CORAL CAY CONSERVATION & JFA
EDUCATIONAL AIDS

UPPER PRIMARY SCHOOL WORKBOOK

Science and the Home

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STATES OF MATTER

Materials can be classified into three states of matter;

1. Solids
2. Liquids
3. Gases

Each of these states is also known as a phase. The phase or state of matter can change when the temperature changes. Generally, as the temperature rises, matter moves to a more active state.

Phase describes a physical state of matter. The key word to notice is physical. Things only move from one phase to another by physical means. If energy is added (like increasing the temperature or increasing pressure) or if energy is taken away (like freezing something or decreasing pressure) you have created a physical change.

One compound or element can move from phase to phase, but still be the same substance. You can see water **vapour** over a boiling pot of water. That vapour (or gas) can **condense** and become a drop of water. If you put that drop in the freezer, it would become a solid. No matter what phase it was in, it was always water. It always had the same chemical properties. On the other hand, a chemical change would change the way the water acted, eventually making it not water, but something completely new.

Solids

There are three main features that make a solid a solid!

- Keep their shape unless they are broken
- Do not flow
- Cannot be compressed (keep the same volume)

So what is a solid? Solids are usually hard because their particles have been packed together very closely. The forces between particles are strong enough so that the particles cannot move freely but can only vibrate. As a result, a solid has a stable, definite shape, and a definite volume. Solids can only change their shape by force, as when broken or cut. This is one of the **physical** characteristics of solids. Particles in liquids and gases are bouncing and floating around, free to move where they want. The particles in a solid are stuck.

Solids can be made up of many things. They can have pure elements or a variety of compounds inside. When you get more than one type of compound in a solid it is called a **mixture**. Most rocks are mixtures of many different compounds. Concrete is a good example of a manmade mixture.

Liquids

- Do not keep their shape, they take the shape of the container that they are in
- Flow
- Cannot be compressed (keep the same volume)

Solids are hard things you can hold. Gases are floating around you and in bubbles. What is a liquid? When a solid is heated above its melting point, it becomes liquid. Particles have enough energy to move relative to each other and the structure is mobile. This means that the shape of a liquid is not definite but is determined by its container.

Water is a liquid. Your blood is a liquid. Liquids are an in-between state of matter. They don't have to be made up of the same compounds. If you have a variety of materials in a liquid, it is called a solution.

One characteristic of a liquid is that it will fill up the shape of a container. If you pour some water in a cup, it will fill up the bottom of the cup first and then fill the rest. The water will also take the shape of the cup. It fills the bottom first because of **gravity**. The top part of a liquid will usually have a flat surface. That flat surface is because of gravity too. Putting an ice cube (solid) into a cup will leave you with a cube in the middle of the cup; the shape won't change until the ice becomes a liquid.

Another trait of liquids is that they are difficult to compress. When you compress something, you take a certain amount and force it into a smaller space. Solids are very difficult to compress and gases are very easy. Liquids are in the middle but tend to be difficult. When you compress something, you force the particles closer together. When pressure go up, substances are compressed.

Gases

- Do not keep their shape, they completely fill the container that they are in
- Flow, spread out quickly from where they are to start with (this is called diffusion)
- Can be compressed (squashed into a much smaller volume)

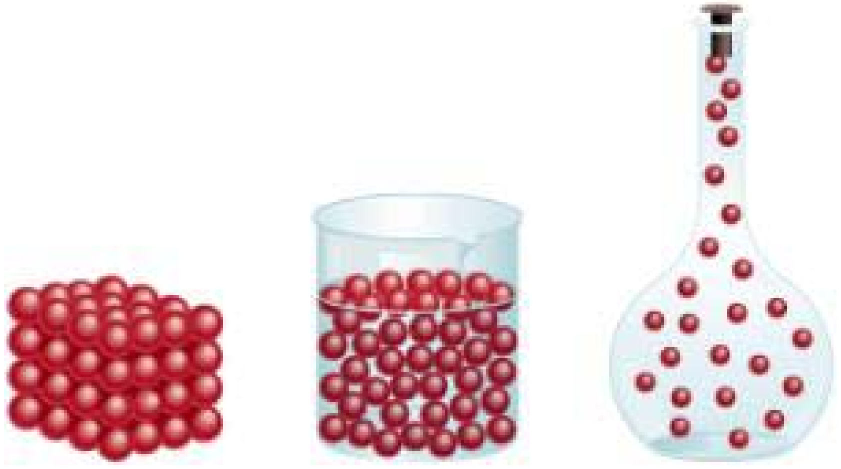
Gas is everywhere. There is something called the atmosphere. That's a big layer of gas that surrounds the Earth. Gases are **random** groups of particles. In solids, particles are compact and close together. Liquids have particles a little more spread out. However, gases are really spread out and the particles are full of energy. They are bouncing around constantly.

Gases can fill a container of any size or shape. That is one of their physical characteristics. Think about a balloon. No matter what shape you make the balloon it will be evenly filled with the gas particles. The particles are spread equally throughout the entire balloon. Liquids can only fill the bottom of the container while gases can fill it entirely.

You might hear the term **vapour**. Vapour and gas mean the same thing. The word vapour is used to describe gases that are usually found as liquids. A Good example is water.

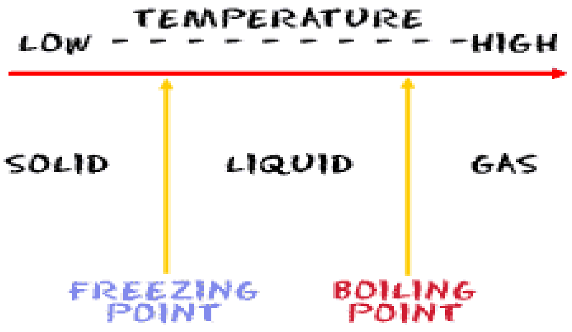
PARTICLES

Solids, liquids and gasses are made from small particles or matter. Matter is anything that has mass and takes up space. These particles or matter are called atoms and molecules.



The Particle Theory of Matter:

- Matter is made up of tiny particles (Atoms & Molecules)
- Particles of Matter are in constant motion.
- Particles of Matter are held together by very strong forces
- There are empty spaces between the particles of matter that are very large compared to the particles themselves.
- Each substance has unique particles that are different from the particles of other substances
- Temperature affects the speed of the particles. The higher the temperature, the faster the speed of the particles.



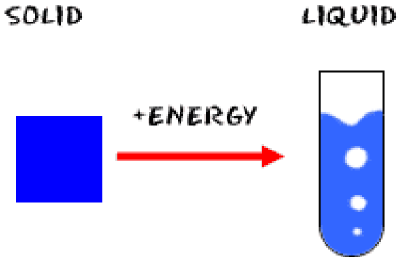
The particle theory of matter explains the following scientific phenomena:

- Pure substance are homogeneous (one phase - one unique kind of particle)
- Physical Changes - Melting, Evaporation, Dissolving
- Characteristic Physical Properties - Density, Viscosity, Electrical & Thermal Conductivity

PROPERTY	**SOLID**	**LIQUID**	**GAS**
shape	fixed	same as container (indefinite)	same as container (indefinite)
volume	definite	definite	fills entire container (indefinite)
ability to flow	no	yes	yes
can be compressed	very slightly	very slightly	yes
volume change with heating	very small	small	large

CHANGING STATES OF MATTER

All matter can move from one state to another. It may require very low temperatures or very high pressures, but it can be done. Phase changes happen when certain points are reached. Sometimes a liquid wants to become a solid. Scientists use something called a **freezing point** to measure when that liquid turns into a solid. There are physical effects that can change the freezing point. Pressure is one of those effects. When the pressure surrounding a substance goes up, the freezing point also goes up. That means it's easier to freeze the substance at higher pressures. When it gets colder, most solids shrink in size. There are a few which expand but most shrink.



Now you're a solid. You're a cube of ice sitting on a counter. You dream of becoming liquid water. You need some **energy**. Particles in a liquid have more energy than the particles in a solid. The easiest energy around is probably heat. There is a magic temperature for every substance called the **melting point.** When a solid reaches the temperature of its melting point it can become a liquid. For water the temperature has to be a little over zero degrees Celsius. If you were salt, sugar, or wood your melting point would be higher than water.

The reverse is true if you are a gas. You need to lose some energy from your very excited gas particles. When the temperature drops, energy will be sucked out of your gas particles. When you reach the temperature of the condensation point, you become a liquid. If you were the steam of a boiling pot of water and you hit the wall, the wall would be so cool that you would quickly become a liquid.

MIXTURES

A **chemical substance** is a material with a specific chemical composition.

A common example of a chemical substance is pure water; it has the same properties and the same ratio of hydrogen to oxygen whether it is isolated from a river or made in a laboratory. A pure chemical substance cannot be separated into other substances by a process that does not involve any chemical reaction and is rarely found in nature. Some typical chemical substances can be diamond, gold, salt (sodium chloride) and sugar (sucrose). Generally, chemical substances exist as a solid, liquid, or gas, and may change between these phases of matter with changes in temperature or pressure.

Elements

Main article: Chemical element
See also: List of elements by name

An element is a chemical substance that is made up of a particular kind of atoms and hence cannot be broken down or transformed by a chemical reaction into a different element, though it can be transmutated into another element through a nuclear reaction. This is so, because all of the atoms in a sample of an element have the same number of protons, though they may be different isotopes, with differing numbers of neutrons.

There are about 120 known elements, about 80 of which are stable - that is, they do not change by radioactive decay into other elements. However, the number of chemical substances that are elements can be more than 120, because some elements can occur as more than a single chemical substance (allotropes). For instance, oxygen exists as both diatomic oxygen (0_2) and ozone (0_3). The majority of elements are classified as metals. These are elements with a characteristic lustre such as iron, copper, and gold. Metals typically conduct electricity and heat well, and they are malleable and ductile.[6] Around a dozen elements,[7] such as carbon, nitrogen, and oxygen, are classified as non-metals. Non-metals lack the metallic properties described above, they also have a high electronegativity and a tendency to form negative ions. Certain elements such as silicon sometimes resemble metals and sometimes resemble non-metals, and are known as metalloids.

[edit] Chemical compounds

Main article: Chemical compound
See also: List of organic compounds and List of inorganic compounds

A pure chemical compound is a chemical substance that is composed of a particular set of molecules or ions. Two or more elements combined into one substance, through a chemical reaction, form what is called a chemical compound. All compounds are substances, but not all substances are compounds.

A chemical compound can be either atoms bonded together in molecules or crystals in which atoms, molecules or ions form a crystalline lattice. Compounds based primarily on carbon and hydrogen atoms are called organic compounds, and all others are called inorganic compounds. Compounds containing bonds between carbon and a metal are called organometallic compounds.

Compounds in which components share electrons are known as covalent compounds. Compounds consisting of oppositely charged ions are known as ionic compounds, or salts.

In organic chemistry, there can be more than one chemical compound with the same composition and molecular weight. Generally, these are called isomers. Isomers usually have substantially different chemical properties, may be isolated and do not spontaneously convert to each other. A common example is glucose vs. fructose. The former is an aldehyde, the latter is a ketone. Their interconversion requires either enzymatic or acid-base catalysis. However, there are also tautomers, where isomerization occurs spontaneously, such that a pure substance cannot be isolated into its tautomers. A common example is glucose, which has open-chain and ring forms. One cannot manufacture pure open-chain glucose because glucose spontaneously cyclizes to the hemiacetal form.

[edit] Substances versus mixtures

Main article: Mixture

All matter consists of various elements and chemical compounds, but these are often intimately mixed together. Mixtures contain more than one chemical substance, and they do not have a fixed composition. In principle, they can be separated into the component substances by purely mechanical processes. Butter, soil and wood are common examples of mixtures.

Grey iron metal and yellow sulfur are both chemical elements, and they can be mixed together in any ratio to form a yellow-grey mixture. No chemical process occurs, and the material can be identified as a mixture by the fact that the sulfur and the iron can be separated by a mechanical process, such as using a magnet to attract the iron away from the sulfur.

In contrast, if iron and sulfur are heated together in a certain ratio (56 grams (1 mol) of iron to 32 grams (1 mol) of sulfur), a chemical reaction takes place and a new substance is formed, the compound iron(II) sulfide, with chemical formula FeS. The resulting compound has all the properties of a chemical substance and is not a mixture. Iron(II) sulfide has its own distinct properties such as melting point and solubility, and the two elements cannot be separated using normal mechanical processes; a magnet will be unable to recover the iron, since there is no metallic iron present in the compound.

1. **Element**- is a pure substance (homogeneous material) that broken down further (decomposed) by ordinary chemical means. (An element is made of only one kind of atom). Example: aluminum, hydrogen, calcium, mercury.

Elements are listed on the *periodic table*. Scientists have found 90 elements in nature, and about 20 more have been produced in the laboratory.

2. **Compound**- two or more elements chemically combined. (Note: if a sample of matter is made of atoms of two or more elements joined together, always in the same ratio, then that matter is a compound.)
Example: alcohol (C2H5OH), water (H2O), salt (NaCl), sugar C12H22O11) ammonia (NH3).

NOTE: When scientists refer to substances, they mean elements or compounds. A substance always has a definite composition.

Mixture- two or more elements or compounds that are blended without combining chemically. Each part of the matter in a mixture has its own identity (properties). Mixtures can be separated using physical or mechanical means.
Example: fabrics, vinegar, soil, rocks, rocks, milk, lemonade

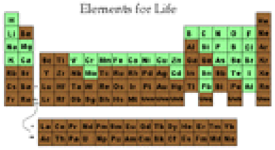
Mixtures can be heterogeneous mixtures or homogeneous mixtures

Heterogeneous mixtures- the substances in the kind of a mixture are not spread out evenly. Example: a bottle of liquid salad dressing.

Homogeneous mixtures- the substances are spread evenly throughout, a homogeneous mixture is called a solution. Example: vinegar (water and acetic acid are mixed evenly throughout). Other examples: sea water, soft drinks, glass

Pure Substances vs. Mixtures

I. Matter can be classified in to two broad categories: pure substances and mixtures.
  II. Pure substances
    i. Elements - all the same type of atom.

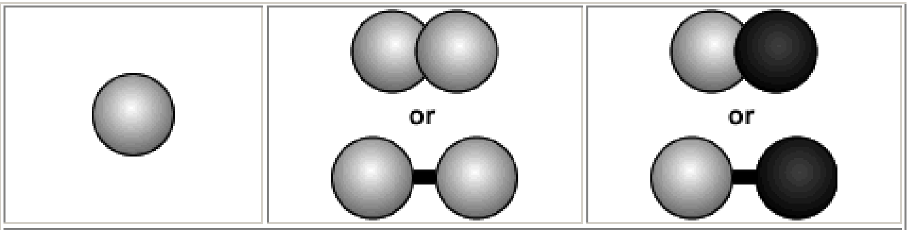


      a. elemental info
      b. The Elements Song by Tom Lehrer
      ii. Compounds - substances made from two or more different kinds of atoms.
    III. Mixtures
  . Homogeneous
    . Mixtures which are the same throughout with identical properties everywhere in the mixture.
      a. Not easily separated.
      b. This type of mixture is called a solution. A good example would be sugar dissolved in water or some type of metal alloy like the CROmium-MOLYbdenum steel used in many bike frames.
      i. Heterogeneous
    . Mixtures which have different properties when sampled from different areas.
      a. Examples of this would be sand mixed with water or peanuts mixed with raisins.
      IV. Atoms vs. Molecules
  . Atoms - the smallest piece of matter you can have that chemists can do reactions with is an atom. Each element has it's own type of atom. How to distinguish between atoms will be explained in a later unit.
    i. Molecules - two or more atoms bonded together with a covalent bond (more on that bond later) is called a molecule.
    . If all the atoms bonded together are of the same time the molecule formed is still an element.
      a. If different types of atoms are bonded together, then the molecule formed is a compound.

a single atom (of an element)	a molecule (of an element)	a molecule (of a compound)

ELECTRICITY CHARGES THE NEON WITH ENERGY AND THE GAS BECOMES A PLASMA.

THESE PIPES ARE IN THE MIDDLE OF CHEMICAL CHANGES AS THEY RUST.



Note: Atoms don't have a color. The colors here are used to differentiate between kinds of atoms.

V. Click the image below for a graphical representation of these ideas.

VI. Using molecular modeling kits create several examples of an element, compound, and a mixture.

CHEMICAL VS. PHYSICAL CHANGES

It is important to understand the difference between chemical and physical changes. The two types are based on studying chemical reactions and states of matter. We admit that some changes are obvious, but there are some basic ideas you can use. Physical changes are about energy and states of matter. Chemical changes happen on a MOLECULAR level.

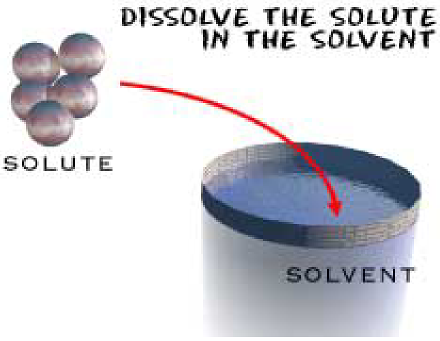
When you step on a can and crush it, you have forced a physical change. The shape of the object has changed. It wasn't a change in the state of matter, but something changed. When you melt an ice cube you have also forced a physical change (adding energy). That example caused a change in the state of matter. You can cause physical changes with forces like motion, temperature, and pressure.

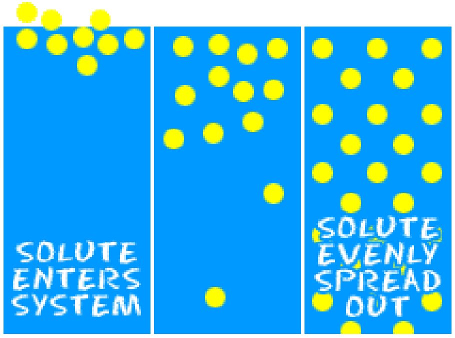
Chemical changes happen on a much smaller scale. While some experiments show obvious chemical changes such as a color change, most chemical changes happen between molecules and are unseen. When iron (Fe) rusts you can see it happen over a long period of time. The actual molecules have changed their structure (the iron oxidized). Melting a sugar cube is a physical change because the substance is still sugar. Burning a sugar cube is a chemical change. The energy of the fire has broken down the chemical bonds.

Some changes are extremely small. Chemical changes can happen over a series of steps, and the result might have the same number of atoms but

HAVE A DIFFERENT STRUCTURE. THE SUGARS GLUCOSE, GALACTOSE, AND FRUCTOSE ALL HAVE SIX CARBON ATOMS, TWELVE HYDROGEN ATOMS, AND SIX OXYGEN ATOMS. EVEN THOUGH THEY ARE MADE OF THE SAME ATOMS, THEY HAVE VERY DIFFERENT SHAPES AND ARE CALLED STRUCTURAL ISOMERS. THEY EACH HAVE DIFFERENT CHEMICAL REACTIONS BECAUSE OF THEIR MOLECULAR STRUCTURE.

SOLUTIONS AND MIXTURES





Before we dive into solutions, let's separate solutions from other types of mixtures. Solutions are groups of molecules that are mixed up in a completely even distribution. Hmmm. Not the easiest way to say it. Scientists say that solutions are **homogenous** systems. Other types of mixtures can have a little higher concentration on one side of the liquid when compared to the other side. Solutions have an even concentration throughout the system. An example: Sugar in water vs. Sand in water. Sugar dissolves and is spread throughout the glass of water. The sand sinks to the bottom. The sugar-water could be considered a solution. The sand-water is a mixture.

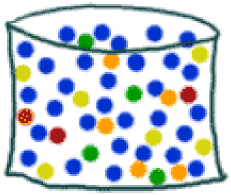
CAN ANYTHING BE IN SOLUTION?

Pretty much. Solutions can be solids dissolved in liquids. They could also be gases dissolved in liquids (such as carbonated water). There can also be gases in other gases and liquids in liquids. If you mix things up and they stay at an even distribution, it is a solution. You probably won't find people making solid-solid solutions in front of you. They start off as solid/gas/liquid-liquid solutions and then harden at room temperature. Alloys with all types of metals are good examples of a solid solution at room temperature. A simple solution is basically two substances that are going to be combined. One of them is called the **solute**. A solute is the substance to be dissolved (sugar). The other is a **solvent**. The solvent is the one doing the dissolving (water). As a rule of thumb, there is usually more solvent than solute.

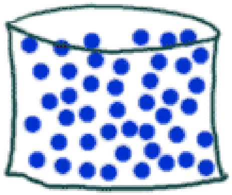
MAKING SOLUTIONS

So what happens? How do you make that solution? Mix the two liquids and stir. It's that simple. Science breaks it into three steps. When you read the steps, remember... Solute=Sugar, Solvent=Water, System=Glass.

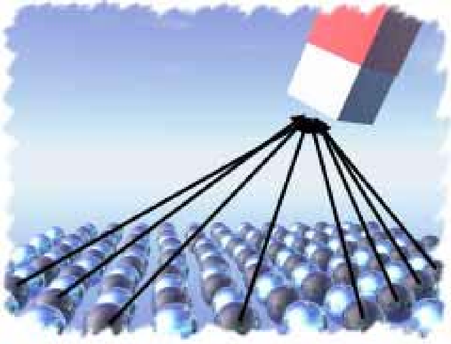
1. The solute is placed in the solvent and the concentrated solute slowly breaks into pieces.
2. The molecules of the solvent begin to move out of the way and they make room for the molecules of the solute. Example: The water has to make room for the sugar molecules.



Tap Water



Distilled



IN A MIXTURE OF SALT AND IRON. THE IRON CAN BE REMOVED WITH A MAGNET.

3. The solute and
solvent interact
with each other
the two
throughout the
concentration of
be the same from
bottom, or middle

until the concentration of
substances is equal
system. The
sugar in the water would
a sample at the top,
of the glass.

CAN ANYTHING CHANGE SOLUTIONS?

Sure. All sorts of things can change the concentrations of substances in solution. Scientists use the word solubility. Solubility is the ability of the solvent (water) to dissolve the solute (sugar). You may have already seen the effect of temperature in your classes. Usually when you heat up a solvent, it can dissolve more solid materials (sugar) and less gas (carbon dioxide). Next on the list of factors is pressure. When you increase the surrounding pressure, you can usually dissolve more gases in the liquid. Think about your soda can. They are able to keep the fizz inside because the contents of the can are under higher pressure. Last is the structure of the substances. Some things dissolve easier in one kind of substance than another. Sugar dissolves easily in water; oil does not. Water has a low **solubility** when it comes to oil.

MIXTURE BASICS

Mixtures are absolutely everywhere you look. Mixtures are the form for most things in nature. Rocks, air, or the ocean, they are just about anything you find. They are substances held together by **physical forces**, not chemical. That statement means the individual molecules enjoy being near each other, but their fundamental chemical structure does not change when they enter the mixture.

When you see **distilled water**, it's a pure substance. That fact means that there are just water molecules in the liquid. A mixture would be a glass of water with other things dissolved inside, maybe salt. Each of the substances in that glass of water keeps the original chemical properties. So, if you have some dissolved substances, you can boil off the water and still have those dissolved substances left over. Because it takes very high temperatures to boil salt, the salt is left in the container.

MIXTURES ARE EVERYWHERE

THERE ARE AN INFINITE NUMBER OF MIXTURES. ANYTHING YOU CAN COMBINE IS A MIXTURE. THINK OF EVERYTHING YOU EAT. JUST THINK ABOUT HOW MANY CAKES THERE ARE. EACH OF THOSE CAKES IS MADE UP OF A DIFFERENT MIXTURE OF INGREDIENTS. EVEN THE WOOD IN YOUR PENCIL IS CONSIDERED A CHEMICAL MIXTURE. THERE IS THE BASIC CELLULOSE OF THE WOOD, BUT THERE ARE ALSO THOUSANDS OF OTHER COMPOUNDS IN THAT PENCIL.

SOLUTIONS **ARE ALSO MIXTURES. IF YOU PUT SAND INTO A GLASS OF WATER, IT IS CONSIDERED TO BE A MIXTURE. YOU CAN ALWAYS TELL A MIXTURE BECAUSE EACH OF THE SUBSTANCES CAN BE SEPARATED FROM THE GROUP IN DIFFERENT PHYSICAL**

WAYS. YOU CAN ALWAYS GET THE SAND OUT OF THE WATER BY FILTERING THE WATER AWAY. A SOLUTION CAN ALSO BE MADE OF TWO LIQUIDS. EVEN SOMETHING AS SIMPLE AS BLEACH AND WATER IS A SOLUTION.

A CLOSE LOOK AT SOME DRIED CONCRETE FROM A SIDEWALK.

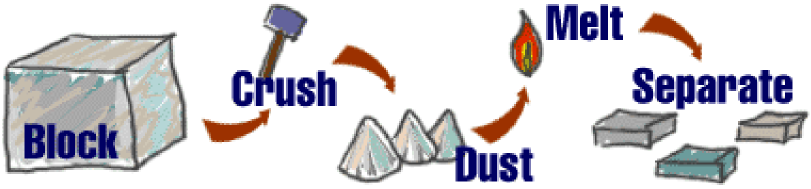
MIXTURES AROUND YOU

Two classic examples of mixtures are **concrete** and salt water. If you live near the ocean, they surround you every day. Even if you're inland, you need to remember your tap water also has many compounds inside, and they act the same way salt would. That is, concrete is a mixture of lime (CaO)/cement, water, sand, and other ground-up rocks and solids. All of these ingredients are mixed together. Workers then pour the concrete into a mold and the concrete turns into a solid (because of the cement solidifying) with the separate pieces inside.

While the cement hardening might be a chemical reaction, the rocks and gravel are held in place by physical forces. They are included in the mixture to increase the strength of concrete. The rocks and gravel are not chemically bonded to the cement. The gravel is also not evenly distributed. There are pieces of gravel here and there. The concentrations of gravel change from area to area. Salt water is different. First, it's a liquid. Second, it's an ionic solution. The salt is broken up into sodium (Na) and chloride (Cl) ions in the water.

You might be wondering why concrete and salt water are not new compounds when they are mixed together. The special trait of mixtures is that physical forces can still remove the basic parts. You can take the solid concrete and grind it up again. The individual components can then be separated and you can start all over. Salt water is even easier. All you have to do is boil the water off and the salt is left, just as if you never mixed the two compounds.

PUTTING TOGETHER AND BREAKING APART



The thing to remember about mixtures is that you start with some pieces, combine them, and then you can do something to pull those pieces apart again. You wind up with the same molecules (in the same amounts) that you started with. The way you separate the molecules is as unique as the mixture. We have talked about grinding and boiling. If you have a mixture of salt and tiny pieces of iron, you could use a magnet to separate the iron from the mixture.

PHYSICS STUDIES MANY DIFFERENT TYPES OF MOTION AND FORCES.

THIS SOLID GOLD CAR HAS A MASS, A VELOCITY, AND A RATE OF ACCELERATION.

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.

Speed it Up, Slow it Down

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.)

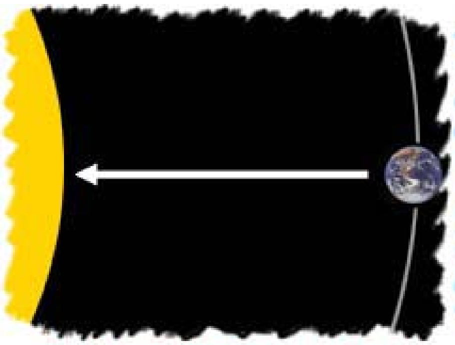
Acceleration is a twist on the idea of velocity. Acceleration is a measure of how much the velocity of an object changes in a certain time (usually in one second). Velocities could either increase or decrease over time. **Mass** is another big idea in motion. Mass is the amount of something there is, and is measured in grams (or kilograms). A car has a greater mass than a baseball.

SIMPLE AND COMPLEX MOVEMENT

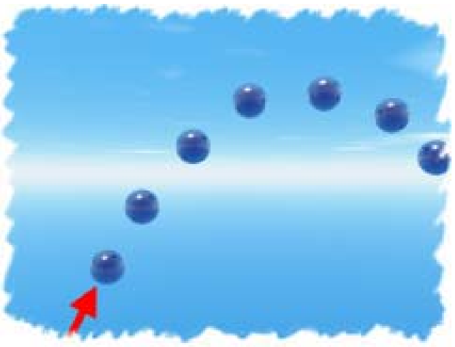
There are two main ideas when you study mechanics. The first idea is that there are **simple movements**, such as if you're moving in a straight line, or if two objects are moving towards each other in a straight line. The simplest movement would be objects moving at constant velocity. Slightly more 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.



THE GRAVITATIONAL PULL OF THE SUN IS ONLY ONE TYPE OF FORCE.



THE FORCE OF GRAVITY CAUSES THE BALL TO RETURN TO THE SURFACE.

FORCES OF NATURE

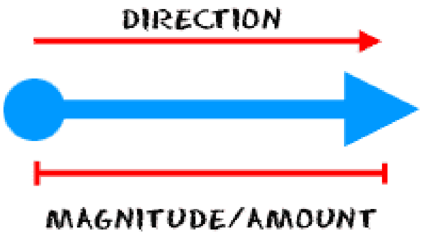
Forces are a big part of physics. Physicists devote a lot of time to the study of **forces** that are found everywhere in the universe. The forces could be big, such as the pull of a star on a planet. The forces could also be very small, such as the pull of a nucleus on an electron. Forces are acting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

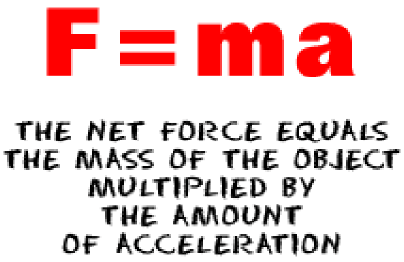
EXAMPLES OF FORCE

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

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

We cover the details of vectors on another page. 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

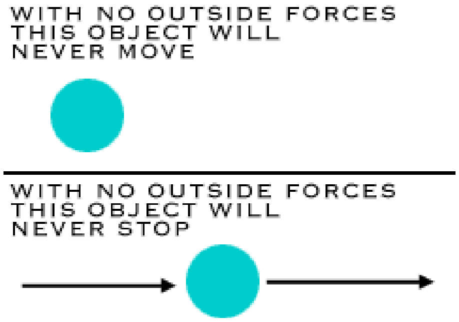
vector is a numerical **value** in a specific **direction**, and is used in both math and physics. The force vector describes a specific amount of force and its direction. You need both value and direction to have a vector. Both. Very important. Scientists refer to the two values as direction and **magnitude** (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.

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

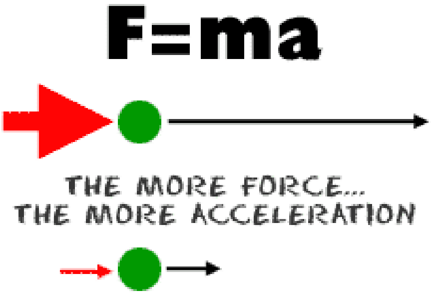


NEWTON'S LAWS OF MOTION

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

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.

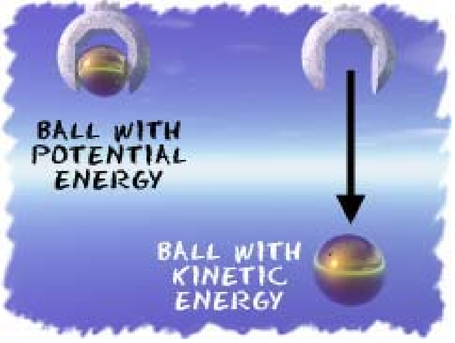
THIRD LAW

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 CAN HOLD HUGE AMOUNTS OF ENERGY. THINK ABOUT THE STRUTS OF CARS.



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

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 arrangment 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.

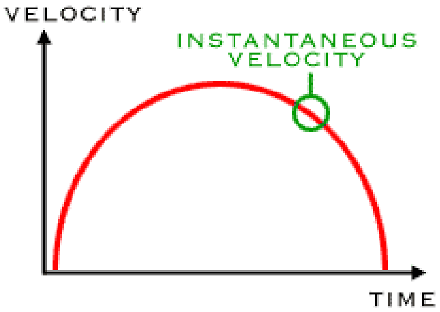
GASES STORING ENERGY

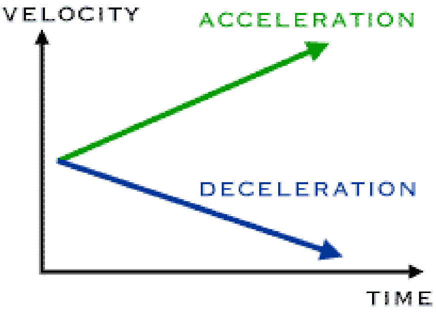
Gases? What can they do? Gases are great because they can **compress** and **expand**. They act as if they were elastic. If the pressure increases and compresses gas molecules, the amount of stored energy increases. It's similar to a spring, but slightly different. Eventually that energy in the compressed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

VELOCITY, SPEED, AND MOTION... OH MY!

Velocity and **speed** are very similar ideas, but velocity is a vector, and speed is not. Suppose we knew that someone was driving at thirty-five kilometers an hour (35 km/hr), but the direction wasn't given. How would you draw an arrow to represent a vector? You can't know how to draw the vector if you only have one value (either amount or direction). In this example, you were never told about the direction. Physicists would say that the speed is thirty-five kilometers an hour (35 km/hr), but the velocity is unknown. On the other hand, if you're moving at 35 km/hr in a northern direction, then you would have an arrow pointing north with a length of 35. Physicists would say that the velocity is 35 km/hr north.





Velocity is the rate of motion in a specific **direction**. I'm going that-a-way at 30 kilometers per hour. My velocity is 30 kilometers per hour that-a-way. Average speed is described as a measure of distance divided by time. Velocity can be constant, or it can change (acceleration). Speed with a direction is velocity.

Remember vectors? You will use a lot of vectors when you work with velocity. Our real world example of navigation on the ocean used velocity for every vector. Velocity is a vector measurement because it has an amount and a direction. Speed is only an amount (a scalar). Speed doesn't tell the whole story to a physicist. Think of it another way. If I tell you I'm driving north and ask you how long until we get to the city. You can't know the answer since you don't know my speed. You need both values.

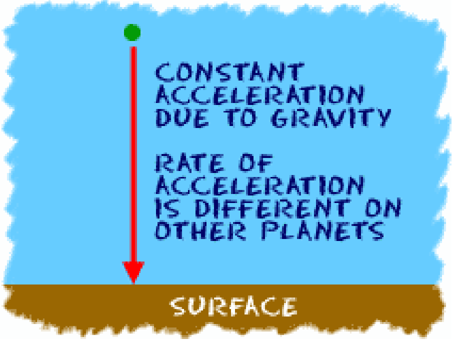
ONE MOMENT IN TIME

There is a special thing called **instantaneous velocity**. That's the velocity at a split second in time. Above, we were talking about your speed and direction over a long period of time. Why would you need to measure a velocity at one moment? Think about the moment you drove over the manhole. It's important to know if you were going 1 km/hr when you drove over the manhole, or 60 km/hr. It wouldn't help you to know that your average speed was 30 km/hr.

The term "instantaneous" refers to something physicists call a **limit**. Scientists "limit" the amount of time they do the measurement. When the "limit" moves to zero, that limit is one tiny moment in time. A physicist would measure your velocity as the "limit for a period of time", zero, to get the **instantaneous velocity**.

CHANGING YOUR VELOCITY

When velocity is changing, the word **acceleration** is used. Acceleration is also a vector. You speed up if the acceleration and velocity point in the same

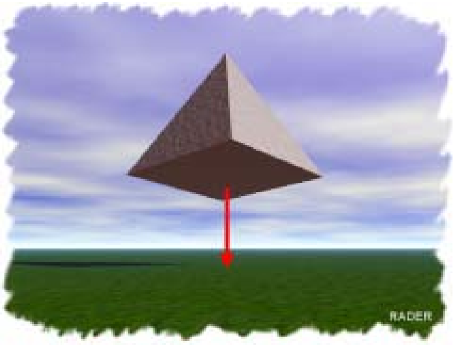


direction. You slow down (also referred to as **decelerating**) if the acceleration and velocity point in opposite directions. When you accelerate or decelerate, you change your velocity by a specific amount over a specific amount of time.

Just as with velocity, there is something called **instantaneous acceleration**. Instantaneous means scientists measure your acceleration for a specific moment of time. That way they can say he was accelerating at exactly this amount at this point during his trip.

CONSTANT ACCELERATION

There are a few special situations where acceleration may be constant. This type of acceleration happens when there is a constant net force applied. The best example is gravity. Gravity's pull on objects is a constant here on Earth and it always pulls toward the center of the planet (Note: Gravity decreases as you move far away from the surface of the planet.). The gravities of other planets are different from Earth's gravity because they may have different masses and/or sizes. Even though the gravity may be smaller or larger, it will still create a constant acceleration near the surface of each planet.



GRAVITY OF THE EARTH PULLS OBJECTS TOWARDS THE CENTER OF THE PLANET.

FORCES OF ATTRACTION

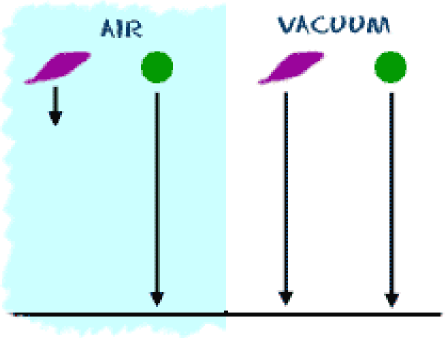
Gravity or **gravitational forces** are forces of attraction. We're not talking about finding someone really cute and adorable. It's like the Earth pulling on you and keeping you on the ground. That pull is gravity at work.

Every object in the universe that has **mass** exerts a gravitational pull, or force, on every other mass. The size of the pull depends on the masses of the objects. You exert a gravitational force on the people around you, but that force isn't very strong, since people aren't very massive. When you look at really large masses, like the Earth and Moon, the gravitational pull becomes very impressive. The gravitational force between the Earth and the molecules of gas in the atmosphere is strong enough to hold the atmosphere close to our surface. Smaller planets, that have less mass, may not be able to hold an atmosphere.

PLANETARY GRAVITY

Obviously, gravity is very important on Earth. The Sun's gravitational pull keeps our planet **orbiting** the Sun. The motion of the Moon is affected by the gravity of the Sun AND the Earth. The Moon's gravity pulls on the Earth and makes the tides rise and fall every day. As the Moon passes over the ocean, there is a **swell** in the sea level. As the Earth rotates, the Moon passes over new parts of the Earth, causing the swell to move also. The tides are independent of the phase of the moon. The moon has the same amount of pull whether there is a full or new moon. It would still be in the same basic place.

We have to bring up an important idea now. The Earth always produces the same **acceleration** on every object. If you drop an acorn or a piano, they will gain velocity at the same rate. Although the gravitational force the Earth exerts on the objects is different, their masses are just as different, so the effect we observe (acceleration) is the same for each. The Earth's gravitational force accelerates objects when they fall. It constantly pulls, and the objects constantly speed up.



BOTH THE FEATHER AND BALL FALL AT THE SAME SPEED IN A VACUUM.

THEY ALWAYS ASK ABOUT FEATHERS

People always say, "What about feathers? They fall so slowly." Obviously, there is air all around us. When a feather falls, it falls slowly because the air is in its way. There is a lot of air resistance and that resistance makes the feather move slower. The forces at work are the same. If you dropped a feather in a container with no air (a **vacuum**), it would drop as fast as a baseball.

WHAT ABOUT THE MOON?

But what keeps the Moon from falling down, if all of this gravity is so strong? Well, the answer is that the moon IS falling; all the time, but doesn't get any closer to us! Remember that if there wasn't a force acting, the Moon would be traveling in a straight line. Because there IS a force of attraction toward the Earth, the moon "falls" from a straight line into a curve (orbit) around the Earth and ends up **revolving** around us. The Earth's gravity holds it in orbit, so it can't just go off in a straight line. Think about holding a ball on a string and spinning it in a circle. If you were to cut that string (no more gravity), the ball would fly off in a straight line in the direction it was going when you cut the string. That direction, by the way, is not directly away from your hand, but **tangent** to the circle. Tangent is a geometry term used to describe a direction that are related to the slope of a curve. Math stuff. The pull of the string inward (toward your hand) is like the Earth's gravitational pull (inward toward the center of the Earth).