# Momentum Notes
## Physics

***Momentum*** is simply inertia in motion. Inertia is measured with mass and motion is measured with velocity. To determine momentum we simply combine the mass and velocity: $\vec{p} = m \cdot v$

Momentum is much like inertia, it tells us the tendency of an object to continue in its current state of motion. Just as we did not stop at identifying inertia, but rather explored its relationship with the state of motion and forces, we must look at the effects of momentum to gain more information about the behavior of objects in motion.

The change in momentum is called ***impulse***. This relationship can be found by exploring the acceleration of an object. If an object's momentum changes either the mass or velocity must change. Most objects we deal with do not spontaneously change mass, so the change in velocity is the most common cause of a change in momentum, impulse.

$$\Delta\vec{p} = \Delta(m \cdot v)$$

If we combine this with the relationship from Newton's Second law we will find that impulse can be imparted to an object. If you multiply the net force applied by the time that the net force is acting on the object you will have a measure of the impulse.

$$\Delta\vec{p} = \vec{F}_{net} \cdot \Delta t$$

This should make sense: more net force…more acceleration; more time with a net force…more acceleration. If you were to roll a bowling ball you would apply a net force to it for a certain amount of time. If you increased the net force, pushed it harder, it would have a greater impulse and roll faster. You could use the same net force, but push for a longer time. This would also cause the ball to roll faster due to a larger impulse. A common use of this time extension is in many sports where you are instructed to "follow through" when hitting a ball: baseball, tennis, golf, etc. By following through you stay in contact with the ball longer and impart more impulse to the ball. Another important aspect of impulse deals with impacts between objects. We have seen in Newton's Third law that there is an equal force on both objects during an impact, but how do you determine the magnitude of that force? Look at the collision of a falling 10 pound bowling ball with the floor. Is the impact force more , less, or equal to 10 lbs? It all depends on the impulse. By observation we can measure impulse if we know the change in velocity of the bowling ball. If it was travelling at 2 m/s and then comes to a stop it has changed momentum and therefore must have experienced an impulse. That amount of impulse will not change no matter how the bowling ball is stopped. However, the impact force will be dramatically affected by how the ball is stopped. If it were to land on a concrete floor and stop in 0.1 seconds, there would be an impact force of about 22 pounds. If the ball were to be dropped on a pillow it would take a longer time to stop, maybe .7 seconds, there would only be around 3 pounds of impact force. In both cases the ball is slowed down the same amount, but remember...the amount of time determines the amount of acceleration and therefore the amount of net force (Newton's Second Law). If the ball were to bounce you could expect twice the impact force. This is because the ball has to stop falling and then be forced back up in the air, twice the impulse.

A very important concept, and law of nature, is the ***conservation of momentum***. This simply means that the momentum of a ***system*** will not change regardless of the forces applied within the system. A system is defined as any collection of objects. We usually experience open systems where objects come and go from our original system of stuff around us. In physics we want to simplify for explanation sake and then we can add to it as necessary, so we will discuss a closed system. A closed system is just that same collection of objects, we just do not let any objects in or out. This also means that no forces from other objects get in or out. If our system includes the effects of gravity, we need to include the earth in our system. A very simple closed system would be a baseball at rest.. If it is the only object in the system, will it ever move? No, there can be no net force applied to it. At the start the ball has no momentum and will continue to have no momentum indefinitely. However if we included a moving baseball in the system the first baseball might move, if they were to collide. A collision is simply when two more objects interact with each other, causing some change to one or both of the objects motions. in the case of the two baseballs the collision will likely be elastic, they pretty much bounce off of each other. Now the system has some momentum, it is all present in the moving baseball. That momentum will not change for the system. If the baseballs do not collide they will both continue as they are and the momentum will stay the same as well. If the baseballs collide momentum will transfer from the moving ball the one at rest, but the momentum will still stay the same, it is conserved. The result of the collision is that the moving ball comes to rest while the other baseball begins moving at the same speed as the other baseball was moving. This result is due to the impulse on each baseball. According to the Third Law they both experience the same force, just in opposite directions. Also the time of collision is the same since they are impacting each other. The impulse on the moving baseball causes it to stop, while the same amount of impulse causes the other baseball to move away with the same velocity. As a result the momentum is conserved. The total momentum of the system (the two baseballs) must remain the same no matter the interaction between them. All of the momentum was initially contained in the moving baseball but now the momentum has transferred to the other baseball. Please recognize that if we were to try this we would have to roll the baseball on the floor or have it move through air and we would need to include the floor or air in our closed system, making it more complicated to analyze. However, if you could measure all momentum changes you would still find that the momentum is conserved. The other type of collision is inelastic, where the objects stick together. For example, one car rolls into another car that is at rest. Make these two cars your closed system and you will recognize the total momentum of the system is initially all in the moving car. When the cars collide their bumpers hook together and now they are one object. In this case the momentum is still conserved, but now it is all in the one resulting object. This two car object will be moving, but at a slower speed than the moving single car. Since the momentum stays the same and the mass increased the speed must decrease. In this case the momentum transfer is not complete between the two cars. A final word about collisions needs to include energy. Energy is that which causes change. Newton believed that impulse was this agent of change. It turns out he missed that one. There are two main forms of energy, kinetic (motion) and potential (stored). In a perfectly elastic collision kinetic energy is conserved. In an inelastic collision the kinetic energy is not conserved, but don't you worry...the total energy is conserved, that's the law.