PHYSICS AND CAR SAFETY

Over the last 40 years, vehicle designs have gone through many adaptions and changes. Automobile designers are constantly evolving their ideas to fit different environments, technologies, safety regulations, and concerns. As the world changes, car designers need to focus on reducing the number of fatalities and serious injuries that occur from car accidents. Ultimately, designers need to make sure they are keeping drivers and passengers safe.

Many of the safety features that are commonplace in cars today can be explained using Newton's Three Laws of Physics:

1. An object at rest will remain at rest and an object at constant velocity will remain at constant velocity, unless acted upon by an unbalanced force.
2. If an unbalanced force exists, then a mass will experience an acceleration depending on the magnitude of the mass.
3. If you exert a force on an object, you experience a force equal in magnitude but opposite in direction.

Seat Belts

Seat belts are the primary safety feature in all vehicles. Modern seat belts use a three-point anchoring system. Two points are attached to either side of the seat, while the third anchor point is usually attached to the ceiling of the vehicle.

Seat belts attach the passenger's body mass to the car's mass, meaning that when the car accelerates or decelerates, the passenger does as well. If it were not for seat belts, a passenger would experience the force described by Newton's First Law. For example, if the vehicle came to an abrupt stop after traveling at a constant velocity (like in a motor-vehicle accident) the passenger not wearing a seat belt would continue traveling at a constant velocity. This would result in the passenger colliding with the windshield or seat in front of them. Wearing a seat belt secures the passenger, making them a part of the car. This means that drivers and passengers will stop at the same velocity as the car during an impact. Even if they continue to move, passengers wearing seat belts in a car accident will collide with the seat belt itself rather than a dangerous glass windshield. Wearing a seat belt can still result in a lot of force against a passenger's body, but ultimately it is much safer to keep the body in place than risk a collision with the steering wheel, seats, or console.

Headrests

Headrests sit above the back of a car seat and are often adjustable to fit the driver or passenger. Headrests protect against a specific and very common kind of vehicle injury, whiplash. Whiplash is a neck injury caused by a sudden “whipping” back and forth **that distorts the neck.**

If a car is sitting still and it is rear-ended, this unbalanced force can cause the vehicle to move forward quickly**. If a passenger is wearing a seatbelt, the portion of their body that is strapped will move forward with the velocity of this impact, leaving their head and neck to bend backwards rapidly**. This sudden pull backwards on the neck and head can cause a whiplash injury. Using Newton’s First Law, we can see that this happens because the head and neck as a mass are stationary, until they is acted upon by an unbalanced force. However, the headrest can help protect against this kind of injury by stopping the head and neck from being forced backwards. This allows the head and neck to move forward at the same rate as the torso of the passenger.

Airbags

An airbag is an inflated cushion that is rapidly deployed from the console or dashboard in the event of a vehicular collision. Once inflated, the airbag immediately begins to deflate so that passengers can exit the vehicle once it’s safe.

In the event of a car collision, airbags are designed to inflate with lightning speed. Airbags are meant to act as a cushion before passengers can be thrown forward by the impact of a collision. Airbags work by slowing down the momentum of a passenger’s body before they can impact the windshield, console, or dashboard.

Where F= Force, m=mass and a= acceleration, F=ma

Because a=displacement divided by time, the whole equation reads as F=(mass x displacement) / time, so as the time increases, the total F (force) gets smaller because it is divided by a bigger number. By decreasing the force, the injuries sustained are less severe when an airbag is deployed.

Crumple Zones

Crumple zones are exactly what they sound like, areas of a car that are designed to crumple and buckle easily on impact. These zones are designed in the front and back of vehicles, where a collision is most likely to take place.

If a fast-moving car collides with a solid wall, the equation F=ma tells us that the force it exerts on the wall is going to be quite powerful because of the mass of the vehicle coupled with the acceleration of the vehicle. However, Newton's Third Law states that the same force would be applied in the opposite direction from the wall toward the car. This powerful force would likely total the front of the car, but a crumple zone at the front reduces the danger of that force hitting the engine. A crumple zone also increases the time it takes for the change in velocity to occur. Since acceleration=change in velocity divided by time, there is less total force distributed throughout the vehicle.

When a vehicle comes to a sudden stop, like when it hits a wall**, the passengers inside the vehicle will keep traveling forward according to Newton's First Law.** However, if safety measures are being followed, these passengers will only travel forward until they hit a seat belt or airbag, which will apply the identical and opposite force back on them, **Newton's Third Law**. With the safety feature of crumple zones, the car decelerates before coming to a sudden stop, allowing those inside to travel at a slower momentum. This means that the severity of impact injuries can be decreased.

Cargo Barriers

While not every vehicle has a cargo barrier, these safety features are especially important for those working in the transportation or shipment of materials and heavy equipment. A cargo barrier is typically a metal fence or grill between the storage space in the back of the vehicle and the cabin area were a driver and passenger sit. Cargo barriers protect the cabin from equipment or material flying forward from the back of a vehicle.

When a motor-vehicle accident occurs, it is not only the driver and the vehicle that go into motion. Other items in the car can become deadly projectiles when moving at a high rate of speed. Cargo can shift unexpectedly in accordance with Newton's First Law. When a car is traveling at a constant velocity, so does the cargo inside of it. When the vehicle suddenly stops, swerves, or makes a change in direction, cargo that is not secured will continue to travel at the original velocity **until it is stopped by another force. Cargo barriers must be strong enough to stop the impact of the object, for the safety of those in the car.**

Source:

Student-of-DIY. The physics of car safety. Instructables Workshop. https://www.instructables.com/The-Physics-of-Car-Safety