Accelerated Motion

Newton's Second Law

With Newton's first law, you learned that the motion of an object only changes if a net force acts on it, such as the brakes of a car, or a fast moving hockey stick. Newton's second law elaborates on other components of motion and forces.

Newton's second law states:
a net force acting on an object causes the object to accelerate in the direction of the force

The acceleration is determined by the size of the force and the mass of the object. A larger force acting on an object causes a greater acceleration. A larger mass requires a greater force than a smaller mass would require to achieve the same acceleration.

Newton's second law can be expressed in equation form as:

Force = mass x acceleration

OR F = ma

Mass is expressed in Kg and acceleration is expressed in m/s^2. Thus, force is expressed in units of $Kg \cdot m/s^2$.

You have learned from the section on gravity that one newton is a standard unit for measuring force. A newton is the amount of force needed to accelerate an object with a mass of 1Kg at an acceleration of $1\ m/s^2$. In other words, $1N = 1Kg \cdot m/s^2$.

Force Problems

How much force is needed to accelerate a 70-kg rider and her 200-kg motorcycle at $4m/s^2$?

mass of rider (mr) = 70kg
mass of motorcycle = 200kg
acc = 4 m/s2
270 kg total

$F = 270kg \cdot 4m/s^2 = 1080 N$

It takes a force of 3000 N to accelerate an empty 1000-kg car at 3m/s2. If a 160-kg wrestler is inside the car, how much force will be required to produce the same acceleration?

$F = m \cdot a = (1000kg + 160kg)(3m/s^2)$
$= 3480 N$

A 63-kg skater pushed off from a wall with a force of 300 N. What is the skater's acceleration?

$F = ma,$
$a = \frac{F}{m}, = \frac{300N}{63kg} = \frac{300 Kg \cdot m/s^2}{63 Kg} = 4.76 m/s^2$

Falling Objects

It's hard to believe, but if you drop a bowling ball and a marble from a bridge at the same instant, they'd both splash into the water at almost the same instant. This means their _accelerations_ would be about the same. Would you have expected the bowling ball to hit the water first because it has more mass? It's true that the force of _gravity_ would be greater on the bowling ball because of the larger _mass_. But larger mass also gives the bowling ball more _inertia_, so more _force_ is needed to change its _velocity_. The marble has a much smaller mass than the bowling ball, but its _inertia_ is also less.

Near Earth's surface, _gravity_ causes all falling objects to _accelerate_ at _9.8m/s2_. Does the number _9.8_ seem familiar? It should! When you learned about the relationship between mass and weight, you learned that any object with a mass of 1 kg weighs 9.8 N on Earth. This is why:

Any force can be calculated using the equation $F = m \cdot a$.
The weight of an object, W, is the force of gravity acting on its mass. So, we can substitute and write: $W = m \cdot a$.
Acceleration due to gravity is $9.8\,m/s^2$, therefore, $W = m \cdot 9.8\,m/s^2$

This means that a mass of 1 kg weighs $9.8\,kg \cdot m/s^2$ or 9.8 N. You could calculate your weight in newtons if you knew your mass. For example, a person with a mass of 50 kg would have a weight of 490 N.

Remember that this discussion is only concerned with falling objects. This refers to an object that is dropped from some height and allowed to fall freely. As the object is released from your grip, the only downward force acting on it is gravity. The situation changes when the object is thrown downward. In this case, the object is affected by gravity and the downward force of the throwing hand. Therefore, the object's downward acceleration would be greater than $9.8\,m/s^2$.

Air Resistance

Acceleration due to gravity (g) is the Same for all objects, regardless of mass. This means that if no force other than gravity is present, all objects accelerate at $9.8\,m/s^2$. Think about that. Does a leaf accelerate as fast as a pinecone? Does a feather fall as fast as a penny?

Nope.

What would happen if you took two identical sheets of paper, crumpled one up into a ball, and dropped both sheets at the same time?

The crumpled paper falls faster.

The behavior of the two pieces of paper doesn't agree with what you've just learned. How can this be explained?

The only explanation for this observation is that Some force is at work in addition to gravity. Anything that moves in Earth's atmosphere is affected by air resistance. Air resistance is the force air exerts on a moving object. This force acts in the opposite direction to that of the object's motion. In the case of the falling object, air resistance pushes up as gravity pulls down.

The amount of air resistance on an object depends on the speed, size, shape, and density of the object. It is air resistance that helps a Frisbee stay aloft for several seconds. The larger the surface area of the object, the greater the amount of air resistance on it. This is why feathers, leaves, and sheets of paper fall more slowly than pennies, pinecones, and crumpled pieces of paper.

As an object falls through the air, air resistance gradually increases until it balances the pull of gravity. According to the law of inertia, when the forces on an object are balanced, the motion of the object will not change. When this happens, the falling object will stop accelerating. It will continue to fall, but at a constant, final velocity (this is what happens to people who choose to jump out of a perfectly good airplane!). This is called terminal velocity, and it is the highest velocity that will be reached by a falling object.