STUDENT ACTIVITY

Name: _____ Class: _____ Date: _____

CRASH SCIENCE IN THE CLASSROOM

PAPER CAR CRASH!

MATERIALS

Provided by teacher for each student or pair of students

- Two sheets (8½ in. x 11 in.) copy paper
- Four wheels
- Two axles
- One plastic drinking straw (only to be cut and used for axle housings as explained by your teacher)
- Access to a metric balance
- One large, Grade A raw egg (NOTE: Wash hands thoroughly with soap and water after handling raw eggs, especially if they crack or break!)
- One to two copies of the "Paper Car Crash" Student Activity Sheet

Materials you will need to build your car outside of class:

- Glue (low-temp glue sticks and glue guns recommended)
- Scissors
- Centimeter ruler
- Colored pencils, crayons, and markers for vehicle decoration (no stickers or paint)

Key Question

- Is it possible to build a car frame and body from paper and glue that is strong enough to protect a raw egg during a head-on collision?
- What engineering and design features determine a vehicle's crashworthiness?

Purpose

The objective of the Paper Car Crash Contest is to apply your science and engineering knowledge and skills to design and build the most crashworthy car that includes a minimum of three safety design features. The winning car's crashworthiness will be based on two criteria:

1. The car with the greatest momentum at the time of collision, and,
2. A car in which the occupant (raw egg) is neither injured (cracked shell) nor killed (broken shell) as a result of the collision.

Grouping Format

You may work alone or with a partner.

Safety Warning

Hot glue and glue guns can burn. Please use caution if using hot glue guns. Low-temp glue guns are recommended and also work very well.

Design Considerations

Successful science and engineering inquiry requires a variety of skills to identify problems/needs, create initial design plans, and test, change, and improve designs. Habits of mind and other traits such as logical reasoning, patience, insight, energy, creativity, persistence, and openness to new ideas must be combined with a sound knowledge base in order to succeed. To assist with your design process, consider the following questions:

- Should your vehicle be rigid and strong (like a 1950s muscle car) or is it better if it collapses (like an Indy racing car)?
- Should the occupant (egg) be able to move freely in the vehicle or should it be strapped tightly to the vehicle?
- How can your vehicle be designed to easily remove and inspect the egg after a crash?

Design Product/Presentation

Your challenge is to design and build a car with the greatest momentum (i.e., fast and massive) using only two sheets of copy paper and unlimited amounts of glue for the car's frame and body. Your paper car must be able to carry a raw egg down an inclined track ramp and protect it during a crash with a concrete block. Your teacher will provide the wheels, axles, and axle housing for construction of your car. Read the Rules & Specifications listed below before beginning your design process and remember that in order to win, you must have BOTH a car with the greatest momentum AND an egg occupant that survives the crash unharmed.

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Design Product/Presentation (continued)

On the day before the car crash contest, you must introduce your design to the class and identify at least 3 safety design features you incorporated into your car's design.

Design Timeline

You have 1-2 weeks to design and build your car (your teacher will specify the exact due date). Approximately 100 minutes of class time (two 50-minute periods) will be provided for design brainstorming, vehicle building, vehicle testing, and design revision. The rest of your work should be completed on your own time.

Rules & Specifications

1. Maximum car width: less than equal to 6.5 centimeters (including axles and wheels)
2. Maximum car length: less than or equal to 16.5 centimeters
3. Minimum car mass without the egg: greater than or equal to 40 grams
4. Glue, paper, wheels, axles, and the straw-axle housing are the only construction materials allowed. The entire frame of the car must be made of paper and glue.
5. Your vehicle will be disqualified if it exceeds length and width dimensions, does not meet minimum mass requirements, or contains stickers, paint, tape, cardboard or any other non-licensed materials that contribute to the structural integrity of the vehicle.
6. Vehicle designs must allow for easy access to and removal of the egg (occupant) for inspection after the crash.
7. Vehicle designs should be able to withstand 2-3 trials/collisions without parts replacement or repairs.
8. There can be no physical contact between the vehicle and the designer once the vehicle has been released onto the track.
9. All vehicles must visibly display the following information on their frames:
   a. vehicle name
   b. builder's name
   c. vehicle length in centimeters
   d. vehicle mass in grams

Assessment Options

In addition to completing the design, construction, and crash-testing process for your car, your teacher may also assess your project by one of the following two options:

***Option 1** - Project Assessment Categories (50 Total Points)*

CATEGORY	POINTS	DESCRIPTION
Quality of construction	20	Construction of car shows evidence of time and effort invested in the building process.
Performance of car	10	Car swiftly carries the egg the entire length of the track during test runs. Car does not drag due to excess friction between car parts.
Car specifications	5	Car meets required specifications of length, width, and mass.
Crash report	15	Report thoroughly and accurately communicates data and calculations. (See specific report criteria below.)
Total	**50**	
Extra credit (optional)	+1	Cars that keep the egg from cracking receive 1 point of extra credit per successful completion of each round of competition.

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Crash Report Criteria for Option 1 (15 Points)

» Submit a report addressing Items 1-4.

» Report should be double-spaced, 12-point font, Times New Roman.

1. **Purpose (2-3 paragraphs, 4 points)**

a. Describe the project's challenge and rules. What factors determine the winner?

b. Describe how you applied your understanding of momentum and impulse to design a safer car.

c. Define and discuss impact force and impact time. What is their relationship to each other? How are they related to impulse and the change in momentum?

d. How do crumple zones and airbags affect impact time and impact forces to keep you safe during a collision?

2. **Photograph or Diagram (2 points)**

a. Include a photograph or large hand-drawn picture of your vehicle.

b. Label key design features.

3. **Data Table (3 points)**

Construct a 2-column data table that includes the following, including units:

a. distance traveled by car (cm)

b. time of run (seconds)

c. width of car (cm)

d. length of car (cm)

e. mass of car without egg (grams)

f. mass of car with egg (grams)

4. **Calculations (6 points)**

Show all equations and calculations used to obtain the quantities listed below:

a. Convert distance traveled by your car from centimeters to meters.

b. Convert mass of your car with the egg from grams to kilograms.

c. Calculate average velocity (m/s):

Average velocity =
total distance traveled by car in meters ÷ total time from stopwatch of distance traveled in seconds

d. Calculate the car's average momentum upon impact (kg x m/s):

Momentum = (total mass of car with egg) x (average velocity)

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Option 2 *- Project Assessment Categories (70 Total Points)*

CATEGORY	POINTS	DESCRIPTION
Creativity of design	6	Overall design or particular features of car design are unique.
Quality of construction	10	Construction of car shows evidence of time and effort invested in the building process.
Performance of car	7	Car swiftly carries the egg the entire length of the track during test runs. Car does not drag due to excess friction between car parts.
Car specifications	7	Car meets required specifications of length, width, and mass.
Crash Report	40	Report thoroughly and accurately communicates data and calculations. (See specific report criteria below.)
Total	**70**	
Extra credit (optional)	+1	Cars that keep the egg from cracking receive 1 point extra credit per successful completion of each round of competition.

Crash Report Criteria for Option 2 (40 Points)

» Submit a report fully addressing Items 1-9.

» Report should be double-spaced, 12-point font, Times New Roman

1. **Purpose (2-3 sentences, 3 points)**

Provide a brief statement describing the project's challenge and rules. What factors determine the winner?

2. **Materials (2 points)**

List materials and quantities used to construct your vehicle.

3. **Methods (2 paragraphs, 5 points)**

Describe your building process. Summarize the problems you encountered during the building process and how you solved them.

4. **Photograph or Diagram (1 page, 2 points)**

a. Include a photograph or large hand-drawn picture of your vehicle.

b. Label key design features (e.g., crumple zones, safety cage).

5. **Data Table (4 points)**

Construct a data table that provides the following (include measurement units)

a. distance traveled by vehicle (cm)

b. total time of run (measured with stopwatch in seconds)

c. width of vehicle (cm)

d. length of vehicle (cm)

e. mass of vehicle without egg occupant (g)

f. mass of vehicle with egg occupant (g)

g. width of photogate flag (cm), (if photogate used)

h. time for photogate flag to pass through photogate timer at end of run (s), (if photogate used)

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Crash Report Criteria for Option 2 (continued)

6. **Calculations (8 points)**

Show all equations and calculations used to obtain the quantities listed below:

» If a photogate was used, use the final velocity to calculate momentum. Otherwise, use the average velocity, but realize this will only provide an estimate of the vehicle's final momentum.

a. Convert distance traveled by your car from centimeters to meters.

b. Convert mass of your car with the egg from grams to kilograms.

c. Final velocity using a photogate:

Convert width of photogate flag from centimeters to meters.

Final velocity (m/s) = width of photogate flag (in meters) ÷ photogate time (in seconds)

d. Average velocity using a stopwatch (no photogate):

Average velocity (m/s) =
total distance traveled by car in meters ÷ total time from stopwatch of distance traveled in seconds

e. Calculate the vehicle's momentum before impact using this equation:

Momentum (kg x m/s) = (total mass of vehicle with egg in kg) x (final or average velocity in m/s

7. **Performance Assessment (2-3 paragraphs, 8 points)**

a. Citing your own measured and calculated data, describe the performance of your vehicle and whether or not it met your expectations.

b. Compare your vehicle's performance to another vehicle in the class.

» What were the strengths and weaknesses of each design?

» Cite data and calculations to support your conclusion.

c. There is always room for improvement in a design. How would you modify your car to improve its performance?

8. **Conclusion (3-4 paragraphs, 8 points)**

a. Identify at least three engineering or design features that determined your vehicle's crashworthiness.

b. Define and discuss impact force and impact time. What is their relationship to each other? How are they related to impulse and changing an object's momentum?

c. How do crumple zones and airbags affect impact time and impact forces to improve a vehicle's crashworthiness?