The Physics of Car Safety

Car design is constantly evolving to adapt to different environments and the safety concerns they present. Particularly in the last forty years, there have been many new design features on vehicles with a focus on safety, drastically reducing the amount of fatalities and serious injuries occurring from car accidents.

What these safety features are and how they work can be better explained using Newton's Three Laws of Physics:

I. "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."

II. "If an unbalanced force exists then a mass will experience an acceleration depending on a magnitude of the mass."*

III. "If you exert a force on an object, you experience a force equal in magnitude but opposite in direction."

**Newton's Second Law can also be explained using the equation to calculate Force, 'F=ma' (or Force is equal to mass multiplied by acceleration).*

Step 1: Seat Belts

Seat Belts are the primary means of injury prevention in all motor accidents, big or small. Modern seatbelts are anchored using a three-point system, as demonstrated in the diagram above- two points are attached to the floor (one on either side of the seat), and the other comes across the body to attach to the ceiling.

Seat belts attach your body mass to that of a car, meaning that when the car accelerates or decelerates, you do also. Were it not for seatbelts, your body would be acted upon by Newton's First Law independently of the vehicle. If the car came to an abrupt halt after travelling at constant velocity (for example, in a motor vehicle accident) and the passenger was not wearing a seatbelt, they would continue travelling at constant velocity, probably resulting in a collision with the windscreen or the back of the seat in front of them. When wearing a seat belt, the passenger is part of a car, meaning that they too would come to a halt- or, if they did travel, they would only go a short distance and collide with the seat belt strap instead of a glass windshield. A lot of force would still be applied from the seatbelt to the body frame, but it keeps the body in place and stops a collision with hard objects like the steering wheel and objects that could cut, like the windscreen.

Step 2: Headrests

The diagram above shows the effect of a collision on a body without the aid of a properly adjusted headrest.

Headrests extend above the seat of a car and can be adjusted to properly fit the driver or passenger. If improperly adjusted, they cannot provide adequate support and stop injury (usually whiplash, which is an injury related to sudden distortion of the neck).

For example, if a car is stationary and it is acted upon by an unbalanced force in a rear impact, it would move quickly forward. If a passenger is wearing a seatbelt, their torso is moved rapidly forward with the car, leaving their head behind and making it bend backwards quickly enough to cause injury. This happens because if a mass (the head) is stationary, Newton's First Law states that it will stay this way until it is acted upon by an unbalanced force. If there is a properly adjusted headrest, the head will be moved forward at the same time and rate as the torso, meaning that the neck does not have to bend uncomfortably. Headrests also provide a small amount of protection from anything thrown forward if the car were to stop suddenly. (For further information on this concept, see *Cargo barriers)*.

Step 3: Airbags

The above slow-motion gif offers a falling glass of water as a speed comparison for the inflation of an airbag. An airbag is a cushion that is deployed rapidly from the dashboard of a car in the event of a crash, so as to reduce damage to the face and torso of the driver and passengers. Big holes in the back of the airbag mean that after being deployed, the airbag begins to deflate immediately. Airbags are not mandatory in Australian cars, despite being proven as very effective safety devices.

In the event of a crash, airbags are designed to inflate before the passengers bodies can be thrown forward by the impact. They increase the amount of time taken for the passenger to decelerate to zero in a similar way to how Crumple Zones slow the deceleration of a car (see *Crumple Zones*.)

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

Because a=displacement divided by time, the whole equation then reads F=(mass x displacement) / time, so if the time increases the total F (Force) gets smaller because it is divided by a bigger number. Less force means the injuries sustained by the passengers in the event of the airbag deploying will be less severe.

Step 4: Crumple Zones

Crumple Zones are areas at the front and back of a car designed to crumple in the event of a collision.

If a car collides with a wall at high speed, the equation F=ma tells us that the force it exerts on the wall is going to be quite big (there is a big mass and a big acceleration). However, Newton's Third Law states that the same force would also be applied in the opposite direction from the wall to the car. This force would destroy the front of the car, but if it is designed to crumple safely, it reduces the danger that could be caused by the engine being involved in a collision. It also increases the time it takes for the change in velocity to occur (e.g. 60km/h to 0km), and since acceleration=change in velocity divided by time, there is less total force distributed throughout the vehicle.

If the vehicle comes to a sudden stop, then the bodies inside the vehicle keep travelling forward according to Newton's First Law (an object travelling at a constant velocity will remain at a constant velocity until acted upon by an unbalanced force). They will travel forward and apply force to the first thing they encounter- hopefully a seatbelt and/or airbag, which will apply identical and opposite force back on them according to Newton's Third Law. If the body decelerates before coming to a sudden stop, such as in the case of a car with Crumple Zones, they are travelling a little slower when they run into whatever is in their path, meaning that they exert less Force and less Force is exerted on them. In turn this means the severity of their injuries would be decreased.

Step 5: Cargo Barriers

Cargo Barriers are enforced metal grilles positioned between storage space at the back of the car and the area where passengers sit. Many utility vehicles or trucks with rear windows also have cargo barriers between the cabin and the cargo tray. They are designed to protect the driver and passengers from the cargo they may be carrying in the event of a crash or accident.

When involved in a motor-vehicle accident, it is not only the driver and vehicle that become dangers. Other items in the car (including other passengers) may become deadly projectiles that turn what could have been a survivable crash fatal. This is why it is so important for children to also wear a seatbelt, and to avoid putting loose items in areas of your car where you could be injured by them in the event of an accident.

Cargo can shift unpredictably in cars in accordance with Newton's First Law. When a car is travelling at constant velocity, so is the cargo inside it or on it. When the vehicle stops suddenly or changes direction, untethered cargo will continue travelling at the velocity it had maintained before until something stops it- this is where the cargo barrier comes in. If a car carrying luggage was travelling at sixty kilometres an hour and it was to stop suddenly, then the luggage would continue travelling at sixty kilometres an hour towards the people in the vehicle. The cargo barriers have to be strong enough to withstand this impact and protect the occupants of the car.

Step 6: Conclusion

Car design has come a long way since its beginning, and shows no signs of slowing down. Newer models of cars are being installed with reversing cameras and systems designed to brake before a human can react in the event of danger. Who knows what new safety features will be developed in the next forty years to minimise human error...

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