Momentum: Myths and Misconceptions

Many myths surround the use of Linear Momentum. They do not appear in any reputable physics book in the world. Most were probably first uttered in an AI/AR class. If the instructor knew his/her physics, the myth was probably spoken of as a guide only. Unfortunately, many of these myths all too often take on a life of their own, becoming true urban legends. One of the veteran AI/AR instructors once said that he had been teaching it (a misconception) this way for years. It was probably true. He was wrong then and is probably still wrong now. His students learn his mistakes and many will probably pass them on to others. Doing or teaching something that is incorrect for a long time does not make it any less incorrect.

Some common misconceptions about momentum with respect to:

1. **360 Linear Momentum and Angular Momentum**
2. **10:1 Mass ratio and Friction**
3. **Cone of Departure**
4. **Vehicles exiting in same quadrant**
5. **Departure angle**
6. **Collision phase**
7. **Restitution phase**
8. **Collision Interface and Centroid of Damage**
9. **Transfer of momentum**
10. **Entrapment**

And a little lagniappe

360 Linear Momentum and Angular Momentum

There is some confusion concerning Linear Momentum that uses angles of Approach and Departure and Angular Momentum that uses degrees of rotation. They are two very different creatures. Linear Momentum does not mean that the collision is in a perfectly straight line (collinear), it means that the vehicles are traveling in a linear fashion or along a line. They do not have to all travel in the same direction. The Sine and Cosine values in Linear Momentum tell us the instantaneous linear direction in which the vehicle is traveling as it enters and leaves the collision.

While Linear Momentum deals with the linear path of the object, Angular Momentum deals with the rotation of the vehicle or object. A spinning vehicle in translational motion has both Angular and Linear momentum. Angular Momentum does not enter into the Linear Momentum equation, which deals with Speed and Mass, and Linear Momentum does not enter into the Angular Momentum equation, which deals with Inertia and Angular Rotation.

10:1 Mass Ratio

The weight or mass of the objects in collision can exacerbate the effect of the frictional forces and create other problems when dealing with momentum. Since the length of a momentum vector is the result of multiplying the weight (mass) of the object times the speed of the object, a 10:1 weight ratio between the objects in collision has been used as the outside limit for using a momentum analysis.

This 10:1 weight ratio limit is an arbitrary ratio used by some as a threshold value. It arose out of the sensitivity of the speeds at impact to the weight (mass) imbalance of the objects. However, this sensitivity does not always occur at a 10:1 ratio. It may not occur at all and it can occur at much smaller ratios. It does not occur when the heavy object strikes the stationary light object. When a light object strikes a heavy object in an oblique collision, the speed of the lighter object is especially sensitive to the imbalance in the weights. It is the sensitivity of the speeds of the vehicles to this weight imbalance that must always be taken into consideration in the analysis, not the 10:1 ratio.

Some collisions are also very sensitive to small changes in one or more of the angles involved. The range of uncertainty of a given angle, or any of the variables, can often have a profound effect on the impact speeds involved.

Each collision must be considered separately. A collision is a unique event and there is no universal rule regarding weights, speeds, or angles that can be applied to all possible collisions. Each situation must be analyzed for the sensitivity of all of the variables involved.

Friction

Weight can also play another role in the computations. During the engagement phase of a collision, the objects are subject to the surface interface friction just as they are during the other phases of a collision. In the engagement (damage) phase, this friction affects the momentum of the objects and the earth.

Consideration must be given to the effect of friction:

1. Between the objects
2. Prior to any change of direction
3. During the change of direction phase of the engagement
4. During the restitution phase of the engagement

Friction between the objects has no effect on the resultant momentum vector. The frictional forces are similar to the restitution forces in that they are internal to the system. Even if the magnitude of the friction forces prevents separation of the vehicles, the resultant momentum vector has not changed.

Usually the forces continue to increase during the course of the collision causing a change of direction and/or speed at the object's center of mass, until the vehicles reach maximum engagement. The individual momentum vectors of both vehicles are undergoing change from the point of initial contact. This change of momentum is relative to the dissipation and restitution of energy that continues up to the point of total separation of the objects or vehicles.

If the objects are both in motion relative to the earth, the friction force involved is the dynamic or kinetic friction at the interface between the object and the surface over which it is moving. If one of the objects is stopped, this friction force is the static friction, which is usually higher than the dynamic, until that vehicle is put in motion relative to the supporting surface. The frictional forces between the vehicles must also be considered in relation to the influence they may have on the angle of the principal direction of force.

The difference between the forces necessary to overcome static friction and dynamic friction can be substantial, especially when dealing with a heavy object. It may be so substantial that the lighter object cannot overcome the static friction of a heavy stationary object.

If the friction coefficient is high when a light object strikes a heavy stationary object, a situation may be encountered where the struck vehicle does not move. This does not mean that the Conservation of Momentum failed. Momentum is still conserved. The Earth's momentum is changed. We simply are not capable of measuring so small a change. Just because we are incapable of accurately measuring some changes does not mean that they are not taking place.

Some insist that momentum is seldom conserved in real world collisions because the external forces are frequently disregarded. The argument is that two of the bodies are being isolated, and therefore, since the analysis does not consider the external forces, momentum is not conserved. The argument is flawed. While the external forces are sometimes disregarded in the higher speed collisions, it is due to their insignificance in the results of the computations, as these are probably within the limits of uncertainty of the measurements. The external forces are disregarded for the sake of simplicity when they either sum to zero or are minimal in these computations.

Cone of Departure

"Cone of Departure" is simply a myth. It does not appear as a limitation or rule in any reputable physics book in the world. The "urban legend" surrounding the Cone of Departure was probably first uttered in an AI/AR class. If the instructor knew his/her physics, that limitation was probably spoken of as a guide only. If the vehicles exit outside of this cone, the collision may deserve a heightened degree of scrutiny, but nothing prevents or prohibits this possibility.