Mechanics and Motion

Motion is one of the key topics in physics. Everything in the universe moves. It might only be a small amount of movement and very, very slow, but movement does happen. Don't forget that even if you appear to be standing still, the Earth is moving around the Sun, and the Sun is moving around our galaxy. The movement never stops. Motion is one part of what physicists call mechanics. Over the years, scientists have discovered several rules or laws that explain motion and the causes of changes in motion. There are also special laws when you reach the speed of light or when physicists look at very small things like atoms.

The physics of motion is all about forces. Forces need to act upon an object to get it moving, or to change its motion. Changes in motion won't just happen on their own. So how is all of this motion measured? Physicists use some basic terms when they look at motion. How fast an object moves, its speed or Velocity, can be influenced by forces. (Note: Even though the terms 'speed' and 'velocity' are often used at the same time, they actually have different meanings.)

Acceleration is a twist on the idea of velocity. Acceleration is a measure of how much the velocity of an object changes in a certain time (usually in one second). Velocities could either increase or decrease over time. Mass is another big idea in motion. Mass is the amount of something there is and is measured in grams (or kilograms). A car has a greater mass than a baseball. There are two main ideas when you study mechanics. The first idea is that there are simple movements, such as if you're moving in a straight line, or if two objects are moving towards each other in a straight line. The simplest movement would be objects moving at constant velocity. Slightly more complicated studies would look at objects that speed up or slow down, where forces have to be acting.

There are also more complex movements when an object's direction is changing. These would involve curved movements such as circular motion, or the motion of a ball being thrown through the air. For such complex motions to occur, forces must also be acting, but at angles to the movement.

In order to really understand motion, you have to think about forces, acceleration, energy, work, and mass. These are all a part of mechanics.

Forces of Nature

Forces are a big part of physics. Physicists devote a lot of time to the study of forces that are found everywhere in the universe. The forces could be big, such as the pull of a star on a planet. The forces could also be very small, such as the pull of a nucleus on an electron. Forces are acting everywhere in the universe at all times.

Examples of Force

If you were a ball sitting on a field and someone kicked you, a force would have acted on you. As a result, you would go bouncing down the field. There are often many forces at work. Physicists might not study them all at the same time, but even if you were standing in one place, you would have many forces acting on you. Those forces would include gravity, the force of air particles hitting your body from all directions (as well as from wind), and the force being exerted by the ground (called the normal force).

Let's look at the forces acting on that soccer ball before you kicked it. As it sat there, the force of gravity was keeping it on the ground, while the ground pushed upward, supporting the ball. On a molecular level, the surface of the ball was holding itself together as the gas inside of the ball tried to escape. There may have also been small forces trying to push it as the wind blew. Those forces were too small to get it rolling, but they were there. And you never know what was under the ball. Maybe an insect was stuck under the ball trying to push it up. That's another force to consider.

If there is more than one force acting on an object, the forces can be added up if they act in the same direction, or subtracted if they act in opposition. Scientists measure forces in units called Newtons. When you start doing physics problems in class, you may read that the force applied to the soccer ball (from the kick) could be equal to 12 Newtons.

A Formula of Force

Net force equals the mass of an object multiplied by its acceleration. There is one totally important formula when it comes to forces, F = ma. That's all there is, but everything revolves around that formula. "F" is the total (net) force, "m" is the object's mass, and "a" is the acceleration that occurs. As a sentence, "The net force applied to the object equals the mass of the object multiplied by the amount of its acceleration." The net force acting on the soccer ball is equal to the mass of the soccer ball multiplied by its change in velocity each second (its acceleration). Do you remember the wind gently blowing on the soccer ball? The force acting on the ball was very small because the mass of air was very small. Small masses generally exert small forces, which generally result in small accelerations (changes in motion).

Forces and Vectors

A vector can be used to represent any force. A force vector describes a specific amount of force that is applied in a specific direction. If you kick that soccer ball with the same force, but in different directions, and you get different results.

Vector Basics

Force is one of many things that are vectors. What the heck is a vector? Can you hold it? No. Can you watch it? No. Does it do anything? Well, not really. A vector is a numerical value in a specific direction, and is used in both math and physics. The force vector describes a specific amount of force and its direction. You need both value and direction to have a vector. Both. Very important. Scientists refer to the two values as direction and magnitude (size). The alternative to a vector is a scalar. Scalars have values, but no direction is needed. Temperature, mass, and energy are examples of scalars.

When you see vectors drawn in physics, they are drawn as arrows. The direction of the arrow is the direction of the vector, and the length of the arrow depends on the magnitude (size) of the vector.

Real World Vectors

Imagine a situation where you're in a boat or a plane, and you need to plot a course. There aren't streets or signs along the way. You will need to plan your navigation on a map. You know where you're starting and where you want to be. The problem is how to get there. Now it's time to use a couple of vectors. Draw the vector between the two points and start on your way. As you move along your course, you will probably swerve a bit off course because of wind or water currents. Just go back to the map, find your current location, and plot a new vector that will take you to your destination. Captains use vectors (they know the speed and direction) to plot their courses.

Combining Vectors

We're hoping you know how to add and subtract. Scientists often use vectors to represent situations graphically. When they have many vectors working at once, they draw all the vectors on a piece of paper and put them end to end. When all of the vectors are on paper, they can take the starting and ending points to figure out the answer. The final line they draw (from the start point to the end point) is called the Resultant vector. If you don't like to draw lines, you could always use geometry and trigonometry to solve the problems. It's up to you. Unlike normal adding of numbers, adding vectors can give you different results, depending on the direction of the vectors.

Newton's Laws of Motion

There was this fellow in England named Sir Isaac Newton. A little bit stuffy, bad hair, but quite an intelligent guy. He worked on developing calculus and physics at the same time. During his work, he came up with the three basic ideas that are applied to the physics of most motion (NOT modern physics). The ideas have been tested and verified so many times over the years, that scientists now call them Newton's Three Laws of Motion.

First Law

The first law says that an object at rest tends to stay at rest, and an object in motion tends to stay in motion, with the same direction and speed. Motion (or lack of motion) cannot change without an unbalanced force acting. If nothing is happening to you, and nothing does happen, you will never go anywhere. If you're going in a specific direction, unless something happens to you, you will always go in that direction. Forever.

You can see good examples of this idea when you see video footage of astronauts. Have you ever noticed that their tools float? They can just place them in space and they stay in one place. There is no interfering force to cause this situation to change. The same is true when they throw objects for the camera. Those objects move in a straight line. If they threw something when doing a spacewalk, that object would continue moving in the same direction and with the same speed unless interfered with; for example, if a planet's gravity pulled on it (Note: This is a really really simple way of descibing a big idea. You will learn all the real details - and math - when you start taking more advanced classes in physics.).

Second Law

As acceleration increases, the force increases. The second law says that the acceleration of an object produced by a net (total) applied force is directly related to the magnitude of the force, the same direction as the force, and inversely related to the mass of the object (inverse is a value that is one over another number... the inverse of 2 is 1/2). The second law shows that if you exert the same force on two objects of different mass, you will get different accelerations (changes in motion). The effect (acceleration) on the smaller mass will be greater (more noticeable). The effect of a 10 newton force on a baseball would be much greater than that same force acting on a truck. The difference in effect (acceleration) is entirely due to the difference in their masses.

Third Law

The third law says that for every action (force) there is an equal and opposite reaction (force). Forces are found in pairs. Think about the time you sit in a chair. Your body exerts a force downward and that chair needs to exert an equal force upward or the chair will collapse. It's an issue of symmetry. Acting forces encounter other forces in the opposite direction. There's also the example of shooting a cannonball. When the cannonball is fired through the air (by the explosion), the cannon is pushed backward. The force pushing the ball out was equal to the force pushing the cannon back, but the effect on the cannon is less noticeable because it has a much larger mass. That example is similar to the kick when a gun fires a bullet forward.

Energy Around Us

We use the concept of energy to help us describe how and why things behave the way they do. We talk about solar energy, nuclear energy, electrical energy, chemical energy, etc. If you apply a force to an object, you may change its energy. That energy must be used to do work, or accelerate, an object. Energy is called a scalar; there is no direction to energy (as opposed to vectors). We also speak of kinetic energy, potential energy, and energy in springs. Energy is not something you can hold or touch. It is just another means of helping us to understand the world around us. Scientists measure energy in units called joules.

Active Energy vs. Stored Energy

One ball with potential energy and one ball with kinetic energy. Kinetic and potential energies are found in all objects. If an object is moving, it is said to have kinetic energy (KE). Potential energy (PE) is energy that is "stored" because of the position and/or arrangement of the object. The classic example of potential energy is to pick up a brick. When it's on the ground, the brick had a certain amount of energy. When you pick it up, you apply force and lift the object. You did work. That work added energy to the brick. Once the brick is in a higher/new position, we would say that the increased energy was stored in the brick as PE. Now the brick can do something it couldn't do before; it can fall. And in falling, can exert forces and do work on other objects.

Season of Springs

The study of springs is a whole section of physics. A spring that just sits there doesn't do much. When you push on it, you exert a force and change the arrangement of the coils. That change in the arrangement stores energy in the spring. It now contains energy and can expand and do work on other things. Anything that is elastic (can change its arrangement and then restore itself), such as a rubber band, can store energy in the same way.

A rubber band can be stretched and then it is ready to do something. That stretching involves work and increases the potential energy. You can flatten a solid rubber ball and it will want to bounce back up. You can also pull the drawstring of a bow and the work done stores the energy that can make the arrow go flying. Those are all examples of your putting energy in, and then something happening when the energy comes out.

Gases Storing Energy

Gases? What can they do? Gases are great because they can compress and expand. They act as if they were elastic. If the pressure increases and compresses gas molecules, the amount of stored energy increases. It's similar to a spring, but slightly different. Eventually that energy in the compressed gas can be let out to do something (work).

In your car, there are shock absorbers. Some shocks have compressed gas in the cylinders rather than springs. The energy in those cylinders keeps your car from bouncing too much in potholes. Think about wind. Wind is caused because of pressure differences in the atmosphere. When the wind blows it can do anything - turn windmills, help birds fly, make tornadoes, and do all types of work.