Applied Science and Innovative Research
ISSN 2474-4972 (Print) ISSN 2474-4980 (Online)
Vol. 4, No. 4, 2020
www.scholink.org/ojs/index.php/asir

Short Research Article

Should One Stop or Turn to Avoid an Automobile Collision?

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Received: November 15, 2020 Accepted: November 20, 2020 Online Published: November 23, 2020

doi:10.22158/asir.v4n4p50 URL: http://dx.doi.org/10.22158/asir.v4n4p50

It is quite difficult to find examples of physics related to the daily life. When we asked the question of the title to the public in many talks, about 80% of the audience said that they will turn to avoid the collision. So later, when we show that it is always better to apply the brakes, they will remember the talk because that can save their life. So let us be more specific about the question:

A man driving an automobile at a speed of 54 km/h (15 m/s) suddenly found a big truck stopped at an intersection 14 meters away. To avoid hitting the truck, the man must either apply the brakes in order to try stop in a forward direction, or turn to avoid the truck, or he can also do both. What is the wisest decision given a certain coefficient of friction μ between tires and road surface?

The frictional force should be used to reduce the speed in a forward direction, or to turn along the circle of minimum radius R, without reducing speed. Also a combination of both procedures could be used.

We need to remember that the static frictional force is always between zero and its maximum value, and it tries to avoid the slipping of the points in contact. For a car tire the static friction coefficient is about $\mu = 0.8$.

During braking the energy is dissipated. On the other hand, the energy is conserved while turning along a circle (without braking), if the same speed is maintained. Three choices are open: (1) to keep on straight ahead and apply the brakes fully, (2) to turn in a circular path, without braking, using all the available friction force to produce a centripetal acceleration with the minimum radius R, (3) to choose some combination of steering and braking, driving along some intermediate path.

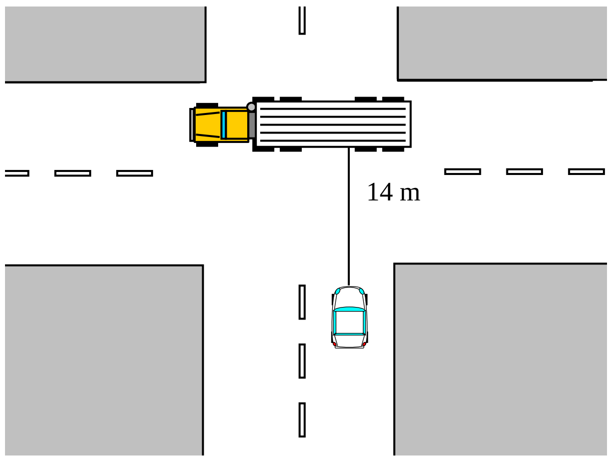

Figure 1. A Truck Stops Suddenly in Front of a Car 14 m Away. The Driver Should Apply the Brakes or Turn the Wheel to Avoid the Truck

If we try to turn with a radius less than R, the frictional force will not be enough and the tires will slip on the road, or a rollover will be produced, depending on the height of the center of mass of the vehicle. It is very difficult to steer a skidding car. Cars with the antilock braking system ABS avoids slipping of the tires by reducing the braking force on any tire near to slipping, and consequently the turning reduces automatically the maximum braking force. A four-wheel system is intended to keep all the wheels rolling during panic braking, in order to prevent yawing and to allow steering throughout the emergency. The combination of stopping and steering is intended to help the driver to avoid mobile and fixed obstacles. The National Highway Traffic Safety Administration NHTSA says: “The effect, however, is not inevitably for the better. ABS confers the capability to steer a car while slamming on the brakes, but the average driver in a panic situation might not always use this capability to advantage, and might even steer the car into a worse situation than the one which the driver was trying to avoid”. And “The tests confirmed that ABS was highly effective in preventing yawing and allowing the driver to steer the car during panic braking. Stopping distances decreased substantially with four-wheel ABS on wet surfaces, but decreased only slightly on dry pavement and increased considerably on gravel”. They only forget to tell that turning only does not reduce the speed of the vehicle. Remember the stopping distance is about the same with or without ABS, on dry pavement (and remember that Mexican highways frequently have some gravel!).

One must remember that the frictional force acts against the slipping of the portion of the tire that is in contact with the floor. The instantaneous friction force depends on the velocity of the skidding car and the angular velocity of each tire. If the car is without ABS, by braking we can lock the tires losing any control about the direction of the skidding. Any difference in the friction acting on the wheels will produce a torque about the center of mass of the car.

From Newton's Second Law we know that in order to produce a uniform circular movement we need a centripetal force constant in magnitude, and for a car moving in a circle that force comes from the friction with the road. The minimum radius R of the circular path of a car of mass m and velocity v is produced when the maximum value of the frictional force (μmg) is equal to the magnitude of the centripetal force:

$$\frac{mv^2}{R} = \mu\, m\, g \qquad \text{Then} \qquad R = \frac{v^2}{\mu\, g}$$

If we apply the brakes the maximum deceleration is μg, and the minimum braking distance x is:

$$x = \frac{v^2}{2a} = \frac{v^2}{2\mu\, g} = R/2 = (15)^2/(2x0.8x9.8) = 14 \text{ m}$$

So, the braking distance is half the minimum radius R.

Using the data one finds: R = 28 m, and x = 14 m. Therefore, by braking the car we can avoid the collision, while by turning the maximum deviation is only 1.7 m (12% R), and the collision occurs at the full speed of 15 m/s. Figure 2 shows that both paths are quite close to each other.

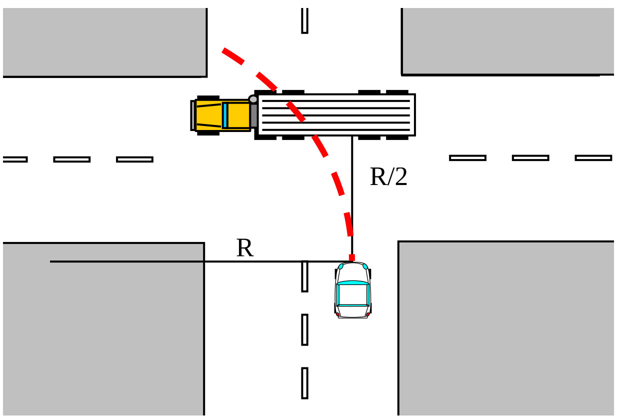

Figure 2. The Minimum Radius for Turning is Always Twice the Braking Distance. The Maximum Deviation is only 12% of the Braking Distance, so Braking is the Best Alternative

If the initial distance is larger than 14 m, by braking, we can stop before impact without any trouble. If the initial distance is less than 14 m, by braking only the speed at the instant of the collision is reduced and therefore so is the kinetic energy to be dissipated in the deformation of the car and truck. By only steering, the collision will need to dissipate all the initial kinetic energy with about 0.75 m of damage to the front of the car (SAAB, 1992). Any path in between produces more damage than braking only.

The driver can choose an intermediate path such that the radius of curvature is twice (56 m), then the deviation is half (0.85 m), the initial centripetal force is 0.5 μmg and the initial maximum braking force is 0.866 μmg. Assuming constant the braking force the arc length is 16.1 m, the arc length to the truck is 14.15 m so the car needs 2 more m to avoid hitting the truck. Using ABS brakes, the arc length traveled is slightly reduced as the factor in the braking force increases from 0.866 to 1 as the centripetal force reduces along with the speed squared. To be more realistic to the calculated distances we need to add the distance traveled by the car before the driver decides what to do or reaction time.

This is an example illustrating that physics is useful in real life if we analyze situations before they happen because during a collision things happen so fast, that we don't have time to think, we need to react. The human tendency is to turn first (according with the answers given in many talks), so now you know that braking is the best option in any case.

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