Crash Course

Understanding Crash Zones

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Name:

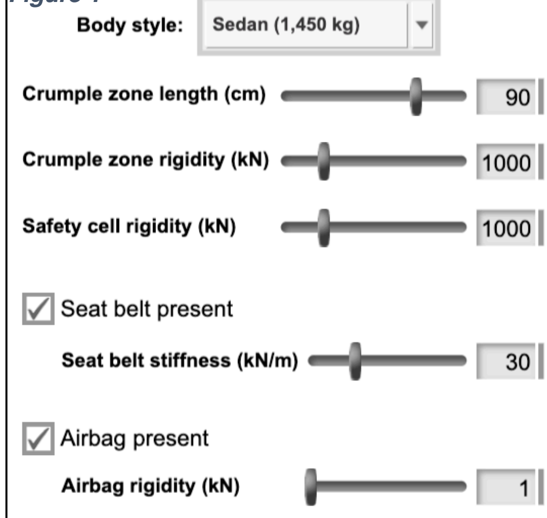
Crash zones, also called **crumple zones**, are structural safety features that were introduced in automobiles around the 1960s by Mercedes-Benz. Originally meant for head-on collisions, these zones are now found in all parts car. Due to inertia (Newton's first law of motion), drivers are at a significant risk to injury because their body continues to move forward at their previous speed before the impact of a collision. Utilizing Newton's second law, crash zones mitigate the amount of force imparted to the driver by increasing the time over which the velocity decreases. These crumple zones also help to limit the deformation to the car's frame while keeping the passenger cabin intact. When combined with other safety features, like seatbelts and airbags, the likelihood of the occupants surviving in an automobile crash increases significantly. Although crash zones end up leaving more physical damage to the vehicle in a crash, the safety it provides far outweighs the cost to repair.

While it often comes off as "cheap", the increase in the use of plastics has helped increase vehicle safety. Not only by understanding that plastic composites are able to absorb more energy, they also reduce the weight of the vehicle, and thus reducing the amount of mass involved in a crash. In high speed racing events like Formula One and NASCAR there has been a shift to using carbon-fiber with zylon covers, which is 1.5 times stronger than Kevlar, the material found in bulletproof vests and body armor. Although very flexible, carbon-fiber is also very brittle and has a shatter point. This is why crashes in these high speed racing events look bad, but often times the driver has minimal or no injuries due to the materials used to help reduce the **impulse**.

PART I – Understanding Crash Zones through the use of a Simulation

This simulation will be used to show how car designs changed after the introduction of safety features like the seatbelt and the airbag. First, we will simulate how a car and passenger from the early 1960s would fare in a collision, even with these safety features included.

Figure 1



☐ 1. In your simulation, set your design with the following settings shown to the right in Figure 1.

☐ 2. Click on the Results tab, then select the play button in the bottom left.

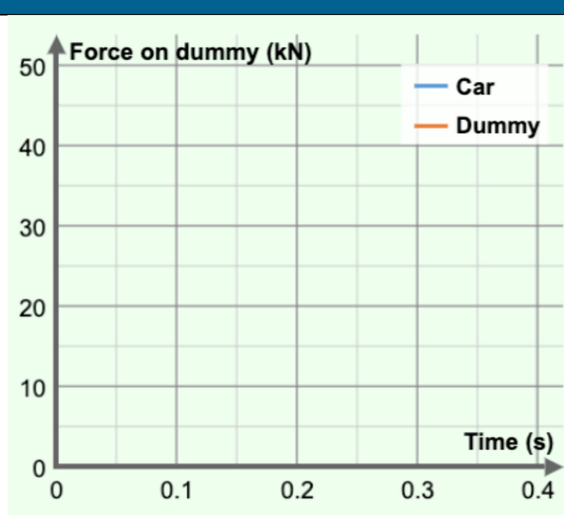
☐ 3. Record your data below in Table 1. Use the slow-mo replay to make observations of what happens to the car and the passenger.

Table 1: Simulation of early years with safety features

Maximum Force on Dummy (kN)	Likelihood of survival (%)	Car observational notes	Dummy observational notes

☐ 4. In the Result tab, select the Graph option. Draw what is shown for Force (dummy) in Table 2 below.

Table 2: Graph of Force on Dummy



Next, we will simulate how changes to the car crumple zone and safety cell can improve outcomes for passengers.

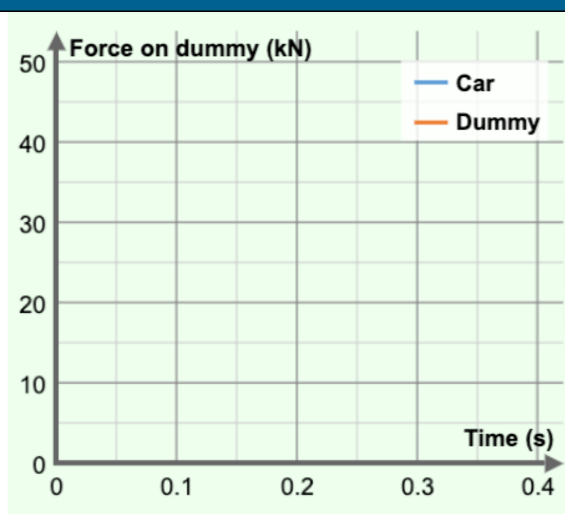
Goal: Decrease the maximum force on the dummy to below 35kN.

☐ 5. Adjust the crumple zone length, crumple zone rigidity and safety cell rigidity to achieve the above goal. Continue testing and adjusting until the goal is accomplished, then record your settings in Table 3 below.

Table 3: Adjusted car settings		
Crumple zone length (cm)	**Crumple zone rigidity (kN)**	**Safety cell rigidity (kN)**

☐ 6. In the Result tab, select the Graph option. Draw what is shown for Force (dummy) in Table 4 below.

Table 4: Graph of Force on Dummy (adjusted settings)



Quick Check: For the force on the dummy, how do the graphs before (table 2) and after (table 4) adjusting settings compare?

PART II – Crash Zone Material Testing

GOAL: Identify materials to include in a bumper assembly to reduce experienced force below 750 N.

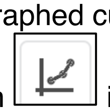
Set Up

☐ 1. Tape the meter stick to the burette stand so that 0 cm is aligned with the top of the force plate.

Zeroing the Force Plate

☐ 2. On the LabQuest, click on the upper left corner picture of an odometer. A red box with the Force meter should appear. Click anywhere in the red box and a drop-down menu appears. Click "**Zero**", making sure there is nothing on top of your force plate.

Data Collection:

☐ 3. To collect your data, select the "Collect" button at the top of the screen. The screen should say "Waiting for increase in force".
☐ 4. Hold the medicine ball so the bottom of the ball is 50 cm above the center of the force plate.
☐ 5. Drop your medicine ball onto your force plate and a graph will appear on the screen.
☐ 6. Use the mouse and highlight the collision. This is the large curve that appears. Select from t=0 until the graphed curve hits a force of 0.
☐ 7. Select the graph tools icon  in the bottom left under the graph.
☐ 8. Select "**View Statistics**".
☐ 9. On the graph, a box will appear with the data from your experiment.
☐ 10. Write down your time (Δx) and peak force (max) data in the data table below.

No bumper assembly materials		
	Time in ms (Δx)	**Peak Force in N (max)**
Trial 1		
Trial 2		
Trial 3		
Average		

☐ 11. Repeat this procedure (steps 2-10) with a bumper assembly material placed on the force plate. Be sure to zero the force plate after the materials have been placed.
Note: Bumper assembly materials can be tested individually or in combination.

Materials(s) tested:		
	Time in ms (Δx)	**Peak Force in N (max)**
Trial 1		
Trial 2		
Trial 3		
Average		

Materials(s) tested:		
	Time in ms (Δx)	**Peak Force in N (max)**
Trial 1		
Trial 2		
Trial 3		
Average		

Materials(s) tested:		
	Time in ms (Δx)	**Peak Force in N (max)**
Trial 1		
Trial 2		
Trial 3		
Average		

Conclusions

Which material(s) worked the best at reducing force in the impact?

Using Newton's Second Law, explain how increasing the time of the collision reduced the maximum force experienced?

How well have the bumper assembly materials held up after testing? Note any damage or blemishes to the materials.