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Crumple Zones Lesson Info

ANSWERS AND EXPLANATIONS

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Jake Massey	Q1	Q2	Q3	Q4	Q5	Score
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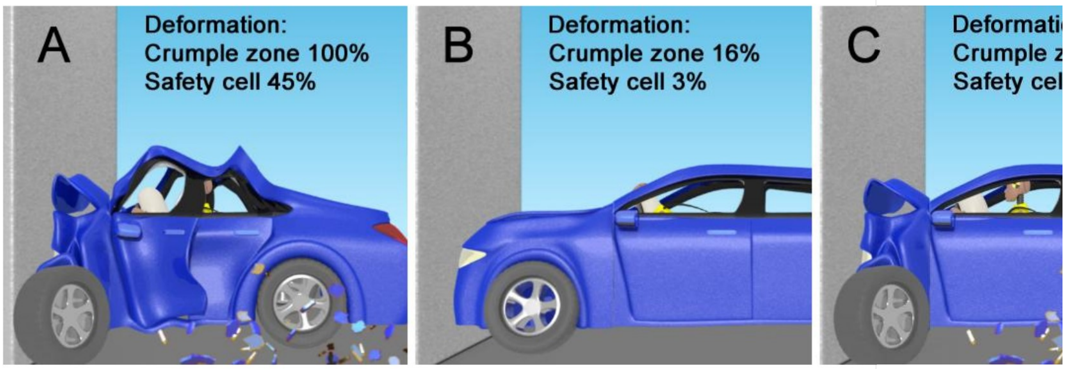
1. Three cars are tested in a 16 m/s frontal crash. The results of the crash tests are shown below, with data indicating how much the crumple zone and safety cell of each car deformed. In each car the dummy was secured by the same seat belt and airbag. Which car did the best job of protecting the dummy?



YOUR ANSWER CORRECT

Car C

EXPLANATION

The safest car will have a less rigid, or "soft" crumple zone and will protect the passengers with a rigid safety cell. Car A has a relatively soft crumple zone but the safety cell has collapsed also, likely causing major injuries to the dummy. Car B has a rigid safety cell but also has a very rigid crumple zone. As a result, the distance over which the dummy can decelerate is very small and the force on the dummy will be very high. (In this scenario the dummy hit the steering wheel.) Car C has the desired characteristics of a relatively soft crumple zone and a rigid safety cell. Car C will allow the dummy to slow down more gradually than car B and will protect the dummy from being crushed.

2. Four cars are designed to protect passengers in a 16 m/s crash. The characteristics of the cars are shown below. Which car is most likely to do the best job of protecting the passengers inside?

Characteristic	Car 1	Car 2	Car 3	Car 4
Car mass	1,450 kg	950 kg	2,000 kg	1,450 kg
Crumple zone length	110 cm	50 cm	85 cm	120 cm
Crumple zone rigidity	200 kN	1,000 kN	50 kN	1,000 kN
Safety cell rigidity	4,000 kN	200 kN	2,000 kN	1,000 kN
Seat belt stiffness	20 kN/m	None	11 kN/m	14 kN/m
Airbag rigidity	10 kN	10 kN	None	45 kN

YOUR ANSWER CORRECT

Car 1

EXPLANATION

The safest cars will have a large crumple zone, a rigid safety cell, and a crumple zone with an ideal rigidity so that it deforms significantly but not completely during the crash. The safest cars also include seat belts and airbags. Car 1 has all of these characteristics. The crumple zone is long and much less rigid than the safety cell. Car 1 has both a seat belt and an airbag. The stiffness of the seatbelt and rigidity of the airbag will prevent the dummy from hitting the steering wheel while not exerting too much force on the dummy.

The other cars have problems in their designs. Car 2 has a very short crumple zone and the crumple zone is very rigid compared to the safety cell. As a result, the safety cell is likely to collapse, injuring the dummy. Car 3 has a crumple zone that is not rigid enough to slow down the car much during the crash. As a result, the car will decelerate rapidly when the rigid safety cell hits the barrier. Car 4 has a long crumple zone but the crumple zone is much more rigid than in car 1 so the deceleration of the dummy will be much greater. Car 4 also has a very rigid airbag that could injure or kill the driver.

3. During a crash, a dummy with a mass of 60.0 kg hits an airbag that exerts a constant force on the dummy. The acceleration of the dummy is $-250\ m/s^2$. What force did the airbag exert on the dummy?

YOUR ANSWER CORRECT

–15.0 kN

EXPLANATION

Newton's second law states that force is equal to mass times acceleration: $F = ma$. If the mass of the dummy is 60.0 kg and the acceleration is –250 m/s^2, the force is 60.0 kg · (–250 m/s^2) = –15,000 N, or 15.0 kN. (Recall that 1 kN = 1,000 N.)

4. An SUV crashes into a wall. The mass of the vehicle is 2,150 kg and the crumple zone rigidity is 342 kN. Assuming the safety cell is perfectly rigid, what will be the acceleration of the SUV during a crash as the crumple zone is collapsing?

YOUR ANSWER CORRECT

–159 m/s^2

EXPLANATION

The relationship between force, mass, and acceleration is given by Newton's second law: $F = ma$. This can be rewritten $a = F/m$. In this problem the force of the crumple zone on the wall is given as 342 kN, which is equivalent to 342,000 N. Based on Newton's third law, the wall will exert an equal but opposite force on the car (–342,000 N). Therefore, the acceleration of the car is equal to:

–342,000 N ÷ 2,150 kg = –159 m/s^2

5. A car has a crumple zone that is 0.80 m (80 cm) long. In this car, the distance from the dummy to the steering wheel is 0.50 m. The car has a mass of 1,600 kg and the dummy has a mass of 75 kg. At the time of the crash, the car has a speed of 18 m/s. Based on the work-energy theorem, what is the smallest possible force that the dummy could experience during the crash?

YOUR ANSWER CORRECT

–9.35 kN

EXPLANATION

The work-energy theorem states the work (Fd) is equal to the change in kinetic energy: $Fd = \Delta KE$. Before the crash, the kinetic energy of the dummy is equal to one-half mass times velocity squared, or 0.5 · 75 kg · (18 m/s)^2, which is equal to 12,150 J. The kinetic energy of the dummy after the crash is 0 J, so the change in kinetic energy is –12,150 J. If the crumple zone collapses completely and the dummy just misses hitting the steering wheel, then the distance d is 0.80 + 0.50 = 1.30 m. So we have:

$F \cdot d = \Delta KE$

$F = \Delta KE/d$

F = –12,150 J/1.30 m = 9,346 N, or 9.35 kN

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