after collisions: *What do you note about the impact on a car that is in motion when it is hit? A car that is standing still when it is hit? The car that is being hit vs. the car that is hitting?* Also, have students notice the different sizes of the cars and how this might affect what happens to the car. Lead in to description and purpose of lab experiment.

ACTIVITY:

Choose the option that works best for your class.

Activity 1- Students follow these steps:

1. Place a single layer of tissue across the large ring and tape it down.
2. Set the pea in the middle of the tissue and set the ring stand on the floor. The pea represents the car.
3. Suspend and tether the weight about five feet above the ring. (The weight represents the train.)
4. Drop the weight. (Be sure the weight stops before it hits the ground.)
5. Observe the pea after the collision and any change in the speed of the weight.
6. Write a conclusion.

Activity 2- Students follow these steps:

1. Assemble a car (per kit instructions) to represent a train.
2. String 60 feet of fish line, on which the car will run. Attach the line to screw eyes on wooden blocks at each end.
3. Place a pea on a toothpick to represent a car and put it on a piece of modeling clay or tape.
4. Detonate the CO2.
5. Observe what happens to the speed of the "train" and effect on the "car."

6. Write a conclusion.

Activity 3- Set up an experiment similar to Activity 2 using the air track.

CONCLUSION:
After students complete the activity, have them work out the physics problems provided on the student worksheet. Discuss momentum, force and impact during collisions, as observed in experiments. Emphasize car-train collisions. Review relationship of experiment to safety messages.

HIGHER ORDER THINKING

To assure students are using critical thinking skills, present questions such as these at an appropriate place within the lesson: *What different things could happen to a car during/after a collision? List at least three examples. Why do these different things happen?* Discuss forces, differences in velocity, speed and mass of trains.

ASSESSMENT

- Completion of lab activity as member of a group (Demonstrate the effects of impact between a train and a car.)
- Participation in discussion (Discuss difference between size and mass.)
- Completion of problems on worksheet and conclusions (Analyze change in momentum before and after collision.)
- Discussion (Relate the experiment to train-car incidents that can occur if safety messages are not followed.)

EXTENSIONS

Language Arts/Communications: Have students produce a short video to demonstrate why safety messages should be followed.

Driver's Ed: Have students present their findings to a class of students who are preparing for their driver's permit.

TEACHER RESOURCES

Die Hard If You're Dumb video
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*
Teacher's guide for physics problems
General background information

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
Benchmark: Writes compositions that fulfill different purposes (e.g., to reflect, to analyze, to persuade)

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
Benchmark: Adds, subtracts, multiplies, divides, and simplifies rational expressions
Benchmark: 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>

Physics Problems: Solve the Following

Your teacher will provide you with appropriate formulas.

1. A 100-car freight train weighing 15,000 tons is traveling at 50 mph when the engineer sees the signal suddenly turns red and applies the brakes. How far (in feet) does it take the train to stop if the braking force is 500 tons? How many seconds does it take to stop? (Assume it takes 15 sec. for the brakes to fully apply and begin stopping the train.)

2. A passenger train is traveling at 79 mph. It has 10 cars weighing 45 tons each and 1 locomotive of 200 tons. After the brakes are applied, it stops in 1300 ft. What braking force was needed?

3. A 70 car trailer train is traveling 60 mph when the engineer sees a pick-up truck stuck on the tracks. Fifty of the cars are loaded and weigh 80 tons each and 20 are empty and weigh 30 tons each. The train is powered by 3 locomotives weighing 200 tons each. If the engineer puts on the emergency brakes, determine the stopping distance (in feet) of the train. Braking force of each car is 10,200 lbs. Be sure to add the distance the train travels while the engineer is applying the brakes and the time the air travels through all 70 cars - 18 seconds. Assume braking does not occur until air reaches the last car.

4. A train traveling 125 mph can make a stop in 5500 ft. What is the deceleration rate of the train?

5. A 30-ton boxcar is traveling at 2 ft/sec and hits a stationary 55 ton boxcar. The 55-ton boxcar obtains a velocity of 1.2 ft/sec. What is the velocity of the 30 ton car?

PHYSICS TEACHER'S GUIDE: SOLUTIONS TO PROBLEMS (Page One of Two)

All problems are based on kinetic energy formulas and/or laws of momentum.

$KE = Fd$ $\qquad$ $KE = 1/2\ mv^2$ $\qquad$ Momentum $= m_1v_1 + m_2v_2$

Terms

d = Distance (ft) $\qquad$ W_T = Weight of train (tons) $\qquad$ v = velocity (mph)

F_b = braking force (lbs) $\qquad$ t = time (sec)

Braking Force (F_b) is an average calculated from the weight of the car x braking ratio x efficiency of braking system x coefficient of friction of steel wheels on rail. Average values are 10,200 lbs for a freight car and 20,500 lbs for a passenger car. (THIS IS PER CAR)

Railroad specific formulas based on kinetic energy are:

$$d = \frac{70 \times W_T \times v^2}{F_b} \qquad t = \frac{95.6 \times W_T \times (v_i - v_f)}{F_b}$$

Constants

$\dfrac{70 \text{ lbs ft hr}^2}{\text{tons miles}^2}$ Derived from unit conversions mph to ft/sec and tons to lbs.

$\dfrac{95.6 \text{ lb hr sec}}{\text{ton miles}}$ Derived from unit conversions similar to proceeding constant.

To convert mph to ft/sec, multiply mph x 1.46

ANSWERS

1. (a) $d = 70 \times W_T \times v^2 / F_b$

$d = 70 \times 15{,}000 \text{ tons} \times (50 \text{ mph})^2 / 500 \text{ tons} \times 2000 \text{ lbs/ton}$

$d = 2625$ ft.

Distance traveled before brakes apply = v(ft/sec) x time (sec)

$d = 73 \text{ ft/sec} \times 15 \text{ sec} = 1095 \text{ ft}$

Total distance = 2625 ft + 1095 ft = 3720 ft

(b) $t = 95.6 \times W_T \times v / F_b$

$t = 95.6 \times 15{,}000 \text{ tons} \times 50 \text{ mph} / 500 \text{ tons} \times 2000 \text{ lbs/ton}$

$t = 71.7$ sec $\qquad$ Total time = 71.7 sec + 15 sec =86.7 sec

2. Rearranging distance formula $F_b = 70 \times W_T \times v^2 / d$

$F_b = 70 \times 650 \text{ tons} \times (79 \text{ mph})^2 / 1300 \text{ ft} = 218{,}435 \text{ lbs}$

PHYSICS TEACHER'S GUIDE: SOLUTIONS TO PROBLEMS (Page Two of Two)

3. W_T = 50 x 80 tons + 20 x 30 tons + 3 x 200 tons = 5200 tons

   $d = 70 \times W_T \text{ X } v^2 / F_b$

   d = 70 x 5200 tons x (60 mph)^2 / 70 cars x 10,200 lbs = 1836 ft

   Distance before brakes apply = 18 sec x 88 ft/sec = 1584 ft

   Total distance = 1836 ft **+** 1584 ft = 3420 ft

4. $(v_f - v_i)^2 = 2\ a \times d$ (182.5 - 0 ft/sec)^2 = 2 a x 5500 ft

   a = -3.0 ft/sec^2

5. $m_1v_1 + m_2v_2 = m_{1A}v_{iA} + m_{2A}v_{2A}$

   30 tons x 2 ft/sec **+** 55 tons x 0 = 30 tons x v_{iA} **+** 55 tons x 1.2 ft/sec

   60 tons ft/sec **-** 66 tons ft/sec = 30 tons x v_{iA}

   - 6 tons ft/sec = 30 tons x v_{iA}

   - 0.2 ft/sec = V_{iA}