La Joya ISD

High School

IPC

Week 1
March 23rd - 27th

Objective 4

The student will demonstrate an understanding of the structures and properties of matter.

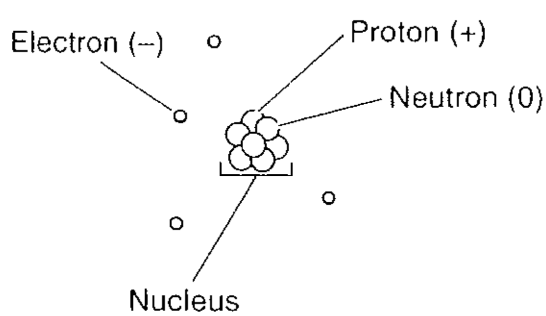
Why does matter matter?

Matter is anything that has mass and takes up space. That includes everything from this study guide, to the chair you're sitting in, to you! Scientists describe matter by describing its properties. For example, matter can be classified as an element, a compound, or a mixture. You need to understand what matter is made of and what some of its properties are.

What is matter made of?

Elements are the building blocks of matter. They cannot be broken down into simpler substances by a chemical reaction. Elements are made up of atoms.

Model of an Atom



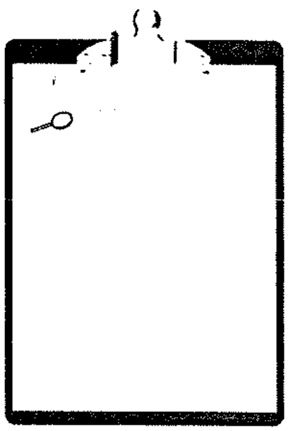
The nucleus of an atom is made up of positively charged protons and neutral neutrons. A cloud of negatively charged electrons surrounds the nucleus of an atom.

The atoms of different elements have different numbers of protons. For example, all carbon atoms have six protons, while all chlorine atoms have 17. Ninety-two elements exist naturally on Earth, and about 20 more have been made in laboratories.

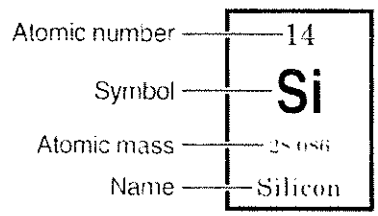
That's over 100 different elements! How am I supposed to keep track of all of them?

Lucky for you, scientists came up with the periodic table. The periodic table groups elements with similar properties together. That makes them much easier to deal with. Take a look at the periodic table on page 9 of this book.

What are all those numbers and letters on the periodic table?



The elements in the periodic table are arranged in order of atomic number. The *atomic number* is equal to the number of protons in the atoms of an element. The periodic table also shows the chemical symbol for each element. The *chemical symbol* is a one- or two-letter abbreviation for the element.



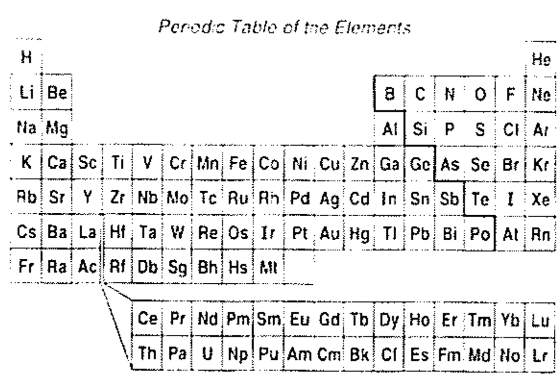
This diagram shows an example from the periodic table.

The *atomic mass* of an element is the average mass of one atom measured in atomic mass units (amu). The atomic mass of a single atom is approximately equal to its number of protons plus its number of neutrons.

How does the periodic table help me make sense of the different elements?

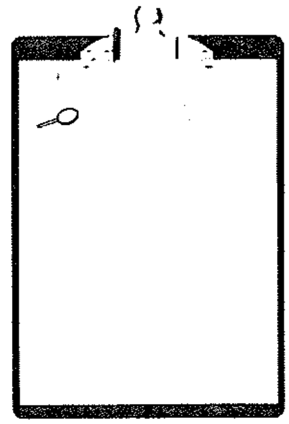
Each column in the periodic table is called a *group*. The elements in each group have similar properties. As a result, *metals*, *nonmetals*, and *metalloids* are clustered together in certain parts of the table.

Notice the heavy bold line on the right half of the periodic table. Metals are found on the left side of this line, and nonmetals are found on the right. Most of the elements that border the heavy bold line are metalloids. Metalloids have properties of both metals and nonmetals.



Properties of Metals, Nonmetals, and Metalloids

Metals	Nonmetals	Metalloids
Shiny Malleable (can be flattened into sheets) Ductile (can be shaped into wires) Good conductors of heat and electricity Most are solids at room temperature	Mostly dull Brittle; not malleable or ductile Poor conductors of heat and electricity Many are gases at room temperature	Varying ability to conduct electricity Can be used to make semiconductors (materials that conduct electricity only under certain conditions)



The real power of the periodic table, though, is that it can help you easily figure out how many valence electrons many elements have.

Valence electrons? What are those?

Most of chemistry is about the movement of electrons. In a chemical reaction, bonds between atoms are formed or broken. These bonds involve the transfer or sharing of electrons between atoms.

Valence electrons are the outermost electrons in the electron cloud surrounding an atom's nucleus. Different elements have different numbers of valence electrons. Because valence electrons are the farthest from the nucleus, they can move from one atom to another much more easily. For this reason, the valence electrons are the electrons that are involved in chemical bonding.

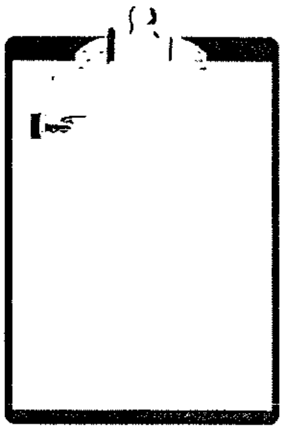
So how does the periodic table help me figure out how many valence electrons an atom has?

All the elements in some groups of the periodic table have the same number of valence electrons. There is a pattern that can be observed.

Group Number	1	2	13	14	15	16	17	18
Number of Valence Electrons	1	2	3	4	5	6	7	8

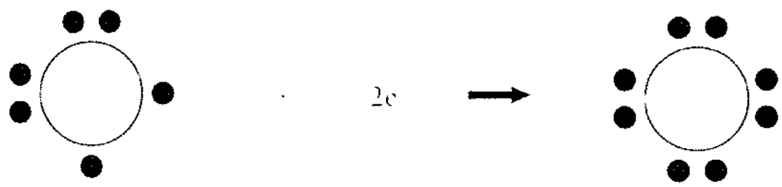
Elements in Group 1 have one valence electron, and elements in Group 2 have two valence electrons. For Groups 13 through 18, the number of valence electrons is the group number minus 10. The exception to this rule is helium (He). Helium is in Group 18. However, helium atoms have only two electrons, so they have two valence electrons, rather than eight.

What good does it do me to know how many valence electrons an atom has?



Knowing the number of valence electrons can help you make predictions about chemical reactions. When atoms react with one another, they tend to do so in a way that either fills up their valence shell or empties it. This ensures that their outer shell stays filled with eight electrons (this is called the octet rule). Elements in Group 17, for example, have seven valence electrons. When they react, they gain one electron to fill up their valence shell. Elements in Group 2 have two valence electrons. When they react, they lose these two electrons to empty their valence shell.

When an atom gains or loses electrons, it becomes an ion. When an atom gains an electron, it becomes a negative ion with a charge of 1−. For example, an oxygen atom gains two electrons to fill its valence shell.



Oxygen atom	Two electrons	Oxygen ion
8 protons (8+)		8 protons (8+)
+ 8 electrons (8−)		+ 10 electrons (10−)
Net charge = 0		Net charge = 2−

The atomic number of oxygen is 8, so a neutral oxygen atom has eight protons and eight electrons. Because oxygen is in Group 16, only six of its electrons are valence electrons. It must gain two electrons to fill its valence shell.

When an atom loses an electron, it becomes a positive ion with a charge of 1+. A calcium atom that empties its valence shell by losing two electrons forms a calcium ion (Ca^{2+}).

$$\bullet Ca \bullet \longrightarrow Ca^{2+} + 2e^{-}$$

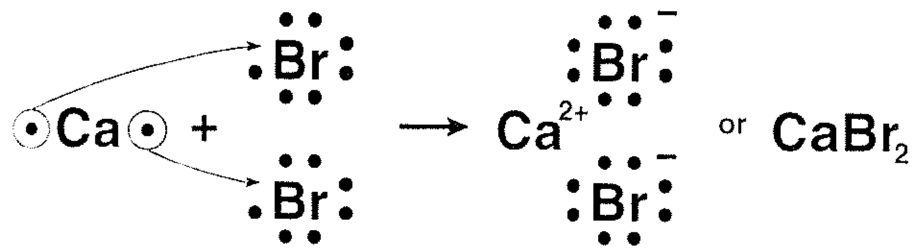
Calcium atom	Calcium ion	Two electrons
20 protons (20+)	20 protons (20+)	
+ 20 electrons (20−)	+ 18 electrons (18−)	
Net charge = 0	Net charge = 2+	

The atomic number of calcium is 20, so a neutral calcium atom has 20 protons and 20 electrons. Because calcium is in Group 2, only two of its electrons are valence electrons. It must lose two electrons to empty its valence shell.

How do ions bond?

When a metal and a nonmetal react, they usually form ions. For example, when sodium reacts with chlorine, the sodium atoms give up their one valence electron to become sodium ions (Na^+). The chlorine atoms fill their valence shell by gaining the electrons lost by sodium, becoming chloride ions (Cl^-). Because the sodium and chloride ions have opposite charges, they are attracted to each other. The force of attraction that holds the ions together is called an *ionic bond*.

Ionic compounds have no net charge. In other words, the positive and negative charges on the ions always cancel out. For example, when calcium reacts with bromine, the product is calcium bromide ($CaBr_2$), which has two bromide ions for every calcium ion. The 2+ charge on the calcium ion (Ca^{2+}) balances the two 1− charges on the bromide ions (Br^-).



Calcium atom   Bromine atoms   Calcium bromide

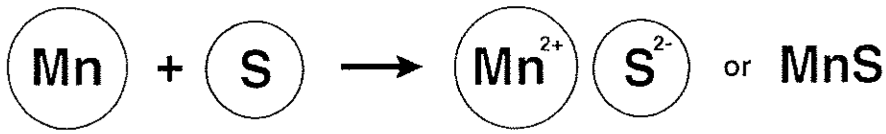
Calcium ion (2+)
Bromide ion (1−)
+ Bromide ion (1−)

Net charge = 0

What about the metals that aren't in Groups 1 or 2? Do they form ionic compounds, too?

Yes, they do. The metals in the middle of the periodic table, such as manganese (Mn), also react with nonmetals to form ionic compounds. However, the charge of the ions formed by these metals can vary, depending on the conditions. For example, manganese atoms can give up two electrons to form Mn^{2+}, or they can give up four electrons to form Mn^{4+}.

The name of an ionic compound containing one of these metals tells you what the charge on the metal ion is. The name of the metal is followed by a Roman numeral equal to the charge of the metal ion. For example, manganese(II) sulfide is made up of Mn^{2+} ions and S^{2-} ions. The chemical formula of this compound is MnS.

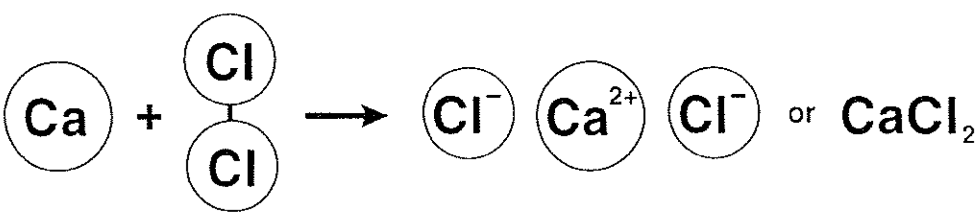


1 Manganese atom | 1 Sulfur atom | Manganese(II) sulfide molecule

Manganese(II) ion	(2+)
+ Sulfide ion	(2−)
Net charge	= 0

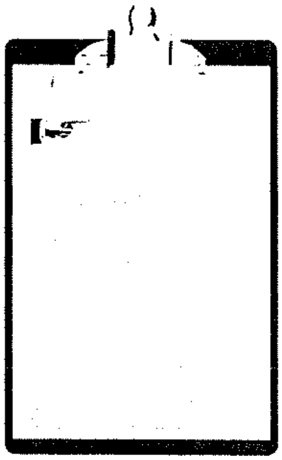
Can we try another one? What's the chemical formula of calcium chloride?

Calcium is a metal, and chlorine is a nonmetal. When these two elements combine, they will form an ionic compound. Calcium is in Group 2, so the calcium ion will have a charge of 2+. Chlorine is in Group 17, so the chloride ions will have a charge of 1−. The net ionic charge of the formula has to be zero, so there must be two Cl^- to balance one Ca^{2+}. The chemical formula of calcium chloride is therefore $CaCl_2$.



1 Calcium atom | 1 Chlorine molecule | 1 calcium chloride molecule

Calcium ion	(2+)
Chloride ion	(1−)
+ Chloride ion	(1−)
Net charge	= 0

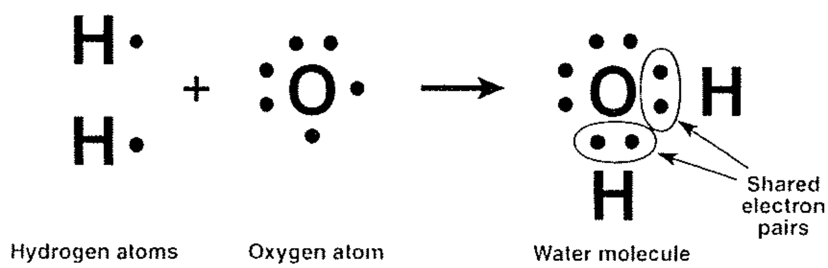


What's a covalent bond?

When two nonmetals react, they both need to gain electrons to fill their valence shells. To do this, they share electrons. When atoms share electrons, they form a *covalent bond*. Each covalent bond contains two shared electrons (one from each atom).

Water (H_2O) is one example of a compound that contains covalent bonds. An oxygen atom has six electrons in its valence shell, so it needs two more to fill its shell to be stable. A hydrogen atom has one electron in its valence shell. It needs one more electron in its valence shell to have the same electron structure as helium, one of the stable noble gases.

In a water molecule, the oxygen atom forms one covalent bond with each of two hydrogen atoms. As a result of these bonds, the oxygen atom has eight valence electrons, and each hydrogen atom has two.



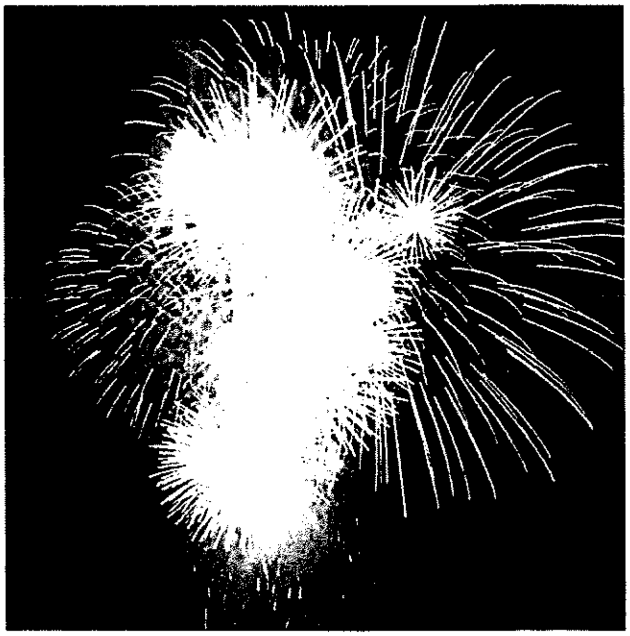
What happens when compounds and elements react with one another?

A *chemical change* occurs. A chemical change is a change in which new substances are formed. The atoms of the original substances are rearranged to form the new substances. The new substances often have properties that are very different from those of the original substances.

For example, nitrogen gas and hydrogen gas can react to form ammonia (NH_3) under certain conditions. This reaction is a chemical change. The atoms of nitrogen gas and hydrogen gas are rearranged to form ammonia molecules. Ammonia has very different properties from either nitrogen or hydrogen. Nitrogen and hydrogen are both odorless, for instance, while ammonia has a very strong smell.

How can I spot a chemical change?

One sign of a chemical change (or chemical reaction) is a change in temperature. Some chemical changes produce heat; others absorb heat from their surroundings. When firewood burns, for instance, you can feel the heat produced by the chemical change.



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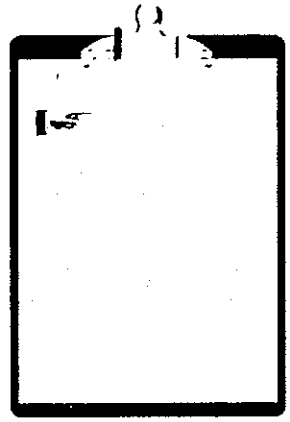
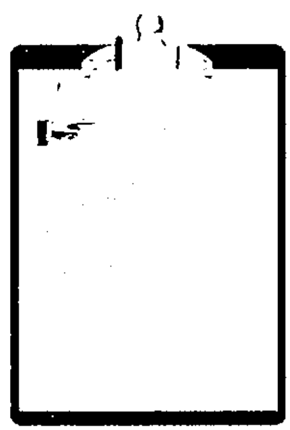
The heat and light given off by exploding fireworks are signs of a chemical change.

Another sign of a chemical change is a change in color. When an iron nail rusts, the color changes from gray to reddish brown. The iron has reacted with oxygen and water in a chemical change to produce rust.

The production of a gas or a precipitate also signals a chemical reaction. For example, a precipitate forms when calcium nitrate, $Ca(NO_3)_2$, mixes with sodium carbonate, Na_2CO_3, in water. The precipitate, calcium carbonate, $CaCO_3$, is a new substance formed from a chemical change. Calcium carbonate is one of the compounds that cause calcium buildup on shower walls and faucets.





It is important to remember that if you observe only one of these signs, a chemical reaction may not necessarily have taken place. For example, when you stir a packet of grape drink mix into a pitcher of water, the solution turns purple. However, no chemical change is occurring as the drink mix dissolves, because no new substances are formed.

To be sure you're seeing a chemical change, look for more than one sign. For example, a chemical change takes place when iodine comes into contact with starch. Not only is there a color change (the appearance of dark blue), but the mixture also gives off heat. Both of these signs indicate that a chemical change has taken place. Remember, however, that the only sure sign of a chemical change is the production of a new substance.

Can you help me with chemical equations?

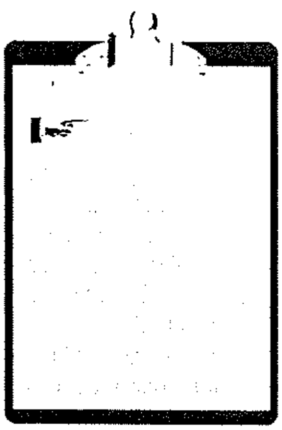
No problem! A chemical equation is a shorthand way of writing down what happens during a chemical reaction. For example, a chemical equation can be used to describe the reaction of potassium with chlorine gas.

(unbalanced)

Reactants Product

A chemical equation contains a lot of information. Let's go through it part by part.

The equation shows one atom of potassium reacting with one molecule of chlorine gas to form one formula unit of the ionic compound potassium chloride. The left side of the equation shows what you started with (the *reactants*). In this example, the reactants are potassium (K) and chlorine gas (Cl_2). The right side of the equation shows what you ended up with (the *products*). In this example, the product is potassium chloride (KCl).



This chemical equation, however, isn't quite finished. To complete the equation, we need to balance it.

Balance it? How do we do that?

When we balance an equation, we make sure that the left side of the equation has the same number and types of atoms as the right side of the equation. We need to balance the equation to show that it follows the *law of conservation of mass*.

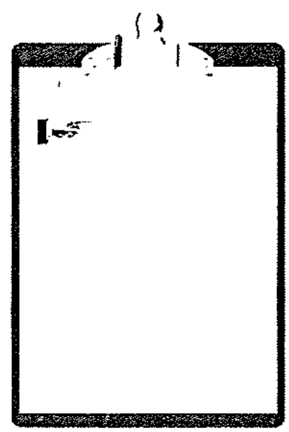
The law of what?

The law of conservation of mass. This scientific law states that matter cannot be created or destroyed in a chemical reaction. All the atoms of the reactants of a chemical reaction are still present in the products; they've just been rearranged. In other words, what goes into the reaction must come out of the reaction. We need to balance the equation to show this.

So how exactly do we do that?

First let's look at chlorine. The left side of the equation has two atoms of chlorine, but the right side has one atom of chlorine. That means that we'll have to add a coefficient of "2" in front of the "KCl". The symbol "2KCl" means "two formula units of potassium chloride," which indicates two atoms of chlorine. Now the chlorine is the same on both sides.

Next look at potassium. The left side of the equation has one atom of potassium, but the right side now has two atoms of potassium. To get two potassium atoms on the left side, we'll have to add a "2" in front of the "K". The symbol "2K" means "two atoms of potassium." Now the potassium is the same on both sides.



$$\begin{matrix} K & & & & K^+ \; Cl^- \\ & + & Cl \; Cl & \longrightarrow & \\ K & & & & K^+ \; Cl^- \end{matrix}$$

Recheck to make sure everything follows the law now. The left side of the equation has two potassium atoms and two chlorine atoms. So does the right side. Everything balances.

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High School

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Week 2
March 30th - April 3rd

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Does a chemical reaction take place when one substance dissolves in another?

No, dissolving is a physical change because no new substances are formed. When one substance dissolves in another, the resulting mixture is called a *solution*. A solution has two parts: the solute and the solvent. The *solute* is the substance that dissolves, and the *solvent* is the substance that the solute dissolves in. The solute breaks up into tiny particles that spread evenly throughout the solvent. In a solution of sugar water, sugar is the solute, and water is the solvent.

Are all solutions liquids?

No! Many types of solutions are possible. Here are a few examples.

Examples of Solutions

Solute	Solvent	Example
Gas	Gas	(oxygen and other gases dissolved in nitrogen)
Gas	Liquid	(carbon dioxide dissolved in water)
Liquid	Liquid	(water dissolved in isopropyl alcohol)
Solid	Liquid	(sugar dissolved in water)
Solid	Solid	(tin dissolved in copper)

How much solute can dissolve in a solvent?

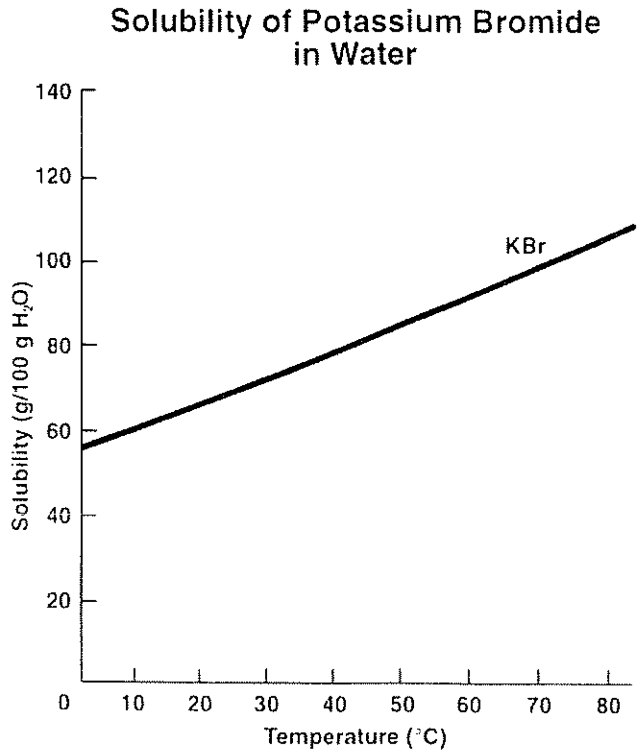
That depends on the solubility of the solute. *Solubility* is how much solute you can dissolve before the solution becomes saturated. A *saturated solution* is one that cannot dissolve any more solute. For example, at 0°C the solubility of table salt in water is 35.7 grams of salt per 100 grams of water. If you added 37 grams of salt to 100 grams of water at 0°C, only 35.7 grams of the salt would dissolve. The rest of the salt would settle to the bottom of the container. Several factors can affect the solubility of a solute, such as temperature and pressure.

How does temperature affect solubility?

When solids dissolve in liquids, solubility usually increases as the temperature of the solution increases. For example, more sugar will dissolve in hot water than in cold water. At higher temperatures, the solute and solvent molecules have more kinetic energy, and the solute molecules are more likely to move throughout the solvent. For this reason, more of the solute can dissolve. (See Example 1 on page 67.)

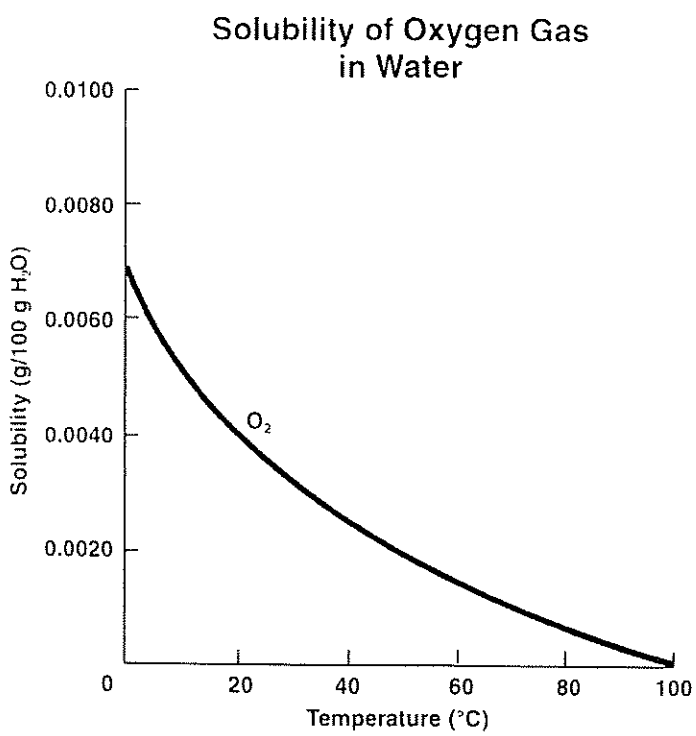
However, temperature has the opposite effect on the solubility of gases in liquids. Gases dissolve better at lower temperatures. If you think about it, this makes sense—as the temperature increases, more of the gas molecules have enough energy to leave the solution. The dissolved gases come out of solution and form bubbles that rise to the surface. (See Example 2 on page 67.) If you've ever opened a warm can of soda, you may have noticed that it fizzed more than a cold soda. This is because warm soda can hold less dissolved carbon dioxide than cold soda. The carbon dioxide leaves the warm soda in the form of fizzing bubbles.

Example 1



The solubility of potassium bromide, a solid ionic compound, increases as the temperature of the water increases.

Example 2



The solubility of oxygen gas decreases as the temperature of the water increases.

When an industrial plant pumps warm wastewater into a lake, the temperature of the lake rises. This type of temperature change is known as thermal pollution. Thermal pollution causes the solubility of gases in the lake to decrease. A decrease in the lake's oxygen level can negatively affect organisms that live there.

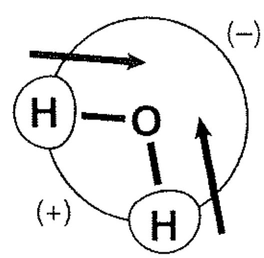
What about the effect of pressure on solubility?

Pressure also affects the solubility of gases in liquids. As the pressure on the gas above the solution increases, more of the gas will dissolve in the solvent. For example, the high pressure in a bottle of soda keeps carbon dioxide gas dissolved in the liquid. Once the bottle is open, the pressure on the soda decreases. Bubbles of carbon dioxide begin to come out of solution and rise to the surface. That's why soda eventually goes flat once you open the bottle. Flat soda contains very little dissolved carbon dioxide.

I know that water is polar. What does that mean?

In a water molecule, the oxygen atom tends to pull the shared electrons away from the hydrogen atoms. So the oxygen end of a water molecule has a partial negative charge, and the hydrogen end has a partial positive charge. Molecules with a slightly negative end and a slightly positive end are called *polar molecules*.

Water Molecule



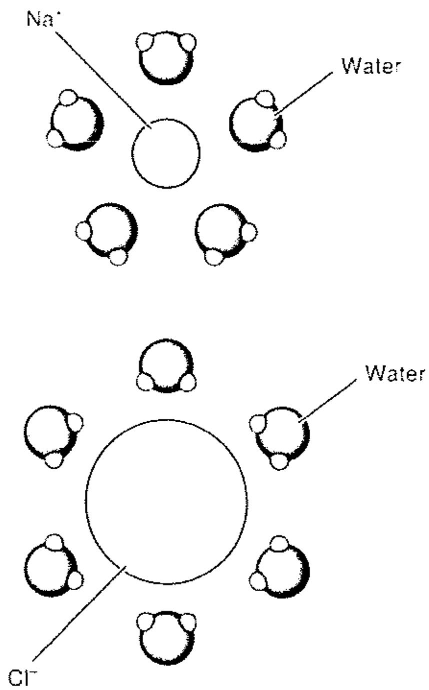
The unequal sharing of electrons in a water molecule gives the molecule a slightly negative end and a slightly positive end.

Does the fact that water is polar affect the way it acts in solutions?

Yes, because water is polar, it tends to dissolve other polar compounds. For example, many ionic compounds dissolve in water. When ionic compounds dissolve, they break up into positive and negative ions.

The negative end of water molecules is attracted to the positive ions, and the positive end of water molecules is attracted to negative ions. Each solute ion becomes surrounded by a "shell" of water molecules. This helps keep the solute ions in solution.

Sodium Chloride Dissolved in Water



When sodium chloride (NaCl) dissolves in water, it breaks up into sodium ions (Na^+) and chloride ions (Cl^-). The negative end of water molecules is attracted to sodium ions, and the positive end of water molecules is attracted to chloride ions.

What are some properties of water?

Because water molecules are polar, they have a tendency to stick to other polar substances. This property is called *adhesion*. For example, glass may carry a partial charge along its surface. That's why rain droplets stick to windows.

Cohesion is another property of water. *Cohesion* is the tendency of water molecules to stick together. It is caused by the attraction of the positive end of one water molecule for the negative end of another.

To see cohesion in action, gently lay a paper clip on top of a glass of water. As long as you don't break the surface, the paper clip will remain on top of the water. The attraction of the water molecules to one another is strong enough to keep the paper clip from sinking.

A third property of water is viscosity. *Viscosity* is the resistance of a liquid to flow. Water is less viscous than honey, for example, because water flows more easily.

Two factors that help determine a liquid's viscosity are its cohesiveness and the size of its molecules. The tendency of water molecules to stick together—water's cohesiveness—makes water more viscous than it would be if it were composed of nonpolar molecules. One reason that water is less viscous than honey, however, is that the molecules in honey are much larger than water molecules and flow past one another less easily.

The polar nature of water also causes ice to float. To understand why, you first have to understand density and buoyancy.

O.K., what is density?

Density is a measure of a substance's mass per unit of volume. A dense object has much more mass in a given space than an object that isn't very dense.

You can calculate an object's density by dividing its mass by its volume.

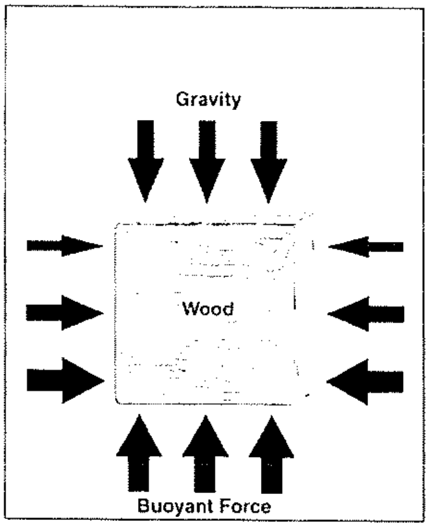
$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad D = \frac{m}{v}$$

Suppose you have two identical balloons. You fill one with air and one with water. The water-filled balloon will be much heavier than the air-filled balloon, even though they're the same size. That's because water has a much greater density than air.

And what about buoyancy? What's that?

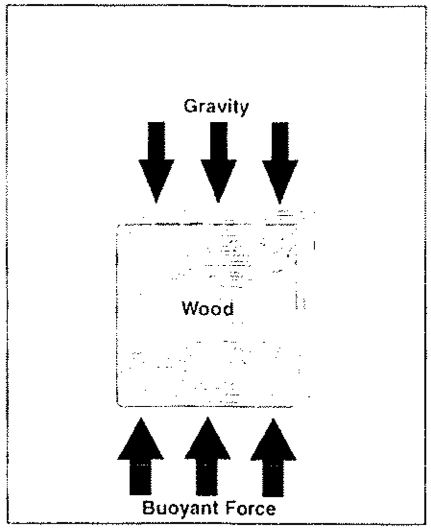
When an object is submerged in water, the water exerts a force on all sides of the object. This force increases with depth, so the force at the top of the object is lower than the force at the bottom of the object. This means that the overall direction of the force is upward. This upward force is called the *buoyant force*.

Before



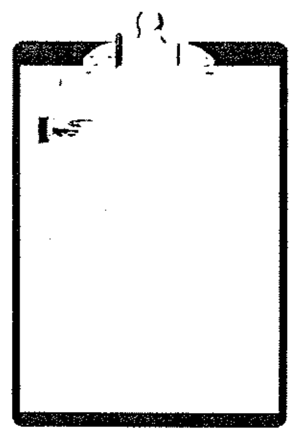
The force at the bottom of a submerged object is greater than the force at the top. The net force—the buoyant force—is upward.

After



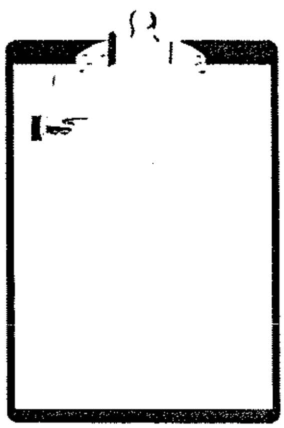
When wood floats, the buoyant force on the wood is greater than the force of gravity on the wood.

When the buoyant force pushing up on the object is greater than the force of gravity pulling down on the object, the object rises to the surface. If the buoyant force is less than the force of gravity, the object sinks to the bottom.



How do we know which is greater, the force of gravity or the buoyant force?

We can determine which force is greater by comparing the density of the object to the density of water. If the density of the object is greater than the density of water, the force of gravity on the object will be greater than the buoyant force, and the object will sink.



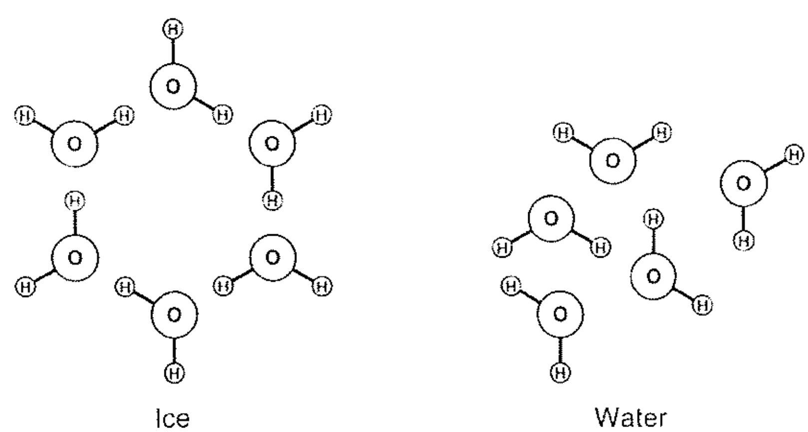
If the density of the object is less than the density of water, the force of gravity on the object will be less than the buoyant force, and the object will float. For example, vegetable oil with a density of 0.93 g/cm^3 will float on water, which has a density of 1.0 g/cm^3.

Now tell me, why does ice float in water? Shouldn't the solid form of water be more dense than the liquid form of water?

When most substances freeze, the molecules making up the substance get closer together. That means that the density of the solid form is greater than the density of the liquid form. For example, solid aluminum is more dense than liquid aluminum, so solid aluminum does not float on liquid aluminum.

But water is different. When water freezes, the partial charges line up, positive to negative, forming a crystalline structure. This pattern causes the molecules to spread slightly apart. This means that ice is less dense than water. Therefore, it floats.

Structure of Ice and Water



Ice has a more orderly arrangement of molecules than liquid water does. This orderly arrangement, or crystalline structure, keeps the molecules in ice from packing as closely together as the molecules in liquid water.

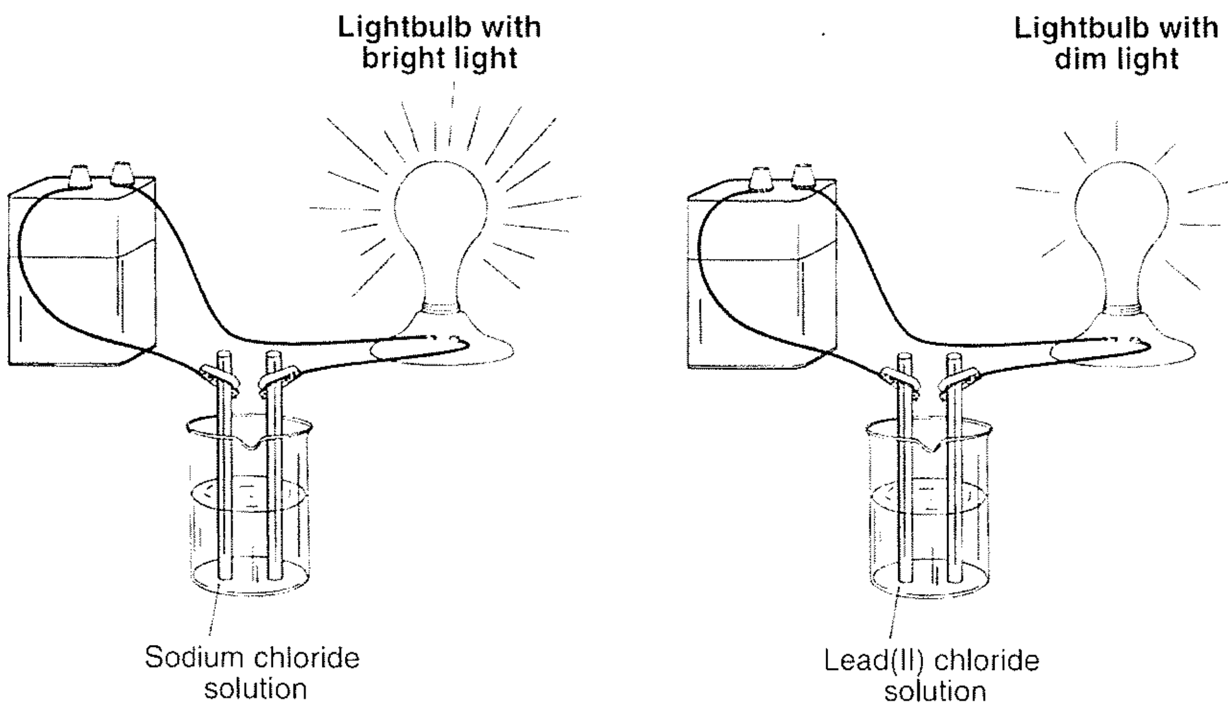
Because ice is less dense than water, lakes begin to freeze from the top down. The layer of ice that forms on a surface of a lake helps shield the water underneath from cold air temperatures. This tends to keep lakes from freezing solid and killing the organisms that live there.

I've heard that water conducts electricity. Is this true?

You might be surprised to learn that pure water doesn't conduct electricity! However, most water isn't pure. Lake water, ocean water, rainwater, and even tap water all contain dissolved substances, including ions such as Ca^{2+}, Mg^{2+}, Na^{+}, and Cl^{-}. Water that contains dissolved ions can conduct electricity.

Substances that can conduct an electric current when they are dissolved in water are called *electrolytes*. Sodium chloride (NaCl) is an electrolyte because it separates into sodium ions (Na^{+}) and chloride ions (Cl^{-}) in solution.

The concentration of ions in a water solution determines how much electric current the solution can conduct. Usually, the higher the concentration of ions, the more current the solution can carry.



Sodium chloride (NaCl) is very soluble in water, so the concentration of ions in the NaCl solution is high. Because the NaCl solution is a strong conductor of electricity, the lightbulb shines brightly. Lead(II) chloride ($PbCl_2$) is only slightly soluble in water, so the concentration of ions in the $PbCl_2$ solution is low. Because the $PbCl_2$ solution is a weak conductor of electricity, the lightbulb is not very bright.

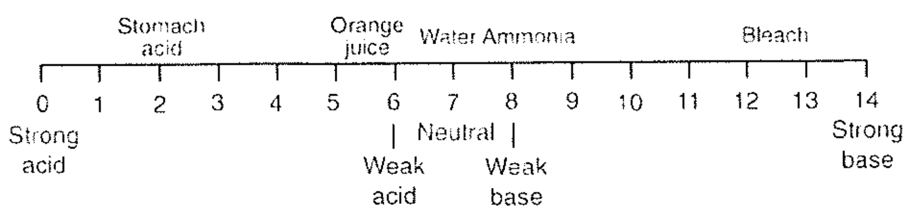
Doesn't pH have something to do with the concentration of ions?

Yes! Specifically, pH is a measure of the concentration of hydrogen ions in a solution. The pH scale goes from 0 to 14. A solution with a low pH is acidic, which means that it has a high concentration of hydrogen ions (H^+). A solution with a high pH is basic, which means that it has a low concentration of hydrogen ions and a high concentration of hydroxide ions (OH^-). A solution with a pH of 7 is said to be neutral: it is neither acidic nor basic. Pure water has a pH of 7.

Suppose you had a solution of hydrochloric acid (HCl), which is a strong acid. What would happen if you added a small amount of a solution of sodium hydroxide ($NaOH$), a strong base? The hydroxide ions (OH^-) from the base would react with some of the hydrogen ions (H^+) from the acid to form water.

The overall concentration of hydrogen ions would decrease as a result of this reaction. The solution would become less acidic, and the pH would increase.

pH Scale



After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

Two steel plates can be joined by a process called arc welding. In this process, tiny droplets of molten metal are deposited on the joint between the plates. The droplets then cool and harden, joining the plates together.

Many metals will react with oxygen when they are exposed to the high temperatures of arc welding. Therefore, the droplets of molten metal are often shielded from oxygen in the surrounding air by a layer of argon gas.

Why would argon gas be a more suitable shield for arc welding than hydrogen gas?

A Unlike hydrogen, argon is a nonmetal.

B Unlike hydrogen, argon is an inert gas.

C Argon has a larger atomic radius than hydrogen does.

D Argon has a greater atomic mass than hydrogen does.

Answer Key: page 115

Which best explains why sodium is more reactive than magnesium?

A Sodium has only one valence electron, while magnesium has two.

B Sodium atoms typically have one more neutron than magnesium atoms do.

C Sodium forms ions with a charge of 2+, but magnesium forms ions with a charge of 1+.

D Sodium atoms tend to attract the electrons of other atoms more than magnesium atoms do.

Answer Key: page 115

Hydrogen and nitrogen gas react in a sealed container kept at a constant temperature. The pressure in the container is less at the end of the reaction than at the beginning.

$3H_2(g)$	+	$N_2(g)$	$\longrightarrow$	$2NH_3(g)$
Hydrogen		Nitrogen		Ammonia

Which is the most likely reason that the pressure in the container decreased?

A There are fewer atoms at the end of the reaction than at the beginning.

B There are fewer molecules at the end of the reaction than at the beginning.

C The mass of the reactants is less than the mass of the products in the reaction.

D The volume of the reactants is less than the volume of the products in the reaction.

Answer Key: page 116

What is one way to distinguish a solution of salt (NaCl) and water from a solution of sugar ($C_6H_{12}O_6$) and water without tasting them?

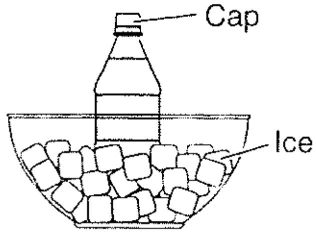
A The salt can be recovered by evaporating the water, but the sugar cannot.

B The salt solution will conduct electric current, but the sugar solution will not.

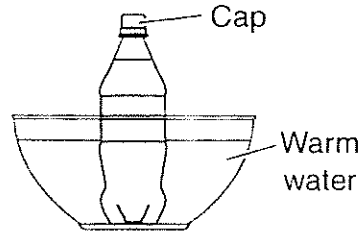
C The sugar can be separated from the water by filtration, but the salt cannot.

D A beam of light passing through the sugar solution will be visible, but a beam of light passing through the salt solution will not.

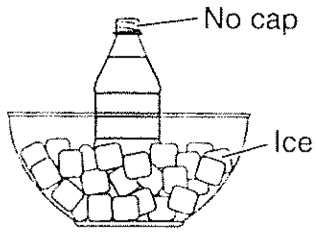
Answer Key: page 116



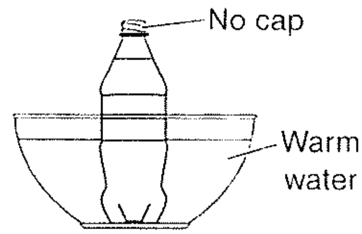
Bottle 1



Bottle 2



Bottle 3



Bottle 4

If each of these bottles of carbonated water initially contained the same amount of dissolved carbon dioxide, which bottle will contain the least amount of dissolved carbon dioxide after 15 minutes?

A Bottle 1

B Bottle 2

C Bottle 3

D Bottle 4

Answer Key: page 116

Scuba divers are exposed to greater pressure the deeper they dive. Which is most likely to occur as a result of this increased pressure?

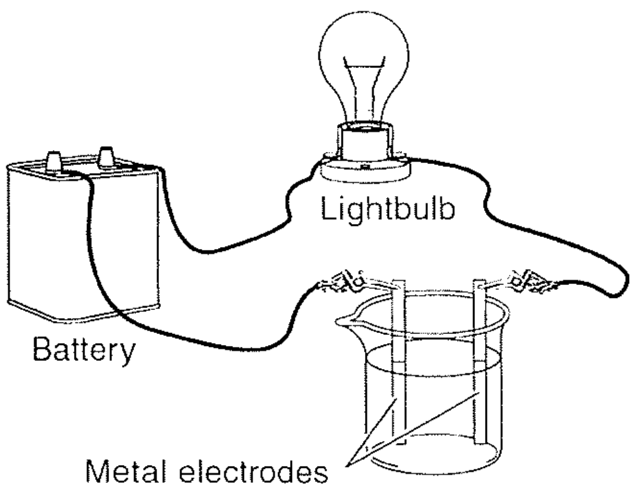
A Glucose will become much more soluble in divers' cells.

B A high level of nitrogen gas will dissolve in divers' bloodstream.

C Small bubbles of carbon dioxide will form in divers' bloodstream.

D The amount of oxygen dissolved in divers' cells will sharply decrease.

Answer Key: page 116



When added to the beaker, which liquid would cause the lightbulb to glow the brightest?

A A concentrated solution of water and table sugar

B A concentrated solution of water and nitrogen gas

C A dilute solution of water and ammonia

D A dilute solution of water and sulfuric acid

Answer Key: page 117

La Joya ISD

High School

IPC

Week 3
April 6th - 10th

Objective 5

The student will demonstrate an understanding of motion, forces, and energy.

What's so important about motion, forces, and energy?

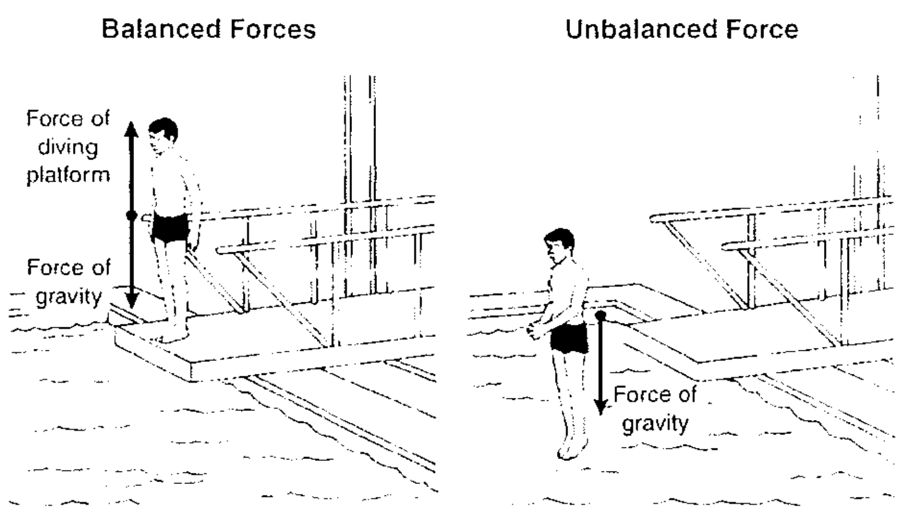
Look around you. What do you see that's moving? Leaves fall from trees; cars move along roads; your hands turn the pages of this book. Physicists use the ideas of force and energy to describe motions in the world around us, from the vibrations of tiny atoms to the orbiting of planets in our solar system.

How are motion and forces related?

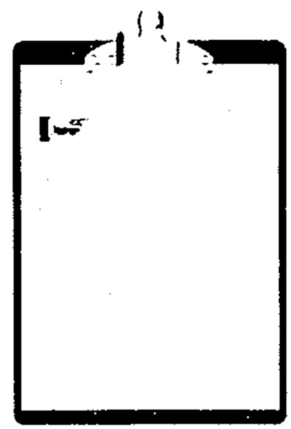
All motion is caused by forces. We can use our knowledge of forces to explain why things move and to predict how they will move. For example, a highway designer needs to understand how forces work on a moving car in order to create safe roads for drivers.

There are often many different forces acting on an object. For instance, when you stand on a diving platform, gravity pulls you down toward the pool, but the diving platform holds you up. These two forces balance each other. As a result, you stay put.

If you step off the end of the diving platform, however, the force of the platform is no longer there to balance the force of gravity. The unbalanced force of gravity causes you to fall into the water.

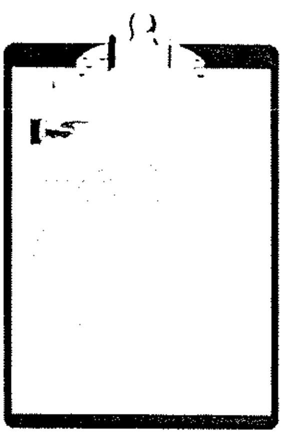


When the forces on the diver are balanced, the diver doesn't move. When the force is unbalanced, the diver falls.



Didn't Isaac Newton have something to do with explaining forces and motion?

Yes. Isaac Newton proposed the laws of motion in the seventeenth century. They were based on his observations of the world around him. Newton's laws describe how forces and motion are related.



Newton's Laws of Motion

First law: Any object in motion will stay in motion, and any object at rest will stay at rest, until it is acted on by an unbalanced force. Newton's first law is also referred to as the law of inertia.

Second law: The net force on an object equals the object's mass multiplied by its acceleration (Force = mass × acceleration).

Third law: When one object exerts a force on a second object, the second object exerts an equal but opposite force on the first object.

These laws sound a bit complicated at first, but they make sense when you think about them carefully.

If I kick a soccer ball along the ground, the ball eventually stops. But Newton's first law says that a moving object should keep moving. How does that make sense?

A soccer ball rolling across the ground does eventually stop. But it doesn't break Newton's first law. To find out why, look more closely at the law. It states that a moving object will keep moving unless there is an unbalanced force on it. There must be a force acting on the soccer ball that causes it to slow down and stop.

What is that force?

It's friction! *Friction* is an unbalanced force that changes the ball's motion. If there were no friction between the ball and the ground, the ball would keep rolling on, and on, and on . . .

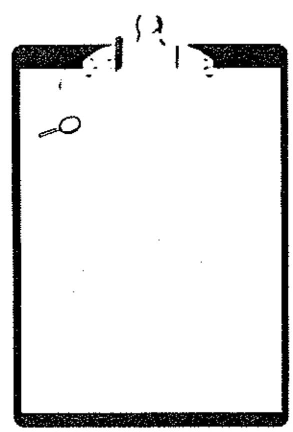
The second law is really just an equation. What's so important about that?

Newton's second law ($F = ma$) is a powerful tool for making predictions about motion. For example, if you know how big a force is and what size mass it acts on, you can predict how fast an object will accelerate.

How can I understand the second law without using math?

It's easy! First, let's look at force and acceleration. According to Newton's second law, a greater force produces a greater acceleration. For example, if you kick a soccer ball as hard as you can, it will accelerate more than if you just tap it lightly. The greater the force you exert, the greater the ball's acceleration. That makes sense, right?

We can also think about mass and acceleration. The greater the mass, the less the acceleration will be under the same force. If you use the same force to kick a soccer ball that you use to kick a bowling ball (ouch!), which rolls a shorter distance? The bowling ball, of course! It accelerates less because it has more mass than the soccer ball.



Could you explain the third law too?

Sure! Newton's third law states that all forces come in pairs. Have you ever hit a baseball? When the bat hit the baseball, the bat exerted a force on the ball, causing it to change direction. But the ball also exerted a force on the bat. You probably felt this force as a vibration in the bat's handle. The bat's force on the baseball was exactly the same size as the baseball's force on the bat, but the two forces acted in opposite directions.

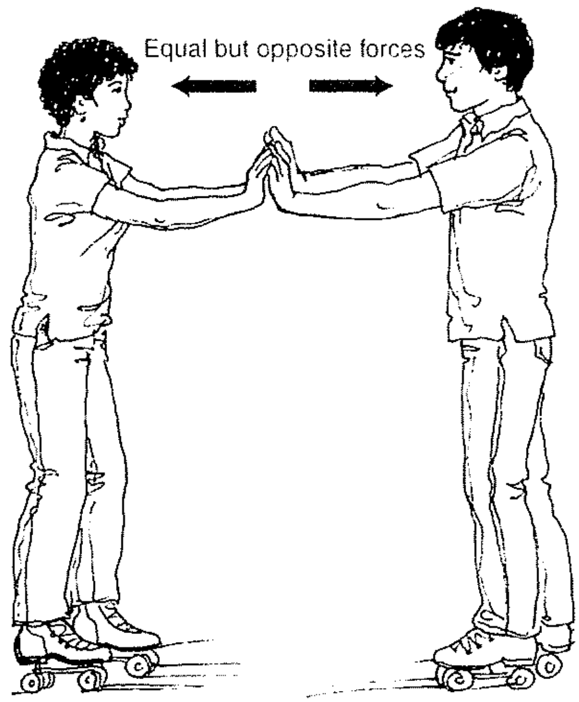
Does the speed of the ball affect the size of these forces?

Yes, it does. The faster the ball is moving, the greater the force it exerts on the bat. A faster ball exerts a greater force because it has more momentum than a slower ball. And because a ball with more momentum exerts a greater force on the bat, the bat will also exert a greater force on the ball, and the batter will be more likely to hit a home run.

Do these pairs of equal and opposite forces cancel out?

No! You might think that since the forces are equal and opposite, they would cancel each other out, but they don't. This is because they are acting on different objects. In order to cancel each other, two opposite forces must act on the same object.

For example, suppose that you and I are wearing roller skates and facing each other. If I push on you, you will push back on me with an equal but opposite force even if you aren't aware of it. My force on you will cause you to move backward, and your force on me will cause me to move backward. Even though the forces are equal but opposite, they do not cancel out because one acts on me and one acts on you.



When one skater pushes on the other, the second skater pushes back with an equal but opposite force. There is a net force on each skater, and each rolls backward.

Are there any other equations I need to know?

Many ideas in physics, such as Newton's second law, can be written as equations, or formulas. You can use these formulas to solve problems and make predictions. Take a look at the formula chart on page 8. To use a formula, you need to know what each variable represents. The words on the left side of the formula chart tell you this. For example, look at the formula.

$$P = \frac{W}{t}$$

The left side of the chart shows that this is the formula for power. P represents power, W represents work, and t represents time.

After the formulas there is a table called "Constants/Conversions." What is this?

This table gives you extra information you might need in order to solve problems. Constants are values for things that don't change. For example, the speed of light (c) and acceleration due to gravity (g) are constants.

A conversion tells you how to change from one unit to another. The table shows some common conversions. For instance, the table shows that 1 newton (N) is equal to 1 kgm/s^2. You can use this conversion to change a problem's answer from 8 kgm/s^2 to 8 N.

Can you show me how to use the formula chart to solve a problem?

Of course! Here's a problem: A roller coaster has a velocity of 3 m/s and an acceleration of 15 m/s^2. How many seconds will it take the roller coaster to reach its maximum velocity of 27 m/s?

First let's
We know:

The current (or initial) velocity: 3 m/s, v

The acceleration: 15 m/s^2, a

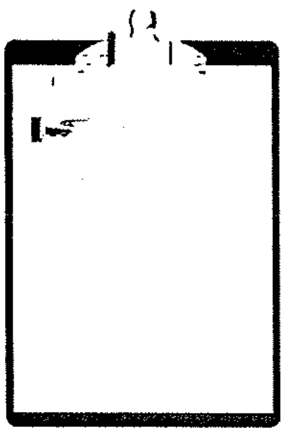
The maximum (or final) velocity: 27 m/s, v

We want to find out how much time it will take the roller coaster to accelerate from 3 m/s to 27 m/s

The acceleration formula has all three of these variables. Can we use that one?

Yes, we can!

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{change in time}} \qquad a = \frac{v_f - v_i}{\Delta t}$$



We want to use this formula to solve for the change in time. We'll need to rearrange the formula so that change in time (Δt) is on one side of the equation by itself. First,

$$\text{Acceleration} \times \text{change in time} = \text{final velocity} - \text{initial velocity}$$

$$a \times \Delta t = v_f - v_i$$

Next,

$$\text{change in time} = \frac{\text{final velocity} - \text{initial velocity}}{\text{acceleration}} \qquad \Delta t = \frac{v_f - v_i}{a}$$

Now we're ready to use the formula.

$$\Delta t = \frac{v_f - v_i}{a}$$

$$\text{change in time} = \frac{\text{final velocity} - \text{initial velocity}}{\text{acceleration}}$$

$$= \frac{27 \text{ m/s} - 3 \text{ m/s}}{15 \text{ m/s}^2}$$

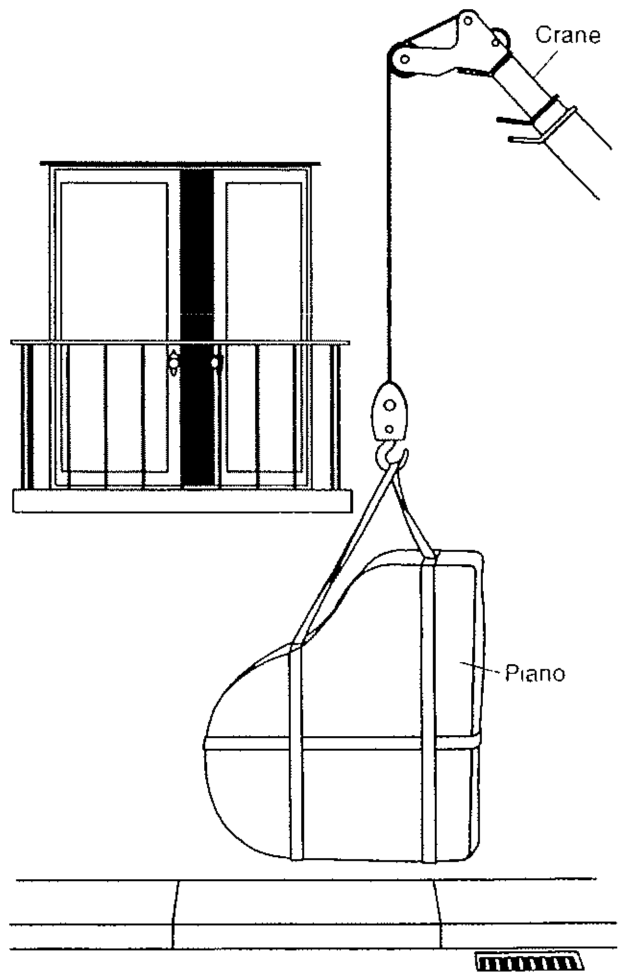
$$= \frac{24 \text{ m/s}}{15 \text{ m/s}^2}$$

$$= 1.6 \text{ s}$$

The roller coaster will reach its maximum velocity in 1.6 seconds.

Cool! We used physics to solve a problem! Can you show me how to do a two-part problem—one with two formulas?

How about this one? Furniture movers use a crane to lift a grand piano with a weight of 2,970 newtons to a height of 5 meters. If the crane does 28,018 joules of work, what is its efficiency?



First,

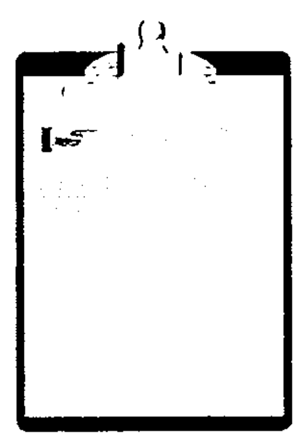
We know:

The piano's weight: 2,970 N, *F*

The distance the piano is moved (height): 5 m, *d*

The work done by the crane (the work input): 28,018 J, *W*

We want to find the efficiency of the crane.



Next

$$\% \text{ efficiency} = \frac{\text{work output}}{\text{work input}} \times 100 \qquad \% = \frac{W_o}{W_i} \times 100$$

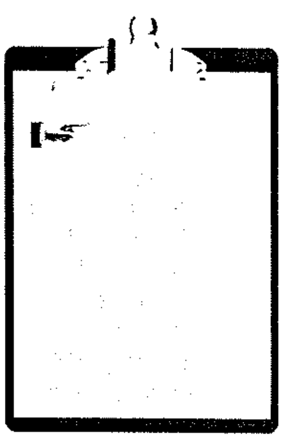
Wait! We don't know the work output. What do we do now?

Because we weren't given the work output, we'll have to calculate it using the information we do have. Look back at the formula chart for a formula that we can use to calculate work.

$$\text{Work} = \text{force} \times \text{distance} \qquad W = Fd$$

The work output is the work done on the piano. To calculate the work output, we need the distance the piano moved (which we know) and the force used to lift the piano. To lift the piano, the crane must pull on it with a force equal to the piano's weight, so we can substitute the piano's weight for force in the work formula.

$$\begin{aligned} W &= Fd \\ \text{Work} &= \text{force} \times \text{distance} \\ &= 2{,}970 \text{ N} \times 5 \text{ m} \\ &= 14{,}850 \text{ Nm} \end{aligned}$$



The work output is 14,850 Nm. But we want the work output to be in units of joules so that it will match the units of the work input. The constants/conversions chart shows that 1 joule (J) is equal to 1 Nm. So, 14,850 Nm = 14,850 J.

Now we're ready to use the efficiency formula, right?

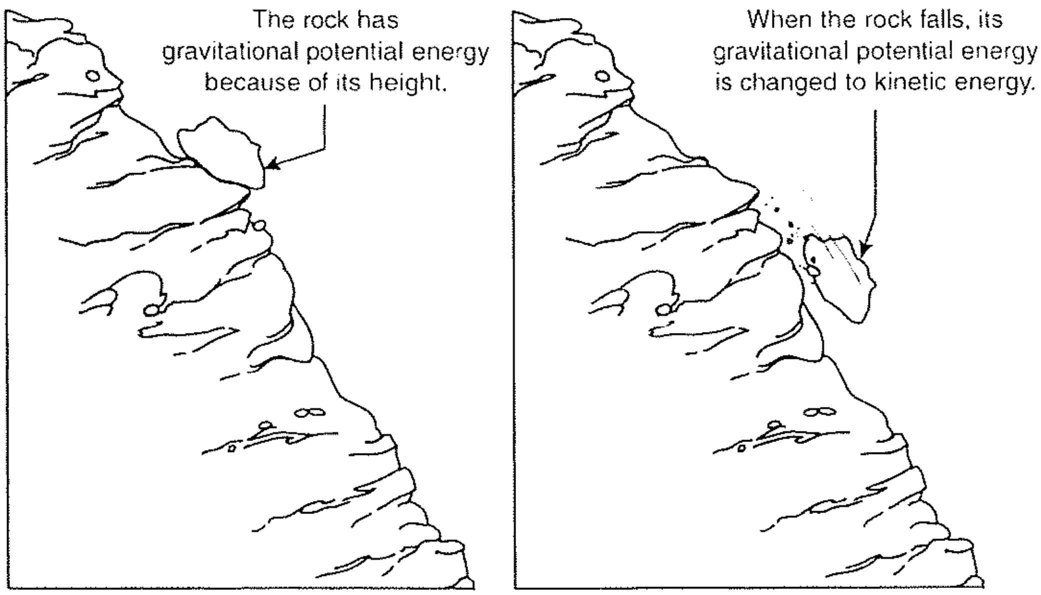
Right!

$$\begin{aligned} \% &= \frac{W_o}{W_i} \times 100 \\ \% \text{ efficiency} &= \frac{\text{work output}}{\text{work input}} \times 100 \\ &= \frac{14{,}850 \text{ J}}{28{,}018 \text{ J}} \times 100 \\ &\approx 53 \end{aligned}$$

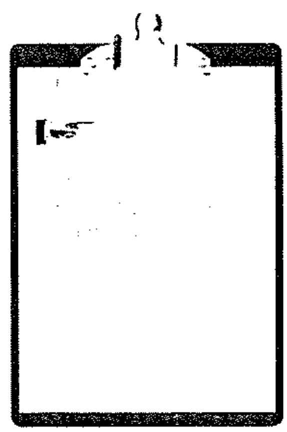
The efficiency of the crane is about 53%.

O.K., we've talked about motion and forces. How does energy fit into all this?

Great question! *Energy* is the ability to change or move matter. All objects have energy. For example, a falling rock has energy of motion, or *kinetic energy*. But that's not all. An object can also have stored energy, or *potential energy*. A rock at the edge of a steep slope has potential energy because of its height. This energy is changed into kinetic energy if the rock falls down the slope.



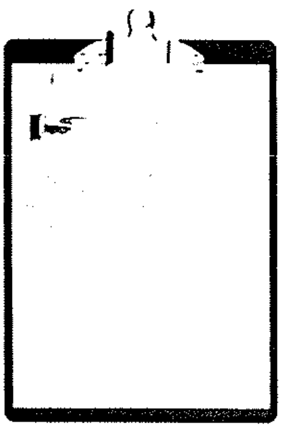
What happens to the rock's energy when it stops at the bottom of the slope? Does it just disappear?



No, it doesn't. Energy can never be destroyed. The *law of conservation of energy* states that energy can never be created or destroyed; it can only change form. As the rock moves down the slope, its mechanical energy is changed into other forms. For example, the rock makes noise as it hits other rocks on its way downhill, so some of its energy is changed into sound energy. In addition, friction between the rock and the ground generates heat, so the rock's mechanical energy is also changed into heat energy.

In the last example, you said that mechanical energy could be changed into sound energy. I know that sound travels in waves. Are waves and energy the same thing?

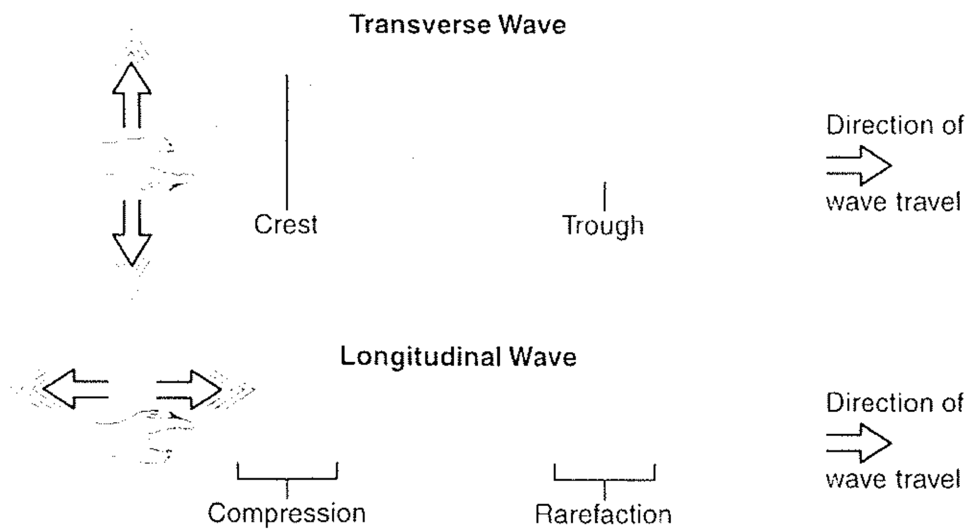
Not exactly. *Waves* are disturbances that transfer energy from one place to another. Imagine a beach ball floating in a swimming pool. If you were to push your arm up and down in the water over and over again, you would make waves at the surface of the water that would spread out through the pool. Eventually the waves would cause the beach ball to move up and down, too. The waves would transfer some of your energy to the beach ball.



How do waves travel?

All waves are produced by some kind of vibration. In a *transverse wave*, the vibration of the wave is perpendicular to the direction in which the wave travels. For example, if a transverse wave travels from left to right, the *medium* vibrates up and down.

In a *longitudinal wave*, such as a sound wave, the vibration of the wave is parallel to the direction in which the wave travels. If a longitudinal wave travels from left to right, the medium vibrates left and right as well.

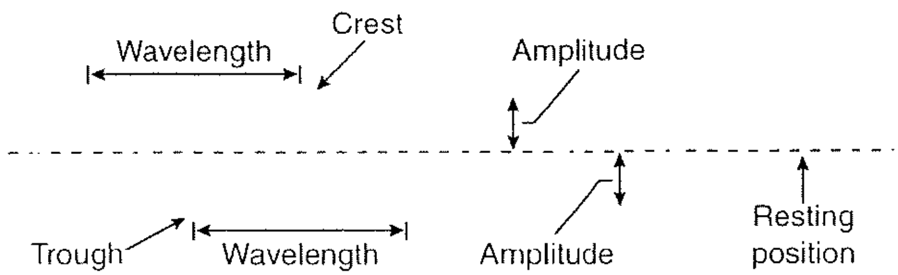


Both waves travel from left to right. In a transverse wave, the medium vibrates up and down, and in a longitudinal wave, the medium vibrates back and forth.

How do scientists measure waves?

Scientists measure waves by describing their properties. Some of the properties of waves are wavelength, amplitude, speed, and frequency. Look at the transverse wave shown below. The *wavelength* is the distance from one *crest* (or high point) to the next, or from one *trough* (or low point) to the next. Because wavelength is a distance, it can be measured in meters (m).

The *amplitude* of the wave is the distance from the resting position to a crest or from the resting position to a trough. Amplitude can also be measured in meters.



The greater the amplitude of a wave, the more energy the wave transfers. If you think about it, this makes sense. Huge waves produced by hurricanes have much larger amplitudes than tiny ripples. They also have more energy. A tiny ripple doesn't have enough energy to do much damage to the shoreline, but a huge ocean wave might.

What's the difference between speed and frequency?

The *speed* of a wave is the distance the wave travels in one unit of time. The speed of a wave can be measured in units of meters per second (m/s). A wave's velocity is its speed in a particular direction.

Frequency is a measure of how many wavelengths pass a particular point in one unit of time. It is measured in units called hertz (Hz). One *hertz* is equal to one wave per second. For example, if four complete wavelengths pass you every second, the frequency is four waves per second, or four hertz.

The following formula relates a wave's velocity to its frequency.

$$\text{Velocity of a wave} = \text{frequency} \times \text{wavelength} \qquad v = f\lambda$$

Suppose a sound wave has a frequency of 440 hertz and a wavelength of 0.78 meter. To find the velocity of the wave, substitute the values for frequency and wavelength into the velocity formula.

$$v = f\lambda$$

$$\begin{aligned} \text{Velocity of a wave} &= \text{frequency} \times \text{wavelength} \\ &= 440 \text{ waves/s} \times 0.78 \text{ m} \\ &= 343 \text{ m/s} \end{aligned}$$

The sound wave has a velocity of about 343 meters per second.

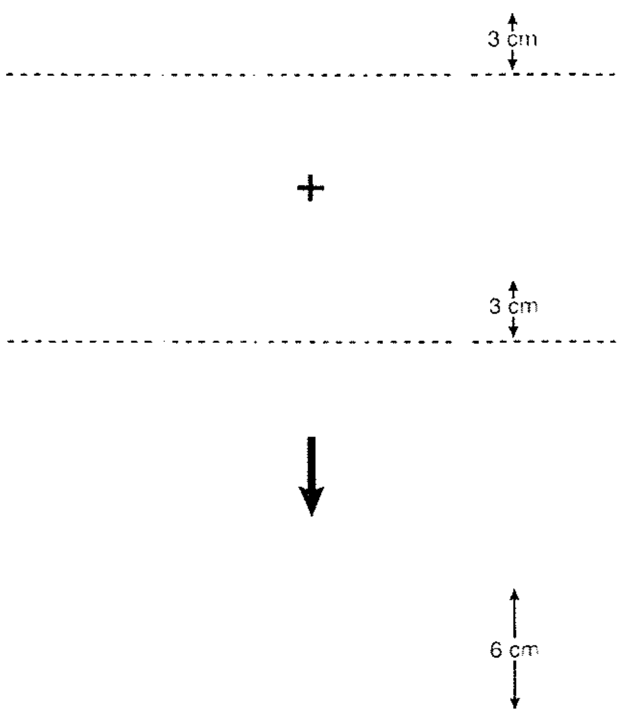
What happens when one wave meets another?

When two waves meet, they occupy the same space at the same time. When this happens, the waves combine to form a new wave with different properties. This is called *interference*. This interaction is different from what occurs when most objects meet. For example, when two marbles meet, they collide and bounce off each other. Two marbles can't occupy the same space at the same time.

How is the new wave that is produced different from the original waves?

That depends on the properties of the original waves. If the crests of the original waves line up with one another, the resulting wave will have a larger amplitude than either of the original waves. The amplitude of the combined wave will be equal to the sum of the amplitudes of the original waves. This type of interference is called *constructive interference*.

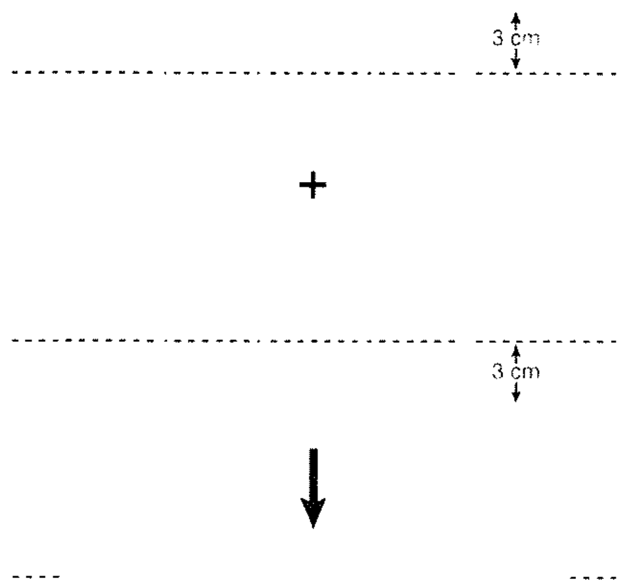
Constructive Interference



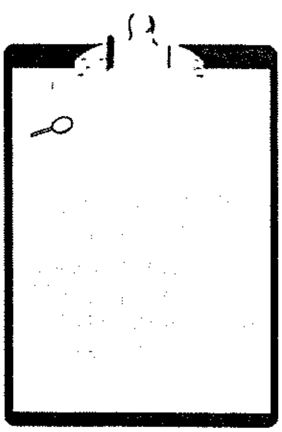
The crests of the original waves line up, so the amplitude of the combined wave is equal to the sum of the amplitudes of the original waves: 3 cm + 3 cm = 6 cm.

Another kind of interference is *destructive interference*. Destructive interference can occur when the crests of one wave line up with the troughs of another wave. In this case, the amplitude of the combined wave is equal to the larger wave's amplitude minus the smaller wave's amplitude. If the waves have the same amplitude, then the waves cancel each other out.

Destructive Interference



The crests of the first wave line up with the troughs of the second wave. The amplitude of the combined wave is equal to the difference of the amplitudes of the original waves. In this case, the amplitudes cancel each other out: 3 cm − 3 cm = 0 cm.

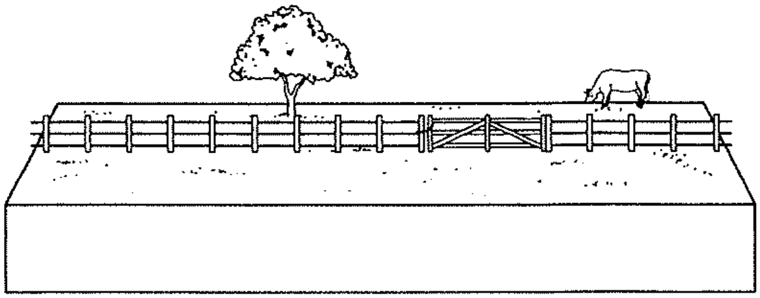


Can waves travel through solids?

Yes! Seismic waves, for instance, can travel through rock. *Seismic waves* are produced by earthquakes. There are three types of seismic waves: primary waves, secondary waves, and surface waves.

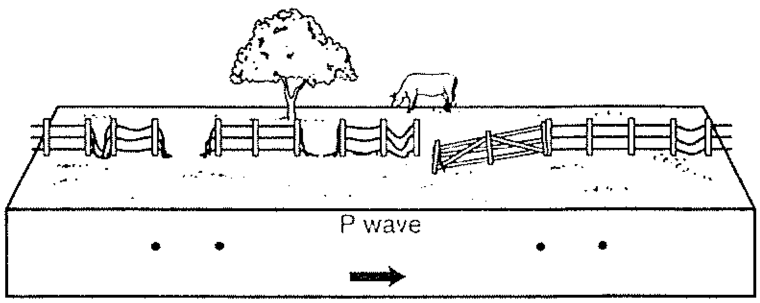
Primary waves (or P waves) are longitudinal waves. They travel faster than the other types of seismic waves. *Secondary waves* (or S waves) are transverse waves. Like P waves, S waves can travel through solid rock, but unlike P waves, they cannot pass through Earth's liquid core. *Surface waves* travel along the boundary between the ground and the air. They are the slowest type of seismic wave, but they can do the most damage.

Before Earthquake



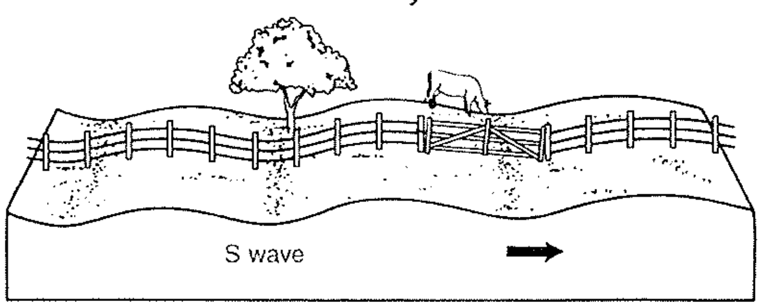
A straight fence provides a reference for future movement.

Motion Caused by a P Wave



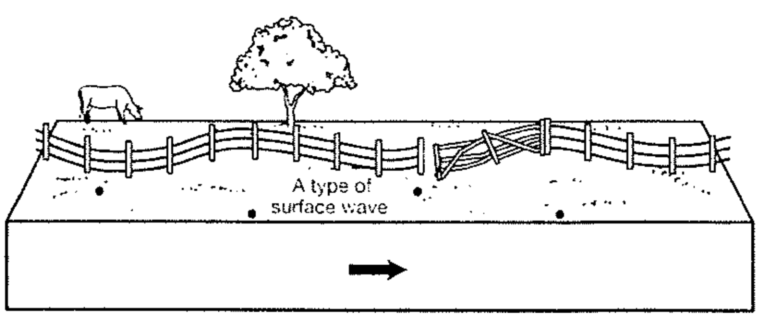
Particles are compressed and expanded in the direction of P-wave travel.

Motion Caused by an S Wave



Particles move up and down at a 90° angle to the direction of S-wave travel.

Motion Caused by a Type of Surface Wave



Particles move side to side at a 90° angle to the direction that this surface wave travels.

Are there any other types of waves I should know about?

Yes. *Electromagnetic waves* include radio waves, infrared waves, visible light, ultraviolet rays, X rays, and gamma rays. Electromagnetic waves are different from other waves because they can travel through a vacuum. They don't require a medium like other waves do. Instead, they travel in the form of changing electric and magnetic fields.

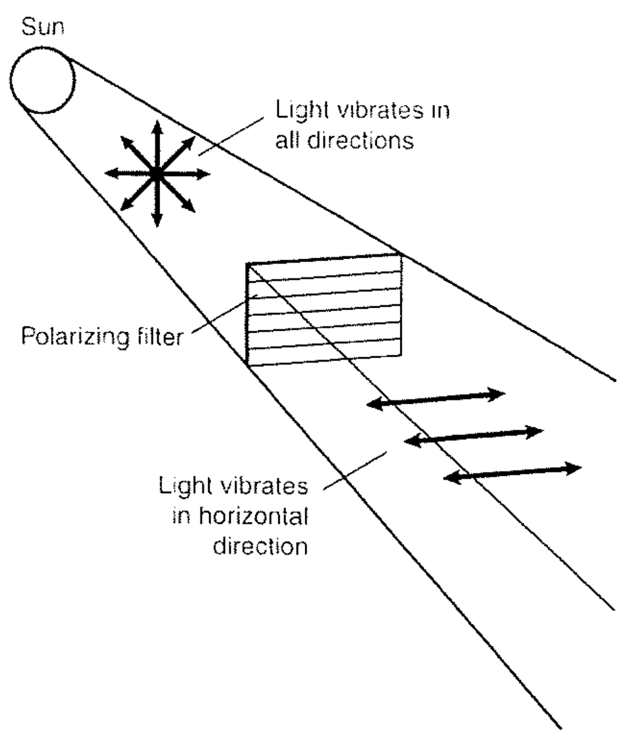
All electromagnetic waves travel through space at the same speed. This constant speed is often called the speed of light. The speed of light is equal to 3×10^8 meters per second.

Just like seismic waves, water waves, and sound waves, electromagnetic waves transfer energy. And it's a good thing they do! We wouldn't be able to survive without the energy that the sun transfers to Earth through light waves.

Do light waves behave like transverse waves or longitudinal waves?

They behave like transverse waves. This means that light can be polarized by passing it through a polarizing filter. Let me explain.

A polarizing filter is made up of long molecules arranged parallel to one another. Between the molecules are narrow slits. The only light that passes through a polarizing filter is light that vibrates parallel to the filter's slits. The light that passes through a polarizing filter is called *polarized light*. Polarized light vibrates in only a single direction, such as a horizontal plane.



Sunlight is unpolarized, meaning that it vibrates in all directions. When sunlight strikes a polarizing filter with horizontal slits, the only light that passes through the filter is light that vibrates in a horizontal direction.

Earlier you said that energy can't be created or destroyed. If energy can't be destroyed, why is there so much talk about conserving energy?

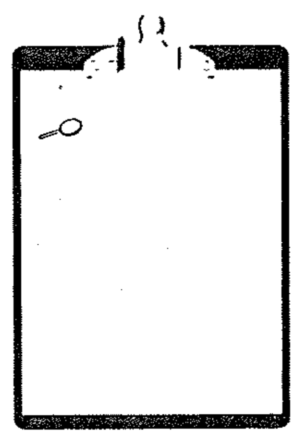
When people talk about conserving energy, they're usually talking about conserving usable energy. After all, even though energy can't be destroyed, it can be converted into a form that we can't easily use anymore. When gasoline is burned in a car's engine, for instance, chemical energy stored in the gasoline is converted to other forms. Only some of this energy is used to move the car forward. Much of the rest is wasted as heat.

Some useful energy sources exist only in limited supplies. Once these sources are used up, they cannot be replaced in a short amount of time. These resources are called *nonrenewable resources*. Fossil fuels, such as coal, oil, and natural gas, are nonrenewable resources. Although fossil fuels are widely used around the world, their supply is limited. Once they are used up, we will not be able to make more.

What are some other energy sources besides fossil fuels?

Some examples of alternative energy sources include solar energy, wind energy, and hydroelectric energy. Solar power plants use energy from sunlight to heat water to steam. The steam is used to turn a turbine and generate electricity. Solar cells, such as those in solar-powered calculators, are able to change light energy directly into electrical energy.

Electricity can also be produced from wind energy. A wind farm consists of a large number of wind turbines (or windmills). As the blades of the wind turbines move, they turn electric generators. In a similar way, hydroelectric power plants use the energy of moving water to turn turbines and generate electricity. Hydroelectric power plants are built near dams or waterfalls.



Alternative energy sources offer an alternative to fossil fuels. Many alternative energy sources are *renewable*—that is, they can be replaced in a short amount of time. In addition, alternative energy resources often cause less pollution than fossil fuels do.

Are alternative energy sources used to produce most of our energy?

No. Right now, fossil fuels are the major source of energy in the United States. One reason for this is that alternative energy sources aren't always practical. For example, hydroelectric power plants can be built only in certain spots. Many suitable rivers have already been dammed, so the number of new hydroelectric power plants that can be built is limited. Another disadvantage of hydroelectric power plants is that they can have a negative impact on some types of river wildlife. For example, the damming of a river changes the river's depth and rate of flow. These changes can affect the types of plants that can live in the river, and changes in the river's plant life can affect the animal life as well.

One problem with solar power is that it can't be used to produce electricity at night or on cloudy days. Solar power plants also require a large area of land where mirrors can be set up to focus the sun's rays. Wind power has similar problems: electricity can be produced only when the wind is blowing, and wind farms take up a large amount of space.

Are there any alternative energy sources for cars?

Hybrid cars are cars that use two or more power sources. For example, hybrid electric cars use both a gasoline engine and an electric motor. Because hybrid cars use two different power sources, they can operate more efficiently than regular cars.

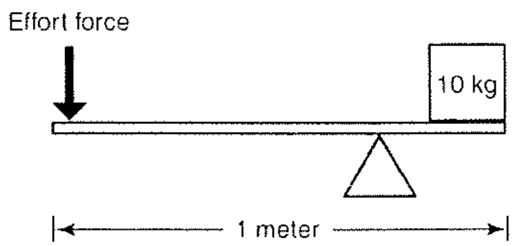
In a hybrid electric car, the electric motor is powered by rechargeable batteries. These batteries are recharged with energy that would otherwise be wasted by the gasoline engine. Because less of the gasoline's energy is wasted, hybrid electric cars tend to get better gas mileage than regular cars. And because they use less gas, they produce less pollution.

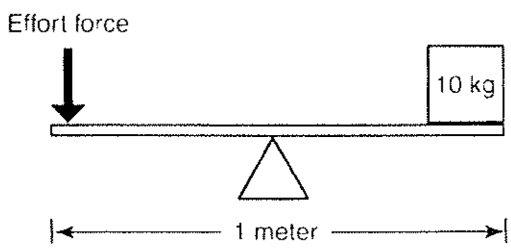
Fuel cells might someday be used to power cars as well. Fuel cells are devices that produce electrical energy from a chemical reaction between oxygen and hydrogen.

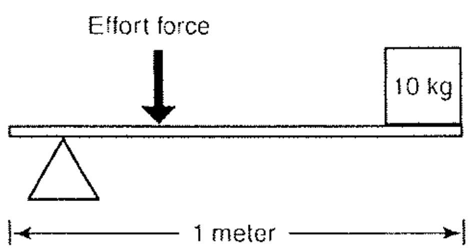
Fuel cells are very efficient because they do not produce much waste heat. Some fuel cells are also nonpolluting. Although fuel cells have been used on spacecraft and in submarines, they are currently too expensive for widespread use.

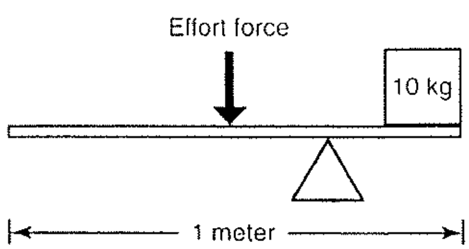
After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

Which lever would require the least force to lift a box with a mass of 10 kilograms?

A


B


C


D


Answer Key: page 117

Sunlight strikes a polarizing filter with horizontal slits. What will happen when the light that passes through this filter strikes a second polarizing filter with vertical slits?

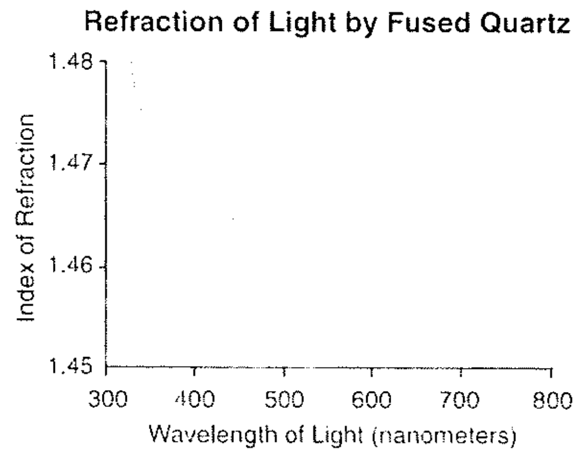
A The second filter will block all of the light that passes through the first filter.

B The second filter will allow light to vibrate in all directions.

C The second filter will allow light to vibrate only in a vertical direction.

D The light that passes through the second filter will vibrate only in a horizontal direction

Answer Key: page 117



What does the graph indicate about the relationship between the index of refraction of fused quartz and the light being refracted?

A The index of refraction does not depend on the wavelength of the light.

B The frequency of the light has no effect on the index of refraction.

C Light with short wavelengths is refracted less than light with long wavelengths.

D The index of refraction increases as the frequency of the light increases.

Answer Key: page 117

A student throws a tennis ball with a mass of 5.7×10^{-2} kilograms into the air. What is the downward force on the ball due to gravity?

A 9.8 N

B 0.56 N

C 0.17 N

D 0.057 N

Answer Key: page 117

A machine lifts a crate 6.0 meters in 3.5 seconds. The weight of the crate is 490 newtons. How many watts of power does the machine use to lift the crate? Record and bubble in your answer.

				.			
0	0	0	0		0	0	0
1	1	1	1		1	1	1
2	2	2	2		2	2	2
3	3	3	3		3	3	3
4	4	4	4		4	4	4
5	5	5	5		5	5	5
6	6	6	6		6	6	6
7	7	7	7		7	7	7
8	8	8	8		8	8	8
9	9	9	9		9	9	9

Answer Key: page 118

A 5.0-kilogram stone falls off a cliff from a height of 20 meters. If the effects of air resistance are ignored, what will be the stone's kinetic energy the instant it strikes the ground?

A 100 joules

B 490 joules

C 980 joules

D 1000 joules

Answer Key: page 118

Batteries produce electricity by means of a chemical reaction. Some batteries are disposable. The reactants of a disposable battery are eventually used up. At that point the battery is dead and can no longer be used. Other batteries are rechargeable. A rechargeable battery can be inserted into a device that uses electric current to convert the products of the reaction back to the reactants. As a result, a rechargeable battery can be used over and over again.

What is an advantage of rechargeable batteries over disposable batteries?

A Rechargeable batteries have a lower initial purchase price.

B Rechargeable batteries produce a stronger electric current.

C Rechargeable batteries result in less pollution of the environment.

D Rechargeable batteries convert chemical energy directly to electricity.

Answer Key: page 119