DISCUSSION ANSWERS

"UNDERSTANDING CAR CRASHES: IT'S BASIC PHYSICS"

Teaching Tip: *Select from these higher-order questions for small group discussions, homework, or assessments.*

Part III: After the Video

Directions: *After viewing the video, work alone, in pairs, or in small groups to answer the questions assigned by your instructor in 2-3 sentences each. (NOTE: Answers provided below include additional elaboration/ information you may want to share with students.)*

1. **Ever tried to stop a 150-pound (68 kg) cannonball fired towards you at 30 mph (48 km/hr.)? No, probably not. But you may have tried to brace yourself in a car collision. How are the two situations similar?**

   Both you and the cannonball have momentum based upon mass and velocity. If you are traveling 30 mph and have a mass of 150 pounds, your momentum would equal the cannonball's. In a major collision, it is impossible to prevent injuries by bracing yourself! No matter how strong you think you are, you are not strong enough to stop your inertia during a collision.

2. **Show mathematically why an 80,000-pound (36,000 kg) big rig traveling 2 mph (0.89 m/s) has the SAME MOMENTUM as a 4,000-pound (1,800 kg) sport utility vehicle traveling 40 mph (18 m/s).**

   Momentum (p) is the product of an object's mass (m) and velocity (v). The formula is p = mv. The product of each is equivalent.

   » *The SI unit for momentum is the kilogram x meter/second (kg x m/s).*

   » *Truck momentum = (36,000 kg)(0.89 m/s) = 32,000 kg x m/s*

   » *SUV momentum= (1,800 kg)(18 m/s) = 32,000 kg x m/s*

3. **During the Egg-Throwing Demonstration, the wall stopped one egg and the bed sheet stopped the other egg.**
   A. Explain why one egg broke but not the other.
   B. Explain why BOTH eggs experienced the same impulse

   A. Impulse = force x time. The egg that hit the wall (crash barrier) experienced a greater impact force (big F) due to the shorter impact time (little t). The egg that collided with the bed sheet experienced a greater time of impact (big T), thereby experiencing a smaller stopping force (little F).

   B. If their momenta are equal before the collisions (same mass and velocity), both eggs experience identical impulses because both are stopped by the collision (Product of f x T is the same as F x t).

4. **Explain why the fortunate race car drivers survived their high speed crashes.**

   The impulse that the wall applied to both cars was identical BUT, remember impulse is the force of impact multiplied by the time of impact. With the fortunate driver, the identical impulse was a product of a small force (little f) extended over a long period of time (big T).

5. **Describe 2 or more examples where momentum is reduced by applying a smaller collision force over a longer impact time (in other words, where things "give way" during a collision to lessen the impact force).**

   Answers will vary. Some examples: Bungee jumping; trampolines; trapeze safety nets; falling on grass compared to concrete; many football players prefer the "give" of natural grass to harder artificial turf.

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6. Which would be more damaging to your car: A. having a head-on collision with an identical car traveling at an identical speed OR B. driving head-on into the Vehicle Research Center's 320,000 pound (145,455 kg) deformable crash barrier? Explain.

Both crashes produce the same result. Either way the car rapidly decelerates to a stop. In a head-on crash of identical cars (same mass) traveling at equal speeds (same velocity), the result is equal impact forces and impact times (according to Newton's Third Law of Motion), and therefore equal changes in momenta. However, using a crash barrier to simulate a head-on collision during a crash test is more cost-efficient since only one car is damaged instead of two!

7. Show mathematically why a small increase in your vehicle's speed results in a tremendous increase in your vehicle's kinetic energy. For example: doubling your speed from 30 mph to 60 mph (48 km/hr. to 97 km/hr.) results in a quadrupling of your kinetic energy.

Velocity is squared in the kinetic energy equation ($KE = \frac{1}{2} mv^2$). Therefore, if the speed is first doubled (2x) then squared (2 x 2 = 4), its kinetic energy must quadruple to keep the equation balanced. $\mathbf{4KE = \frac{1}{2} m^2v^2}$

8. The Law of Conservation of Energy states: Energy cannot be created or destroyed; it can be transformed from one form to another but the total amount of energy never changes. Car crashes can involve huge amounts of energy. How does the crashworthiness of the car affect the transfer and transformations of energy and, ultimately, protect the occupants?

In a crash of a well-designed car, some of the kinetic energy of the crash is absorbed by the car's crumple zones. In addition, some of the kinetic energy of the crash is transformed into heat and sound energy, Finally, to protect the occupants ,the safety cage must be strong enough to withstand the remaining kinetic energy of the crash without deforming and collapsing on the occupants.

9. In the video's "shipping box analogy," which safety feature in a car is analogous to the:
A. Cardboard shipping box
B. Packing foam in the box
Explain how each feature functions differently to protect the occupants.

A. The cardboard shipping box is analogous to the car's safety cage.

B. The packing foam in the box is analogous to the airbags and padding in the dashboard and steering wheel.

The safety cage's primary function is to limit intrusions into the occupant compartment. Airbags and dashboard padding reduce the impact force by spreading it out over a longer impact time as they "slowly" collapse. In other words, their softer surfaces collapse slowly compared to hitting a hard surface such as a windshield.