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The Truth Behind LIIs: What is it we fail to understand?

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The Truth Behind LIIs: What is it we fail to understand?

How many times have we heard I was only going a few miles an hour or I had just started forward at the red light when I hit them. They are only after the money. How can they say they are injured that severely?

The National Transportation Safety Administration (NTSA) estimates “there are approximately 1.5 million passenger vehicle rear end crashes per year. These accidents resulted in approximately 2000 deaths. This equates to 23% of all accidents and 4.5% of all traffic related deaths.” The worst part is the financial burden of $18.3 billion per year for passenger vehicles (National Safety Council 2002).

One must realize these figures represent only reported injuries and accidents. How many go unreported due to no damage to the vehicles or the occupant felt there was no problem at the time of the incident?

First and foremost, we must discuss what is considered a low speed impact. Low speed impacts normally occur at speeds less than 10 MPH (Baldyga 2004). Dr. Jeffrey Tucker reports a low speed impact can start as low as 1-2 MPH and as high as 20-25 MPH (Tucker, 1995). Orner defined a low speed impact as having a closing speed of 5 to 10 MPH or less with vehicular damage often being minor (Orner, 1992). McConnell et al. defined a low speed collision as one in which the struck vehicle speed change is less than or equal to 8 MPH (McConnell et al., 1993). As can be noted, most of the numbers clearly indicate that speeds less than 10 MPH fall within the definition of a “low speed impact”.

So what are some of the common collision types of that are associated with low-speed accidents? The most common is the “rear-end” collision in which the front of one vehicle strikes the rear of another (National Safety Council, 2002). In this case it is the driver behind who is found to be at fault for following too closely. However in extenuating circumstances, like changing lanes and then slamming on the brakes, the vehicle in front could be cited for the accident.

The other to be considered is the sideswipe collision in which two vehicles slide off of one another or one vehicle slides off of a stationary object (Sintra Engineering Inc, 2006).

So how is it in today’s world of advanced mechanical vehicles could a small bump cause such physical damage to the human body? Let us discuss biomechanics or the study of how mechanical forces affect living organisms.

To illustrate the biomechanics let’s look at a very realistic picture. A car is stopped at a traffic signal. The car behind the stopped car reacts rather quickly and starts off along with the front car, which all of a sudden stops for no reason. When the cars hit, the energy in the moving car is now transferred to the stopped car and the stopped car is now moved forward, if even a little. Remember Sir Isaac Newton and his three laws of motion? Let us say this is the beginning of the whiplash theory in 1686. Newton’s first law of motion, known as the Law of Inertia states “every object persists in a state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it” (National Aeronautics And Space Administration, 2008).

In this case the front car is forced forward by the forces applied to it from the rear car. The car seat, which was stationary, now moves forward with the occupant. Since the head of the occupant in the seat is not contacting any portion of the seat, it remains stationary, which leads to the backward motion in relation to the body (Severy, Mathewson, & Bechtel, 1955).

At this point, the front vehicle will stop (either by the occupant braking or it striking something). It is at this moment the occupant’s body is thrown forward. Let us say the occupant is wearing a shoulder restraint, and then the head is thrown forward with a simultaneous twisting motion, which results in greater risk of injury to the neck (Severy, Mathewson, & Bechtel, 1955).

What about the bumper? Shouldn’t this protect the occupants of the vehicle being struck? Yes and no. U.S. Government specifications for bumpers is that “each vehicle shall meet the damage criteria of Sections 581.5(c)(1) through 581.5(c)(9) when impacted by a pendulum-type test device in accordance with the procedures of Section 581.7(b), under the conditions of Section 581.6, at an impact speed of 1.5 m.p.h., and when impacted by a pendulum-type test device in accordance with procedures of Section 5817(a) at 2.5 m.p.h., followed by an impact into a fixed collision barrier that is perpendicular to the line of travel of the vehicle, while traveling longitudinally forward, then longitudinally rearward, under the conditions of Section 581.6, at 2.5 m.p.h.” (Government Printing Office, 1999). To put this in prospective with common English this equates to a crash of 5 MPH into a parked car of the same weight (National Highway Transportation Safety Administration, 2008).

So we have a bumper that meets U.S. Government specifications and a low speed collision. Obviously the occupants are safe. Right?

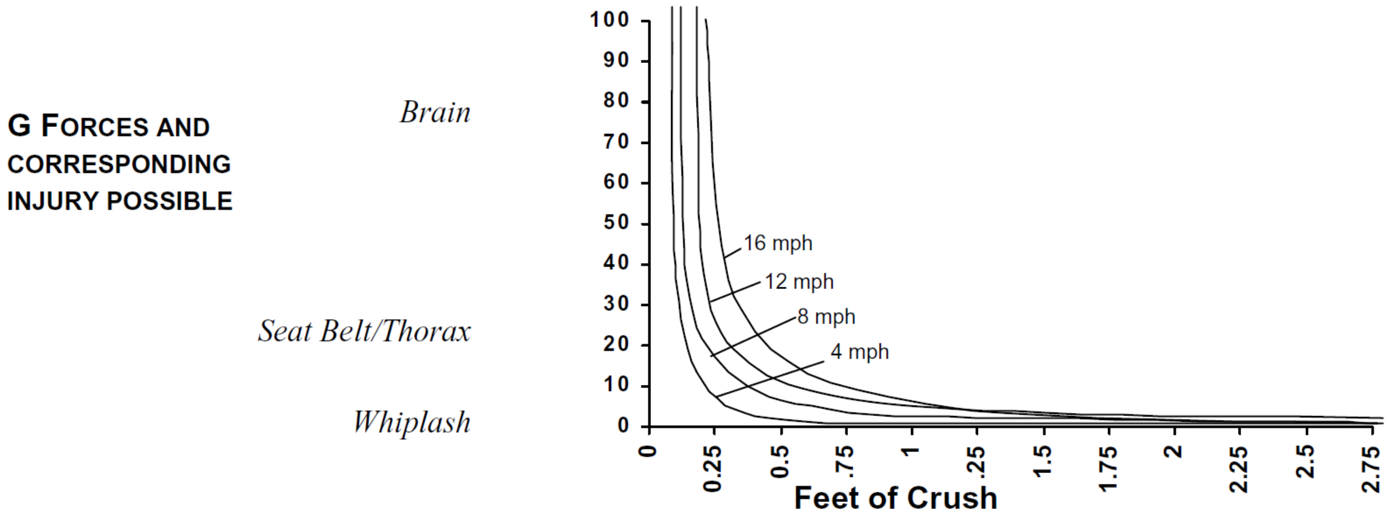
Wrong! Malcolm C. Robbins, an engineer with the Society of Automotive Engineers, reported that “a common misconception formulated is that the amount of vehicle crash damage due to a collision, offers direct correlation to the degree of the occupant injury" (Robbins, 1997). In his paper he discussed the physics of acceleration providing the following equation to substantiate his belief:

$$a=\frac{V^2}{2s}$$

Where:

a = acceleration
V = velocity of impact
s = the crush distance

The chart below indicates that vehicles with very little crush can experience large acceleration even at low indicated speeds.



(Robbins, 1997)

In another series of studies conducted by members of the Mechanical and Manufacturing Engineering Group at Loughborough University in the United Kingdom, seven volunteers seated in normal driving posture were placed on a Japanese Automobile Research Institute (JARI) rear-impact sled (Figure 1).

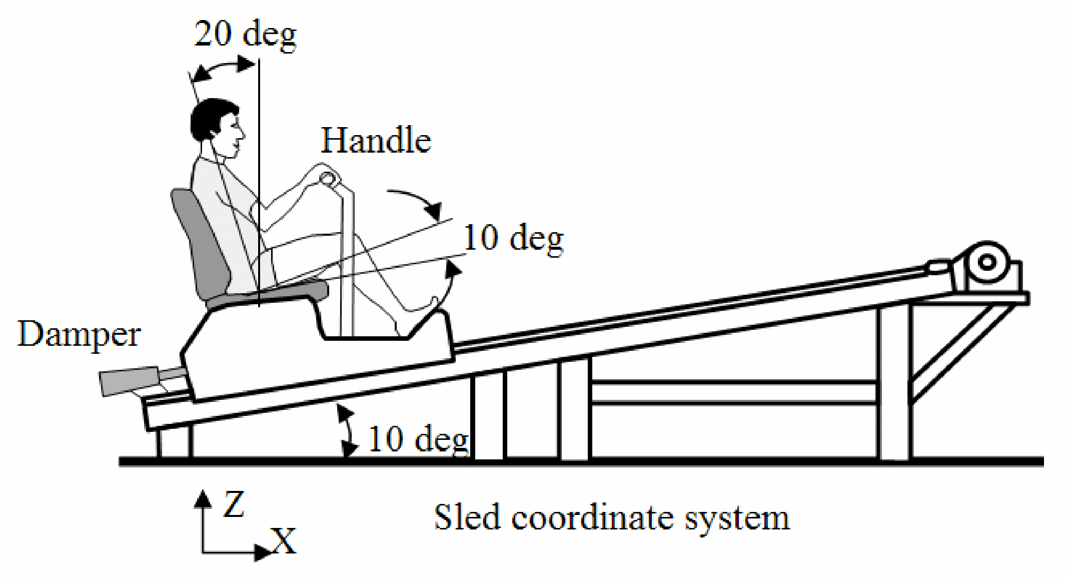


Figure 1 (Himmetoglu, Acar, Taylor, & Bouazza-Marouf, 2007)

The 10^{o} angle with the horizontal of the sled produced the equivalent of a 4.8 MPH impact. There were numerous testing devices attached to the head-neck and torso of the volunteers to record the results of the impact.

There are other factors in a low speed collision which make it virtually impossible to accurately determine the extent of the forces present. At what angle did the collision occur? Was it a straight on collision or was the front vehicle struck at an angle? The angle could be a determinant as to where exactly the damaging forces are being placed on the neck and head, and which tissues are damaged.

The speed and size of the rear vehicle is clearly a factor. A large vehicle traveling at a slower speed can do more damage than a small vehicle traveling at a higher speed (Luo & Goldsmith, 1991).

What are the road conditions at the time of the impact? The movement distance of the car following the collision is critical and the road surface could produce a sever accident from what initially appeared to be a minor one (Croft & Foreman, 1988).

To further aid in understanding what was previously discussed, we need to understand energy cannot be destroyed. It is simply transferred. When an impact occurs the more damage to the vehicle the less damage to the occupants. The metal absorbs a majority of the force and as such collapses or is damaged. If the vehicle has little or no damage something ***or someone*** had to absorb the shock of the impact.

Someone had to absorb the shock! And how long does it take and where is the most damage occurring? Appendix 1 of this document will give a couple of examples of how Newton’s Laws of Momentum, Acceleration and Inertia fit into the big picture.

There are basically four phases associated with what is considered “whiplash” (Himmetoglu, Acar, Taylor, & Bouazza-Marouf, 2007).

In Phase 1, which occurs between 0-50 milliseconds (ms) in time, the head and T1 accelerate starting somewhere in the neighborhood of 25 to 35 ms. There is a noted development of spine extension and straightening, however no significant head or neck motion occurs.

Phase 2 which falls in-between the 50-100 ms timeframe sees a strong straightening of the spine and torso ramps. With respect to T1, the head retracts due to its inertia and the S-shape develops. This leads to an observable flexion in the upper vertebrae and extension in the lower vertebrae. Noted maximum axial compression forces occur at 50 ms. At 80 ms the S-shape becomes very distinct and shear forces increase gradually.

Phase 3 occurs between 100-150 ms and it is at this point T1 rotation has reached its maximum. At approximately the 130 ms point the flexion of the upper vertebrae is transformed into extension and the head extension becomes significant with respect to T1. In addition, shear force is noted at its maximum between 125-150 ms.

The final phase of the process, Phase 4 finds itself occurring between 150-300 ms. At this time the head extension has reached its maximum and head acceleration begins to subside, as do the shear and axial forces.

These series of phases are depicted in Figure 2.

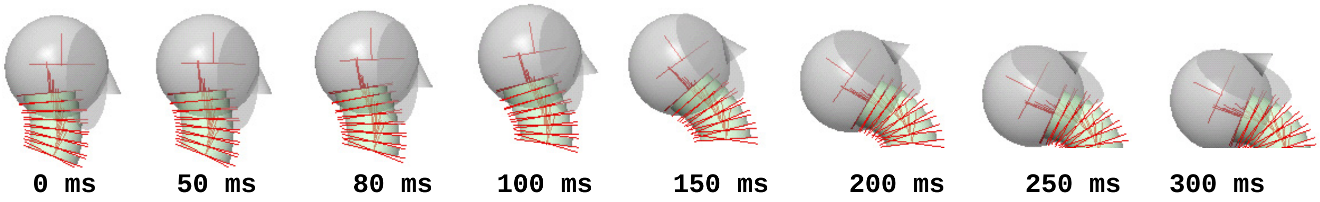


Figure 2 (Himmetoglu, Acar, Taylor, & Bouazza-Marouf, 2007)

To understand this from another aspect let’s look at the studies of Yang et al (Yang, Begeman, Muser, Niederer, & Walz, 1997) who explained:

> It is hypothesized that this axial compression, together with the shear force, are responsible for the higher observed frequency of neck injuries in rear impacts versus frontal impacts of comparable severity. The axial compression first causes loosening of cervical ligaments making it easier for shear type soft tissue issues to occur.

As illustrated in the following (Figures 3 and 4) a compressive force is applied to the cervical spine during Phase 3 of the impact, as individual facet joints are being subjected to shear force. In this instance the shear force is the sliding of C5 in one direction with the upper portion of the spine and C6 is moving in the opposite direction with the torso.

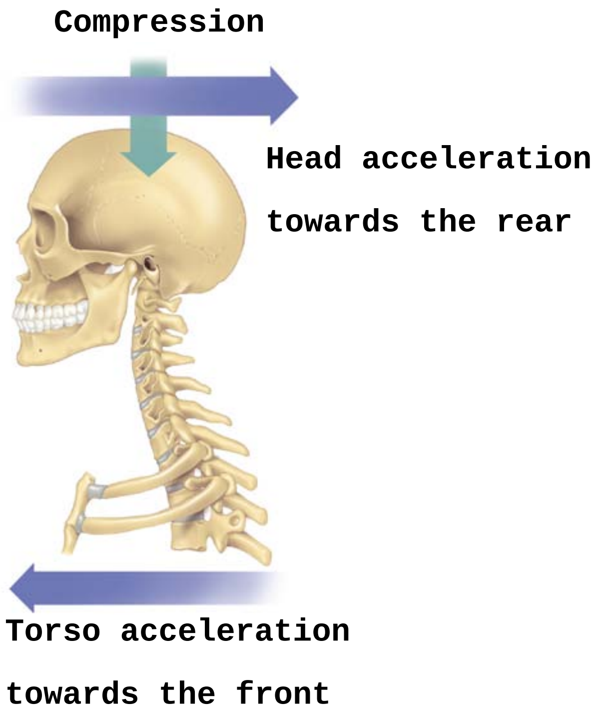


Figure 3

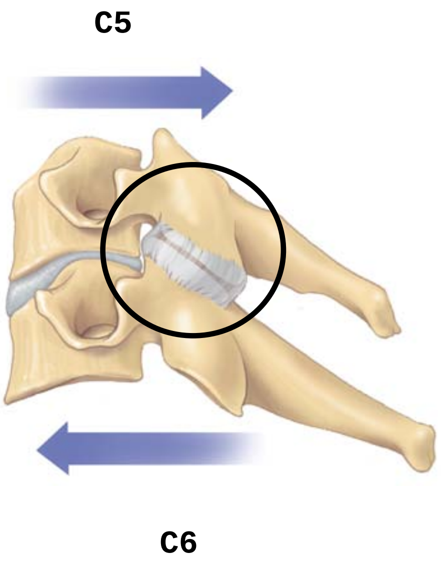


Figure 4

(Primal Pictures, 2003)

So what are some of the common symptoms associated with a low impact injury, or “whiplash.” Studies clearly indicate most of the symptoms associated with whiplash are contained in an area between the head and the torso, to wit: the neck.

In 1994 Radanov expressed a 97% rate of neck pain after whiplash injury in chronic patients (Radanov, Di Stefano, Schnidrig, & Sturzenegger, 1994). Greenfield and Deans report that neck pain occurs in 65% of patients within six hours, 28% of patients within 24 hours, and the remaining 7% within 72 hours (Greenfield & Ilfeld, 1977) (Deans, Magalliard, Kerr, & Rutherford, 1987). Since the cervical spine consists of many important structures it is very susceptible to trauma. The following are a few of the structures which have been known to suffer from low impact occurences.

Myofascial trauma is considered to be the most common form of neck pain when it comes to whiplash injuries. Evans wrote “the vast majority of whiplash injuries result in cervical sprains, i.e. myofascial injuries” (Evans, 1992). In 1992 Friedmann observed the extremely complex manner required to identify muscular strain in the cervical area. This was attributed to the large number of small muscles which have different functions with regards to the position of the head. The cervical area is very open to strain however it may be difficult to identify if the injury is a sprain, strain or nerve root involvement (Friedmann, Marin, & Padula, 1997).

It has been established that most of the forces that cause a low impact injury are those experienced during that phase of the action known as the extension phase, or Phase 3. It is here we find the ligamentous damage commonly referred to as tears of the anterior longitudinal ligament (Figure 5). In a study conducted by Ivancic et al, it was determined that the risk for complete tears of the anterior longitudinal ligament could be witnessed in a small portion of the population. Additionally, there were indications of a loss of cervical stability with the disruption of the anterior stabilizing system causing chronic pain after the injury. Injury to these soft tissues could contribute to facet joint pain due to the increased loading and degeneration of the posterior spinal components (Ivancic, Pearson, Panjabi, & Ito, 2004).

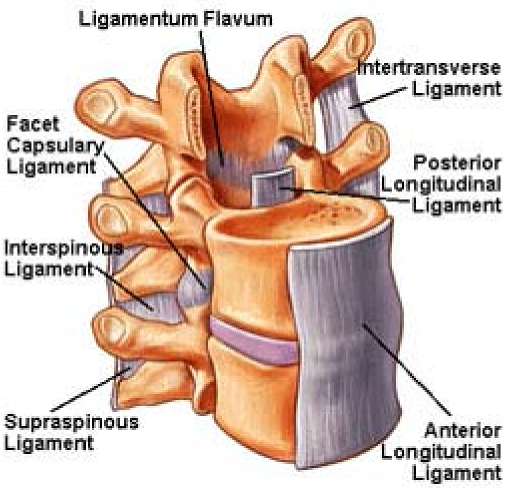


Figure 5

(Spinalhealingarts, 2008)

Whiplash injuries have been documented as leading to degeneration of the spine. Evans documents “evidence suggesting that trauma and whiplash injuries can accelerate the development of cervical spondylosis with degenerative disk disease” (Evans, 1992). Another study supported the conclusion of Evans by observing “cervical changes predisposing to premature degenerative disc disease” in whiplash injuries (Hamer, Gargan, Bannister, & Nelson, 1993). In a study that covered a period of two years, Petterson et al performed magentic resonant imaging

(MRI) on 39 whiplash patients that had experienced whiplash accidents 11 days after the trauma. These MRIs were compared to those that were taken two years post accident and found that 13 of the patients, or 33%, had disc herniations that could be considered moderate or severe. A majority of these were at the C4-C6, indicating this is the most stressed segment (Pettersson, Hildingsson, Toolanen, Fagerlund, & Bjornebrink, 1997).

We discussed the degenerative side now what about nerve damage with respect to indirect and direct damage.

The nervous system in the human spine can be affected by any of the above mentioned traumas. However, the most familiar trauma is that caused by disc herniation, which has been known to put pressure on the nerve roots, leading to radiculitis, headaches, or tingling in the hands or fingers, depending on which of the nerve roots was damaged. Disc herniation has been established as an indirect source of irritation or damage to the nerve, since the nerves are not damaged directly from the accident, but from herniations caused by the accident.

However, with that being said, direct nerve damage, such as a concussion, can be attributed directly to the accident.

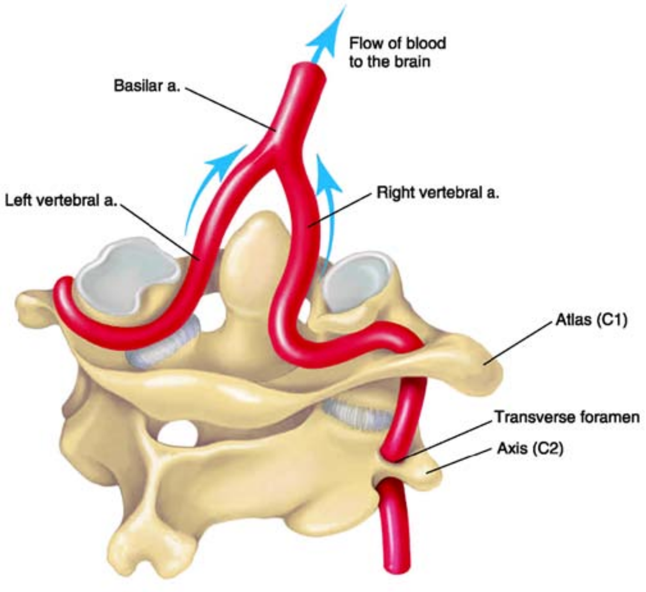
Within the nerve trunk there resides the cervical sympathetic nerve which is susceptible to trauma which occurs during the extension phase of whiplash. Should this event occur, resultant injury could be Horner’s Syndrome, nausea, dizziness, blurred vision and tinnitis (Evans, 1992).

In the same vain of direct nerve damage, there have been documented cases of the occipital nerve being crushed between the bony arches of the atlas and axis during sudden hyperextension (Bogduk, 1981). This damage can be attributed to chronic pain in the upper neck, back of the head and behind the eyes, commonly referred to as Arnold’s neuralgia.

Skeletal trauma, or fractures of the cervical spine during low impact injuries are rare (Bogduk, 1994). However, there are those instances where the force can be severe enough to cause small fractures of vertebrae. Documented damage to the zygapophysial facet joints results in impingement and imflammation of the folds of synovial tissue (Kaneoka, Ono, Inami, & Hayashi, 1999).

And finally vascular damage. What is the outcome of a low impact injury in this instance? The frequency of vascular damage after low impact injuries is not known, but studies do indicate that it does occur. Through an extensive study Friedman et al discovered 24% of patients found with severe cervical trauma (not limited to LIIs, but including LIIs) were diagnosed with abnormal veterbral artery findings (Friedman, Flanders, Thomas, & Millar, 1995). In another study conducted by Giacobetti et al, of the 61 patients admitted to a hospital with cervical spine trauma, 12 of them (19.7%) were found to have “a complete disruption of blood flow through the vertebral artery” (Giacobetti et al., 1997). In these cases flexion injuries were found to be the most common type of injury.

Since the vertebral artery follows an established path between the upper cervical vertebrae, injuries would not be uncommon since any rapid motions in this area of the spine could easily stretch the artery in excess.



(Primal Pictures, 2003)

We have looked at the various issues and injuries surrounding the LIIs and although more could be written concerning this topic when it comes to the medical treatment, I would rather leave that up to those professionals who have accepted the responsibility for assisting those in need.

I hope this paper helps to alleviate any doubt that low impact injuries, better known as whiplash, can occur with only minimal speeds and collisions.

I do agree there will be those that seek the deep pocket out should the opportunity occur, but I would like to think that overall mankind is good.

Appendix 1

Let us discuss Newton’s Third Law of Motion, or the conservation of motion in term’s of a rear-end collision. Remember, the equation for momentum (M) is mass of an object (m) multiplied by its velocity (v) or M = mv.

Vehicle A is stopped at a red-light and Vehicle B is closing on Vehicle A from behind at 3.13 m/sec (7 MPH). In this case both vehicles weigh 1,000 kg (2,200 lbs.) Before the collision we essentially have the following momentums:

Vehicle A

$$M_a = m_a v_a$$

$$M_a = 1,000 \text{ kg} \times 0 \text{ m/sec} = 0 \text{ kg} \cdot \text{m/sec}$$

Vehicle B

$$M_b = m_b v_b$$

$$M_b = 1,000 \text{ kg} \times 3.13 \text{ m/sec} = 3,130 \text{ kg} \cdot \text{m/sec}$$

The total momentum (M) before the collision is equal to the momentums of each vehicle added together. Therefore, total momentum before the collision,

$$\text{Total } M = m_a v_a + m_b v_b$$

$$\text{Total } M = 0 \text{ kg} \cdot \text{m/sec} + 3,130 \text{ kg} \cdot \text{m/sec} = 3,130 \text{ kg} \cdot \text{m/sec}$$

The law states that the momentum must be the same after the collision as it was before the collision. Therefore, we have 3,130 kg·m/sec after the collision as well.

Since Vehicle B has now impacted Vehicle A, there will be a drop in speed of approximately 50%, or in this case 1.57 m/sec (3.5 MPH).

MOMENTUM BEFORE = MOMENTUM AFTER

$$m_A v_A + m_B v_B = m_A v_A + m_B v_B$$

1,000 kg x0 m/sec + 1,000 kg x 3.13 m/sec =

1,000 kg x X m/sec + 1,000 kg x 1.57 m/sec

3,130 kg·m/sec = 1,000X kg·m/sec + 1,570 kg·m/sec

1,560 kg·m/sec = 1,000X kg·m/sec X = 1.56 m/sec

In this case both cars have the same ending momentum.

However with that being said this is not really the case. External forces (friction of the tires, braking, bumper crumpling, etc.) will preclude vehicle A from actually attaining a momentum of 1.56 m/sec.

Now what transpires if Vehicle A is struck by a service vehicle that weighs 3,000 kg (6,600 lbs.)?

M_a= 1,000 kg x 0 m/sec = 0 kg·m/sec

M_b= 3,000 kg x 3.13 m/sec = 9,390 kg·m/sec

Pre-collision Momentum is now equal to 9,390 kg·m/sec

Once again let us assume we have a 50% drop in the velocity of the service truck.

MOMENTUM BEFORE = MOMENTUM AFTER

$$m_A v_A + m_B v_B = m_A v_A + m_B v_B$$

$$9{,}390\ \text{kg}\cdot\text{m/sec} = 1{,}000\ \text{kg} \times X\ \text{m/sec} + 3{,}000\ \text{kg} \times 1.56\ \text{m/sec}$$

$$9{,}390\ \text{kg}\cdot\text{m/sec} = 1{,}000\ \text{kg} \times X\ \text{m/sec} + 4{,}680\ \text{kg}\cdot\text{m/sec}$$

$$4{,}680\ \text{kg}\cdot\text{m/sec} = 1{,}000X\ \text{kg} \times X\ \text{m/sec}$$

$$V_a = 4.68\ \text{m/sec}$$

In this example Vehicle A’s velocity has gone from 0 m/sec to 4.68 m/sec or 10.5 MPH. This would equate to Vehicle A being rear-ended by a car of the same mass at 21 MPH! So it is not only speed but also the respective size of the vehicles.

So where is the damage? The damage is a product of Vehicle A’s acceleration forward, although it is unwanted by the occupant(s).

Acceleration, speaking from a mathematical point of view, is *a change in velocity over a period of time,* and is expressed as

$$a = \Delta v/\Delta t$$

If we assume the transfer of energy between Vehicle A and Vehicle B occurred in 100 milliseconds, or .1 seconds the average acceleration would be:

$$a = \frac{1.56\ m/\text{sec}}{.1\ \text{sec}}$$

$$a = 15.6\ \text{m/sec}^2$$

This result can also be expressed in a more notable function known as G force or the force of gravitational pull on earth. 1 G equals 9.8 m/sec^2 or 32.2 ft/sec^2. With this in mind Vehicle A in *Example 1* experiences an average G force of approximately 3.28 G. However in *Example 2* the final velocity is 4.68 m/sec. Therefore,

$$a = \frac{4.68\ m/\text{sec}}{.1\ \text{sec}}$$

$$a = 46.8\ \text{m/sec}^2\text{, or } 4.77\ \text{G.}$$

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