Forces, motion and egg-xtreme impacts

How does designing cars to crumple and crush during crashes make them safer?

If you were to look at old photographs or footage of car accidents in the 1950's, and compare them to accidents in modern times, you could very easily think that engineers have gone backwards and made vehicles less safe. To understand why, we need to investigate the physics of collisions.

Early automobile design theories saw extremely rigid bodies that were very resistant during an accident and didn't allow too many deformations. As a consequence, all the forces were transferred to the occupants, most of the times this being quite fatal.

One of the most important safety advances was the developments of "crumple zones", which are structures designed to deform and crush in a controlled way, which does damage to the car but not to the occupants. Because of this, car crashes today look really bad with mangled vehicles, but it actually keeps the passengers much safer.

A change in "momentum" happens when a force is applied to an object that is moving or is able to move. The faster the change in momentum, the greater the force involved. Crumple zones do two things: they absorb energy by the crumpling, and slow down the collision which reduces the change in momentum.

In this workshop you will experiment with how mass and speed contribute to collisions, and how much protection/crumple zone is needed to protect a very fragile occupant – a raw egg!

Did you know?

532 cars were destroyed in the making of the Transformers 3 movie!

The Experiment – Protecting eggs from falling weights

Aim: To find out how much impact energy (via height and mass) a rubber crumple zone can withstand, to protect an egg from breaking.

Materials

The demonstrator will split you into groups. Each group is assigned a length of rubber crumple zone, and a weight to drop.

1. Write down the weight your group has been assigned (in kg): _______________ This is called "m"
2. Measure the length of rubber crumple zone (in m): _______________ This is called "L"

Step 1:

Place the egg in a plastic bag, and then into the semi-transparent end cap. Make sure the egg is placed upright, with the larger end towards the bottom.

Step 2:

Place the rubber crumple zone into the end of plastic pipe, and then attach the end-cap (with egg) to the same end.

Step 3:

Place the weight into the open end of the pipe, holding it by the string. Lower the string all the way slowly until it gently touches the top of the crumple zone. Place a clip on the string to mark the top of the pipe.

Step 4:

Using the clip for reference, raise the weight 0.1m (10cm). Drop the weight onto the egg+crumple zone. Undo the end-cap and check whether the egg has broken. Indicate whether the egg has broken (cross) or not (tick) for the 0.1m column in Table 1.

Step 5:

Repeat steps 3 and 4, raising the weight to the increasing heights in Table 1. until the egg finally breaks.

Step 6:

Select a new egg. Repeat the previous steps, beginning with the highest successful (unbroken egg) height first. Do your repeat trials agree?

Table 1. Does the egg break when the mass is dropped from different heights? Use a tick for not broken; and a cross for broken.

Height (m)	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
First Egg								
Repeat Eggs								

Step 7:

Choose the best egg trial. Look across the row in Table 1 and answer the following:

3. What is the largest height that the egg survives? ________ Write into Table 2 at (A)
4. What is smallest height that the egg breaks? ________ Write into Table 2 at (B)

Discussion Point

What do these two heights represent? Do we have to make any assumptions?

Calculations

You will now perform calculations to find out the impact energy that the falling mass imparts to the egg+crumple zone. The formula for Impact Energy is:

Impact Energy = Mass x g x Height

Where: Mass = your test weight

g = the gravitational constant (10 m/s^2)

Height = Height of drop

Calculate the energy for two heights – one for just before the egg breaks (A) and one for just after (B). This will give you a range for which the crumple zone will stop protecting the egg. Use the values for m, (from Q1), and A and B (from Q3 and Q4). Record your results in Table 2.

Table 2. Finding the kinetic energy for egg breakage using crumple zone ______ and weight ______

A (Lower Height)	**Impact Energy** mgA	**B** (Upper Height)	**Impact Energy** mgB

The demonstrator will collate the data from the groups and make a plot of Impact Energy vs Crumple Zone Length, using the information from A and B to make error bars. The exact impact energy required to break the egg will be somewhere between the error bars.

The demonstrator will fit a line of best fit through the data points.

Make a prediction

What is the minimum length of rubber crumple zone needed to protect a mass of 50 grams, dropped from a height of 3 metres? Hint: the first calculate the impact energy.

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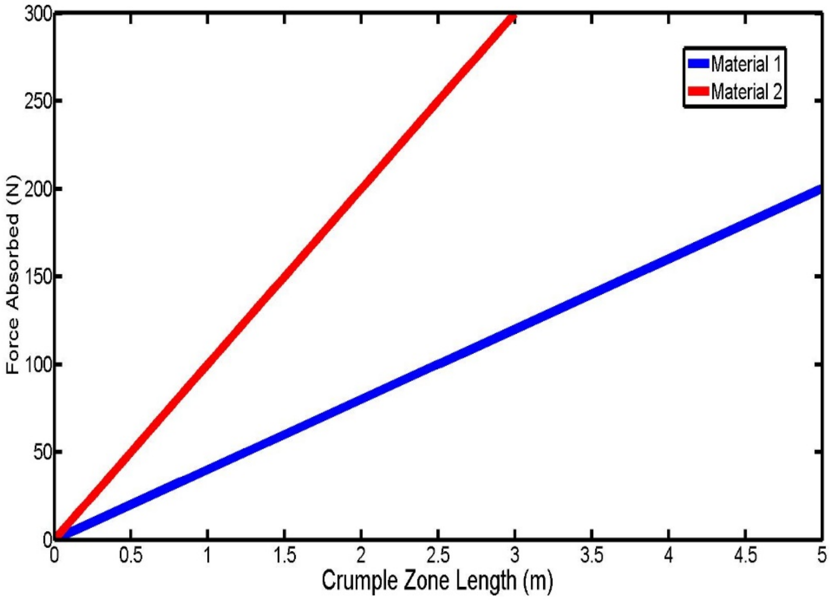
he demonstrator will now test the predictions, working from largest crumple zone length to smallest.

How close was your prediction?

Want to see Mini Coopers being crashed in slow motion?

Check out http://www.youtube.com/watch?v=5GSwXJhwiGE

Challenge



This graph shows how a crumple zone made of two different materials behave. Material 1 costs $10 per metre, while material 2 costs $30 per metre.

The head engineer needs the structure to be able to absorb a force of 200 N. Which material is cheapest for the task?

Puzzle

Five years ago, Kate was 5 times as old as her son was. In five years' time, Kate will be 8 less than 3 times the age her son will be. How old is Kate and how old is her son now?

To gain **EXP** and level-up your mathematician, email your answers to the **Challenge** and **Puzzle** questions to Dr Greg at Gregory.Boyle@my.jcu.edu.au.

Q: What do you call a mischievous egg?

A:A practical yolker!