FACULTAD DE INGENIERIA

Comprendiendo Inglés Técnico-Científico

Inglés Técnico 2

Ing. Roberto Santiago

PRONOMBRES RELATIVOS (that, who, which, whose). *SU OMISIÓN*

EJERCICIO 1.1

Fill in the blanks with the RELATIVE PRONOUNS “which” (= that), “who” (= that) or “whose” and translate the sentences.

1) Specific examples are given in order to understand their meaning and the situations in __________ they are applied.

………

………

2) All circuits must contain a source of electromotive force to establish the difference of potential __________ makes possible the current flow.

………

………

3) This source may be the dry cell __________ will be discussed later in the book.

………

………

4) But regardless of the type of circuit through __________ the current flows, all circuits offer some resistance to the current.

………

………

5) The symbol for a fixed resistor –that is, one __________ resistance is constant- is

………

6) Those are the students__________ measured the original length of the specimen.

………

………

EJERCICIO 1.2

Write within parentheses the relative pronoun omitted in English (who =that, whom = that, which = that). Translate the sentences and underline the word in Spanish which was omitted in English.

1) The problems we shall consider are those of electric charges in motion. (……….)

………

2) The words or characters you want to display are typed on the screen with a quote symbol at each end. (…………)

……

……

3) He took the pressure gage you left on the table. (…………)

……

4) The man you saw in the lab is not a chemical engineer. (……….)

……

5) The value for the yield strength he gave us was wrong. (……….)

……

6) This is the first solution the designer found for a low-cost fabrication. (……….)

……

SOME, ANY, NO Y SUS DERIVADOS

EJERCICIO 2.1

Fill in the blanks with “some”, “any” or “no” and translate the sentences

1) We shall define _______________ of the important terms and concepts used by electrical engineers.

……

……

2) Is there _______________ law governing the behavior of electric charges in this environment?

……

……

3) It does not require _______________ special knowledge of electric networks.

……

4) That brittle bolt had _______________ apparent plastic flow. (neg.)

……

EJERCICIO 2.2

Fill in the blanks with “something”, “anything” or “nothing” and translate the sentences

1) Did he say _______________ about the vapor pressure of a binary mixture?

…….

2) We assume _______________ divides the container and therefore concentration is uniform throughout (neg.).

…….

…….

3) It will not show _______________ during the first stage of the tensile test.

…….

4) _______________ must represent its ability to deform.

…….

EJERCICIO 2.3

Fill in the blanks with “somebody” (= someone), “anybody” (= anyone) or “nobody” (= no one) and translate the sentences

1) Does _______________ know how long the various energy sources of the world will last?

…….

2) No, _______________ knows how long they will last.

…….

3) We suppose that _______________ can solve such an easy problem.

…….

4) I did not find _______________ at the university yesterday.

…….

EJERCICIO 2.4
Fill in the blanks with “somewhere”, “anywhere” or “nowhere” and translate the sentences

1) Those details were given _______________ in this chapter.

…….

2) You go _______________ when you try to apply the simple material balance in atomic fission. (neg.)

…….

…….

3) Did he find it _______________ in his book?

…….

4) We shall not use that formula _______________.

…….

EJERCICIO 2.5
Translate the following sentences

1) You may take *any* tool you need to repair that pump.

…….

2) Computers will perform almost *anything* in the future.

…….

3) You can drive that car *anywhere*.

…….

4) Currents may flow through solid conductors, liquids, gases, vacuums, or *any* combinations of these.

…….

…….

5) I believe that *anyone* knows the meaning of “derivative of q with respect to time”.

…….

EJERCICIO 2.6
Complete the following table according to the explanations given in class

	+	–	?
any			
anything			
anybody/anyone			
anywhere			

EJERCICIO 2.7
Translate the following sentences

1) *Everybody* calculated the average current over the 30-min period.

……

2) You must check *every* switch before starting.

……

3) They told us that was *everything* we needed.

……

4) *Everyone* understands the standard calculus approach.

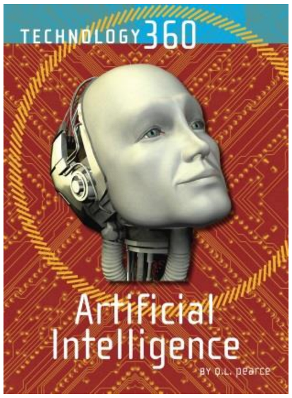
……

5) Consider the same cross-sectional area of the conductor *everywhere*.

……

EJERCICIO 3.1

Read the following text



Artificial Intelligence

Creating an Intelligent Machine

The computers of the early twenty-first century are capable of performing a wide range of tasks at amazing speeds and with incredible accuracy, but most of these computers work under known conditions. This means that they are programmed to deal with the situations that they would be expected to encounter while doing the job that they are instructed to do. True intelligence demands more. An intelligent machine needs to have the ability to learn about its environment and adjust as that environment changes. It should be able to deal with unexpected conditions.

What is Intelligence?

When trying to define intelligence, scientists agree that the only thing they may agree on is that the exact definition is still open to debate. In 1994, fifty-two researchers contributed to a report titled *Mainstream Science on Intelligence*. In it they describe intelligence as "a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience.

The path to true artificial intelligence (AI), or machine intelligence, began with the development of the programmable computer, a machine that could manipulate data according to instructions, or programs, from a human operator. The idea of creating a thinking machine slowly took shape.

Intelligent Robots

The most basic forms of artificial intelligence (AI) are computer programs that solve specific problems, but few forms of AI spark the imagination more than a robot. AI of varying levels has been applied in the science of robotics to make life easier and safer for human beings in many ways, and robots are quickly becoming more commonplace. In fact, modern robots come in so many forms, shapes, and sizes that a person may have contact with one without realizing it. Robots might be described as, "AI systems embedded in space and time. Such machines and mechanical devices may display human-like skills in a wide range of tasks. Robots are used on assembly lines to build cars and trucks. They explore the far reaches of space and the depths of the oceans. They also assist doctors during surgery, clean swimming pools and rain gutters, and remind people to take their medicine.

Unimates

Auto manufacturers became the first to use robots in the workplace. In 1961 the Unimates joined the assembly line at General Motors plant in New Jersey. The Unimates were 4,000-pound (1,814 kg) metal arms that were hydraulically powered and programmed to move in precise repeating patterns. Following commands stored on a magnetic drum, they were flexible enough to perform a number of jobs. They were designed for handling parts weighing up to 500 pounds (227 kg). Unimates could weld auto parts with great accuracy. Unlike people, the Unimates did not get tired of doing the same thing over and over, and they could not be injured on the job or harmed by toxic materials. The main problem with the robotic arms was that they were built for a single purpose or group of purposes, and they could not adapt to new tasks. Another issue was that many angry human workers felt that their jobs were being lost to mindless piles of metal. In fact, robots did replace humans in certain jobs. Despite these concerns, industrial robots like Unimate continue to be in use in the twenty-first century. They are reliable and easy-to-operate, and they have become the most widely used industrial robots in the world.

Introducing Karel the Robot

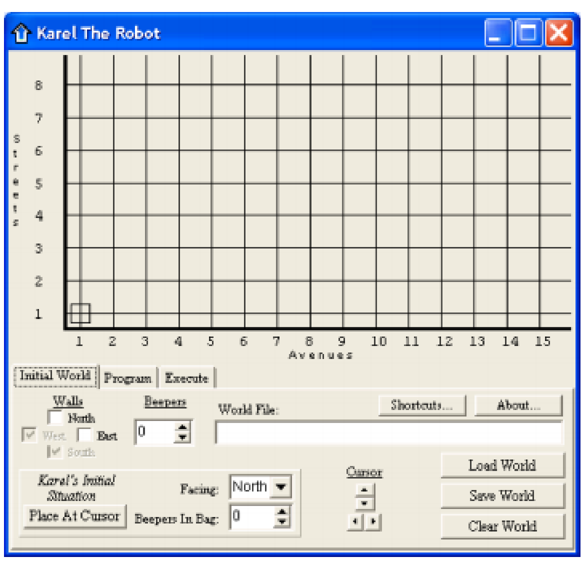
In the 1970s, a Stanford graduate student decided that it would be easier to teach the fundamentals of programming if students could somehow learn the basic ideas in a simple environment free from the complexities that characterize most programming languages. He designed an introductory programming environment in which students teach a robot to solve simple problems. That robot was named Karel.

What is Karel?

Karel is a very simple robot living in a very simple world. By giving Karel a set of commands, you can direct it to perform certain tasks within its world. The process of specifying those commands is called programming. Initially, Karel understands only a very small number of commands, but an important part of the programming process is teaching Karel new commands that extend its capabilities.

When you program Karel to perform a task, you must write out the necessary commands in a very precise way so that the robot can correctly interpret what you have told it to do. In particular, the programs you write must obey a set of syntactic rules that define what commands and language forms are legal. Taken together, the predefined commands and syntactic rules define the Karel programming language. The Karel programming language is designed to be as similar as possible to Java. The critical difference is that Karel's programming language is extremely small, in the sense that it has very few commands and rules. It is easy, for example, to teach the entire Karel language in just a couple of hours. The details are easy to master. Even so, you will discover that solving a problem can be extremely challenging. Problem solving is the essence of programming; the rules are just a minor concern along the way.

World View



Karel's world

Karel's world is defined by streets running horizontally (east-west) and avenues running vertically (north-south). The intersection of a street and an avenue is called a corner. Karel can only be positioned on corners and must be facing one of the four standard compass directions (north, south, east, and west). A sample of Karel's world is shown below. Here Karel is located on the corner of 1st Street and 1st Avenue, facing east.

EJERCICIO 3.2

According to the text "Artificial Intelligence", decide whether each of the following statements are TRUE, FALSE or NOT INCLUDED.

1) Modern computers can work accurately in any condition. [_____]

………

………

2) Some early twenty-first century computers can adjust to unexpected environments. [_____]

………

………

3) Robots are human-like mechanical devices. [_____]

………

4) Artificial intelligence is difficult to define. [_____]

………

5) Robots were first used in car factories. [_____]

………

6) Some industrial robots can do some jobs better than men. [_____]

………

………

7) The early Karel was a robot which was compatible with Java. [_____]

………

………

8) Karel can learn new commands. [_____]

………

LAS FORMAS COMPARTIVAS Y SUPERLATIVAS. USOS ESPECIALES.

EJERCICIO 4.1

Translate the following sentences and underline the COMPARATIVE FORMS in English and in Spanish.

1) At the same time that energy makes more comfortable living conditions possible, it also creates environmental effects.

………

………

………

2) As plastic deformation increases, the specimen becomes stronger (work hardening).

………

………

3) This involves the designer in a consideration of a very much wider range of qualities, such as the ability of the material to be machined, shaped, and joined.

………

………

………

4) They must have a better understanding of the electrical instruments that are being used more frequently than ever before in their professions.

………

………

………

5) Note that at any one temperature the vapor pressure of benzene is larger than that of toluene.

………

………

6) At equilibrium composition the vapor will normally contain a higher concentration of the more volatile component than the liquid.

………

………

7) In order to start the process the gas must be much hotter.

…….

…….

8) After the tensile test, the less ductile bolt showed a very little plastic deformation.

…….

…….

9) When necking occurs, the stress at fracture is always lower than the maximum stress.

…….

…….

10) Jet planes are making distances shorter and shorter, but they are requiring more powerful turbines.

…….

…….

EJERCICIO 4.2

Translate the following sentences and underline the SUPERLATIVE FORMS in English and in Spanish.

1) Some of the most difficult terms and concepts used by engineers will be defined here.

…….

…….

2) An electron has the smallest known electric charge.

…….

…….

3) It can be seen that the largest growths are in the electrical generation and transportation areas of the economy.

…….

…….

…….

4) Although the results of these specialized tests are empirical in nature, they are the most useful tests to the engineer.

………

………

5) It is the most common means of evaluating mechanical properties.

………

………

6) Those were the least important features we found for aluminum alloys.

………

………

7) They brought the thinnest wire they had but it was not thin enough.

………

………

8) Are Los Angeles and San Francisco the fastest growing cities in the United States?

………

………

9) That is the worst engine they made because it works least efficiently of all.

………

………

10) Everybody knows that the Nile is the longest river in Africa and the second longest in the world.

………

………

EJERCICIO 4.3

Translate the following sentences and underline the SPECIAL USES OF COMPARATIVE AND SUPERLATIVE FORMS in English and in Spanish.

1) We shall return in more detail after discussing the testing and examination of most materials.

………

………

2) Most of the time you will be working in low pressure environments.

………

………

3) At least, it is interesting to speculate on the possibility of exploiting the tremendous potential of our solar energy input.

………

………

4) The lower the modulus of elasticity, the greater the elastic deflection will be.

………

………

5) The sooner, the better.

………

EJERCICIO 5.1

Read the following extract

4.1 INTRODUCTION

Energy is of major benefit to mankind, but it is also a major threat to modern society. At the same time that energy makes more comfortable living conditions possible, it also creates harmful environment effects. As a result of rapid increases in energy consumption during recent years, coupled with a current concern to preserve environmental quality, it is apparent that the world will have to make changes in the way energy is produced, transported, and consumed if we are to meet the needs of the future. This chapter will serve as an introduction to the important subject of energy utilization and the resulting environmental pollution that it causes.

In the specific areas of energy conversion and pollution, control engineers are engaged in a variety of functions ranging from creative design and applied research and development to management. Engineers involved in these fields conceive, plan, design, and supervise the manufacture of a wide variety of devices, machines and systems for energy conversion, transportation, environmental control, and other related areas. With such a broad range of opportunities it is not surprising that engineers with an energy conversion background work in occupations in the aerospace, automotive, chemical, electrical power generation, and many other industries. If we are to meet the future's changing energy requirements we shall have to develop new technologies to improve our efficiency in the production, conversion, and consumption of energy and to reduce its adverse effects on the environment. Thus, engineers of the future will have a vital role in relating the world's energy needs to technological reality.

4.2 ENERGY RESOURCES AND USES

The development of society can be characterized by a progressive substitution of machine power for muscle power. As will be discussed in detail later, this machine power became available as engineering systems have been developed to convert heat energy into useful power. With the technological development of energy conversion devices, the only other factor needed to supply energy is the availability of useful energy resources. In this section we shall discuss these resources and their uses and supplies.

The first attempt to use a source of power, other than muscles, occurred in the first century B.C. when water power was used for irrigation purposes. As the size and efficiency of waterwheels increased they were used for grinding grains and later became important power sources of the early Industrial Revolution. Even today, water is an important source of power, especially in mountainous terrain where electricity is generated in hydroelectric power stations. In such systems the kinetic energy of the flowing water drives complex and efficient hydraulic turbines instead of simple waterwheels

With the development of engines driven by heat generated from combustion (heat engines) during the Industrial Revolution, the emphasis on energy sources was shifted from water power to fossil fuels. Other than the obvious fact that water power was restricted to a few geographical areas, one of the important factors that gave impetus to the development of fossil-fuel-fired steam engines was their potential as mobile power sources. Thus, although the steam engine was first used as an auxiliary waterwheel pump, by the middle of the nineteenth century the steam engine became the principal power source for the manufacturing industry of the world. In the present century, a steadily increasing number of energy conversion devices whose chief advantage is mobility have been introduced. The automobile powered by an internal combustion engine is an excellent example.

The interest in energy consumption, energy reserves, and the ability to deliver energy where it is desired can be tied to industrialization. Thus, the great demands to be placed on the energy reserves of the earth can be explained by the fact that almost every country in the world is trying to industrialize –and industrialization takes energy. For example, in the United States, the annual per capita energy consumption is approximately equal to the energy that can be obtained from 10 tons of coal. One can graphically picture the large amount of energy resources necessary to keep our industrial machines working. As Figure 4.1 shows, if we compare the gross national product (a measure of industrialization) and energy consumption per capita for various countries, it is apparent that a key difference between an underdeveloped society and an advanced society in today’s world is the amount of energy consumed per person. In Figure 4.1 we have used a common unit of energy, the Btu. One Btu is the amount of energy needed to raise the temperature of 1 lb. of water 1° F.

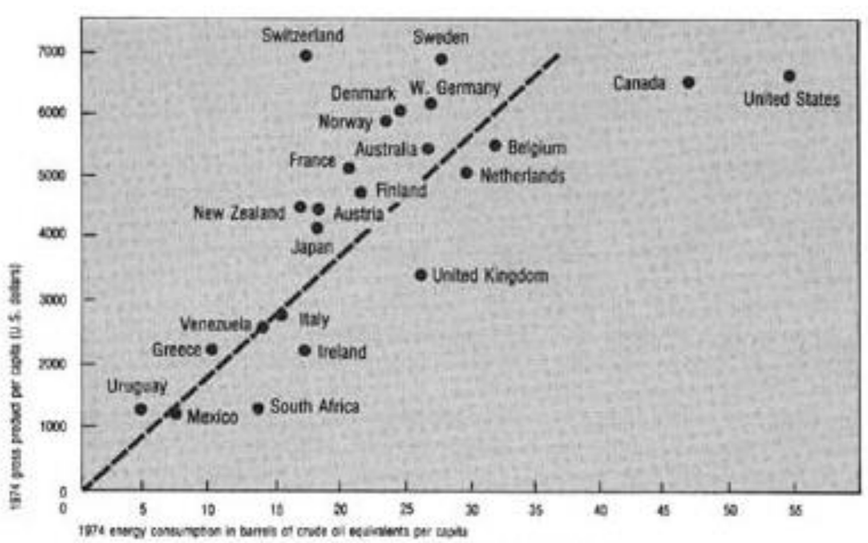


Figure 4.1
Relation between per capita energy consumption and national product

Because gigantic amounts of energy are used, one needs a large unit to talk about the world’s total energy consumption; thus, we use the Q ($1Q = 10^{18}$ Btu). About 15Q have been used during the past 2,000 years, but one-half of this was used in the last 100 years. At the time of the Industrial Revolution the world was consuming only about 1/100 Q/year; by 1960 the rate was 1/10 Q/year. Thus, we had a 10-fold increase in total energy consumption while only doubling the world’s population. Taking into account increasing industrialization and population growth, by the year 2050 the world will have spent about 75Q if the rate of energy use increases at a 3% annual rate or 275Q at a 5% rate of increase.

If one were to look at energy consumption on a regionalized basis, they would discover that the United States with 6% of the world’s population accounts for about 35% of the world’s energy use. By the year 2000 the United States’ share will probably drop to 25% and the world average per capita energy consumption will have increased from the present one-fifth of the United States' average to about one-third of the United States' average.

Not only are the demands for energy sources increasing, but the relative demands on various sources are also changing rapidly as needs increase. For instance, petroleum has been known for centuries, but until the nineteenth century the common energy sources were wood, water power, animals, and humans. With the development of the steam engine, coal became the source of energy of the Industrial Revolution. Even in modern times, the trends in the changing energy scene are striking. This is graphically illustrated in Figure 4.3, which shows the past and projected consumption of various energy resources in the United States. Note the projected use of nuclear energy in this figure: By the year 2000 it will amount to one-fifth of our total energy supply.

To estimate how long the various energy sources of the world will last, one faces the doubly difficult task of estimating the reserves of each sources as well as consumptive demands on each reserve. Many complex factors are involved in determining the energy consumption patterns, and, as was pointed out, an energy need of 200*Q* could be involved by 2050 just based on the predicted rate of energy consumption growth. Political, sociological, and technological factors are involved in growth patterns. To further compound the difficulty in prediction, different energy use sectors are growing at different rates. For example, it is convenient to divide the total demand into household and commercial, industrial, transportation, and electrical generation segments. Figure 4.4 illustrates the changing pattern of energy consumption for the United States. It can be seen that the largest growths are expected in the electrical generation and transportation areas of the economy. This type of information is needed when predicting the demand on any energy reserve. For example, at the present time, the transportation industry is almost entirely dependent on petroleum as an energy source. Thus, any large-scale increases in transportation energy requirements will place immediate demands on petroleum resources.

When one attempts to estimate the total world energy resources he can classify them as capital (nonrenewable) or income (renewable) sources. In the past, energy capital has been limited to the fossil fuels including coal, oil, and natural gas, which were created several hundred million years ago. We now include nuclear fuels in this category, but the amount of energy available from nuclear fuels is variable. For example, the current types of nuclear reactors extract only about 1% of the available energy from nuclear fuels, while proposed breeder reactors may be able to extract close to 100% of the energy from the uranium fuels. When estimating energy capital resources it is also convenient to divide them into proved and potential resources. The proved resources are those that are known to exist and that can be used economically with present technology. Potential resources refer to those resources that may or may not be technically or economically feasible to utilize (oil shale deposits are an example of this type).

The energy income category refers to continuously available energy resources such as water power, geothermal power, farm wastes, wood, and solar energy. Presently, about 85% of the world's needs is supplied from capital reserves. Although this large dependence on energy capital is likely to remain in the near future, it is interesting to speculate on the possibility of exploiting the tremendous potential of our solar energy input.

EJERCICIO 5.2

According to the extract above, decide whether the following statements are *TRUE* or *FALSE* and translate them. Identify the part of the text from which you base your choice by placing the statement number beside the corresponding sentences or paragraphs.

1) Simple waterwheels are substituting the complex hydraulic turbines in today's hydroelectric power stations. [_____]

………

………

………

2) The coal consumption in the United States is approximately ten tons of coal per person. [_____]

………

………

3) In order to raise the temperature of 10 pounds of water 15 degrees (Fahrenheit) you need 150 BTU of energy. [_____]

………

………

………

4) The present average energy consumption of every person who lives in the U.S. is 5 times higher than the world average per capita energy consumption. [_____]

………

………

5) At the present time, the transportation industry depends mainly on petroleum as an energy source.

[_____]

………

………

6) An energy resource is called *capital* if it is proved that it can supply energy with present technology and indefinitely. [_____]

………

………

7) During the Industrial Revolution the interest on energy sources changed from fossil fuels to water power. [_____]

……

……

8) The automobile is an excellent example of a steadily-increasing-energy conversion device whose chief advantage is its mobility. [_____]

……

……

9) The projected consumption of nuclear energy in the United States by the year 2000 will amount 20% of the total energy supply of the country. [_____]

……

……

10) In order to keep our industrial machines working, one can graphically picture the energy resources. [_____]

……

……

11) Men began using water power for irrigation purposes about 18 centuries ago. [_____]

……

……

12) Fossil fuels allow the possibility of having power sources which may be mobile. [_____]

……

……

13) As a general rule, the higher the Gross National Product of a country, the higher its per capita energy consumption. [_____]

……

……

14) From the days of the Industrial Revolution up to 1960 the world's per capita energy consumption increased 10 times. [_____]

……

15) For estimating how long a certain energy source will last, it is necessary to estimate both the reserves and the consumptive demands on such reserves. [_____]

…….

16) Until the present time, nuclear fuels can be considered nonrenewable energy resources. [_____]

…….

…….

17) In the United States uranium is extracted from some resources with approximately 100% of its energy. [_____]

…….

…….

18) Hydroelectric power stations are restricted to some geographical areas because they depend on the availability of some fuel. [_____]

…….

…….

19) Petroleum was not used as an energy resource until the 19th century when it was first known. [_____]

…….

…….

20) Different rates are paid for every kilowatt hour which is consumed in the different use sectors. [_____]

…….

…….

EJERCICIO 6.1

Read the following extract. If the new words are not included in the glossary, look them up in a dictionary.

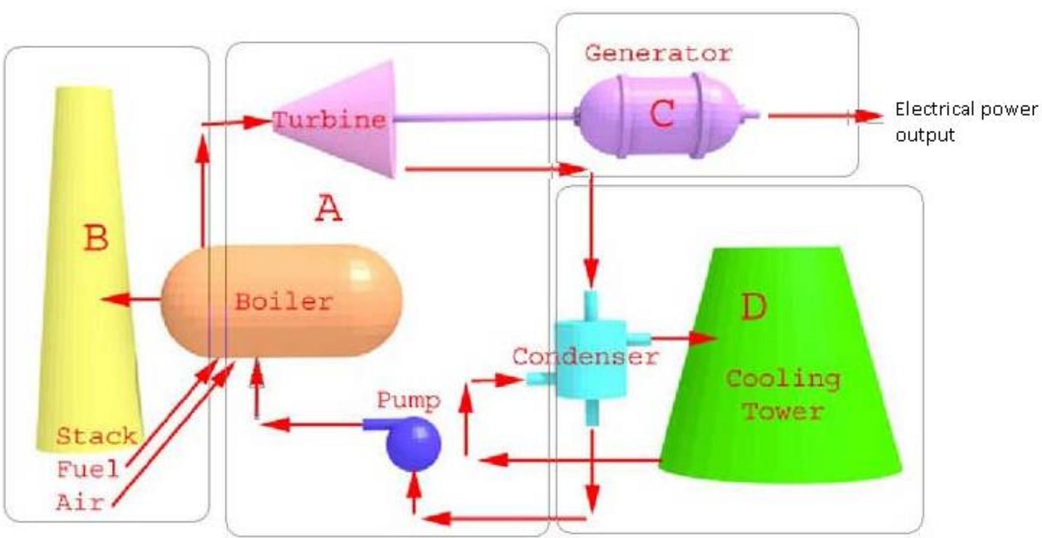
4.4 ENERGY CONVERSION SYSTEM ANALYSIS

4.4.1

Conventional Energy Conversion Systems

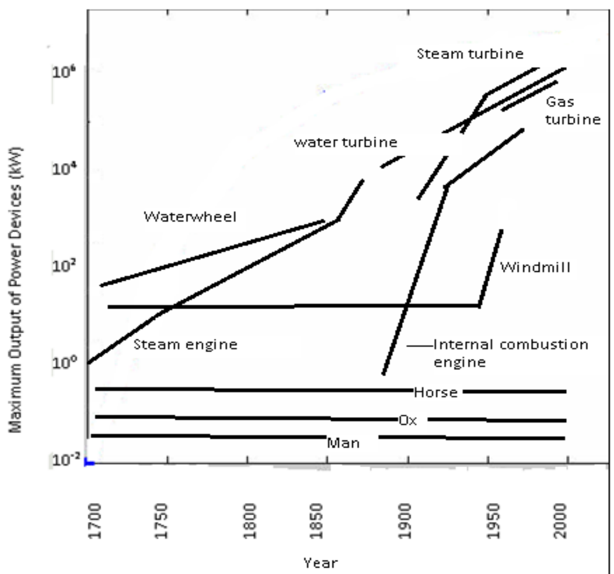
The type of systems that deliver practically all the world's energy needs are based on heat engine systems. Although particular components in such systems have changed with time, in this type of energy conversion system, thermal energy released by combustion or nuclear reaction is converted into mechanical energy by an appropriate heat engine. A schematic of a typical heat engine system, a Rankine cycle, is shown in Figure 4.6. In this system fossil fuel is burned in the combustor and energy is transferred in the form of heat to produce vapor (steam if water is the working fluid). The vapor then expands through a reciprocating engine or turbine to produce mechanical work. The work output can be used to drive a vehicle or, as shown, to produce electricity by driving an electrical generator. After passing through the expander, the heat is rejected as the working fluid passes through the condenser (a necessary condition imposed by the second law of thermodynamics). The fluid then passes through a circulating pump and is returned to the vapor generator to repeat the same power-producing cycle. It is important to point out two characteristics of these systems that can contribute to environmental problems (a subject to be discussed in greater detail in a later section). First it should be recognized that the exhaust products from the combustor may present a potential air pollution problem. Second, the heat rejected (which is a form of low-grade energy) may pose another potential harm to the environment, so-called thermal pollution).

Figure 4.6
Schematic of Rankine cycle



Historically, a system similar in design to that shown in Figure 4.6, using a reciprocating engine, provided the energy to drive the early power sources that became important during the Industrial Revolution. In practice reciprocating steam engines were used in large numbers as locomotive power sources until replaced by more compact and efficient diesel engines in the 1950s. For electrical generation applications, the reciprocating steam engine was replaced by large steam turbines in the early twentieth century. Replacement was due not only to economic and efficiency considerations but also to the ability to build larger power units. We again emphasize that engineers are continually aiming to increase the efficiency and power output of energy conversion machines while decreasing their costs. In Figure 4.7 one can see that the maximum power output of the steam engine and its successor, the steam turbine, has increased by more than 6 orders of magnitude from less than 1 kW to more than 1 million kW. For comparison, the maximum power output of other basic machines is also shown in this figure. It is interesting to note that all these machines are surpassed in power output by the largest liquid fuel rockets, which can deliver more than 16 million kW of power for brief periods.

Figure 4.7
Power output of basic machines

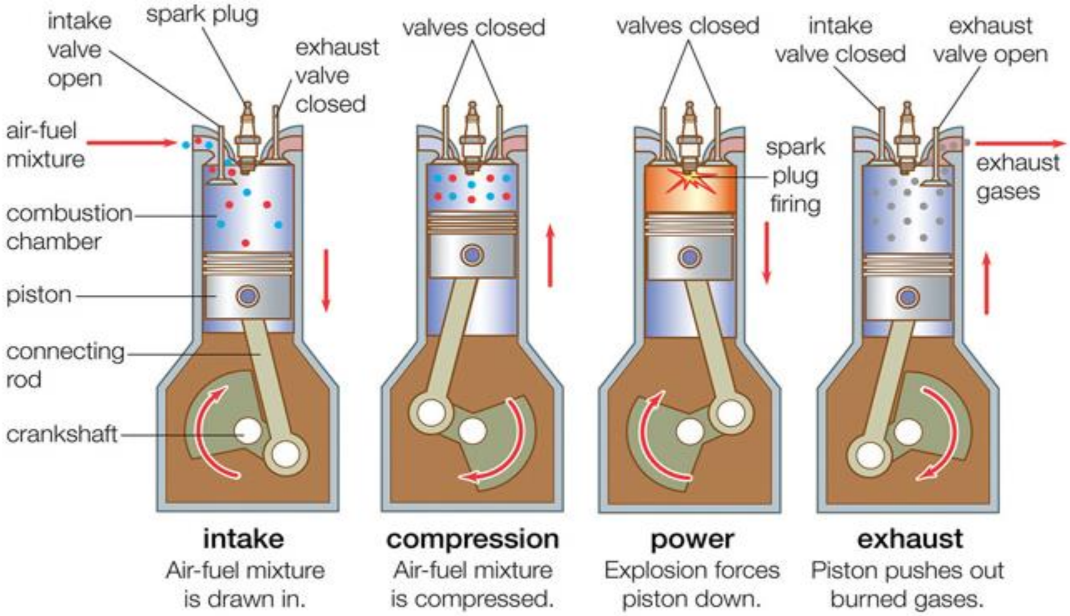


In general, three types of thermodynamic power cycles account for the vast majority of power produced from heat engine systems. These include the previously mentioned Rankine cycle used in large steam-electric generating stations, the reciprocating internal combustion engine in vehicles, and the gas turbine in aircraft or peak power electric generating plants. The use of these cycles will continue to grow, even as more nuclear power plants are built in the future. (In nuclear power plants the fission of uranium releases energy, which is used to make steam, which then goes through the same cycle as in a fossil fuel power plant.)

A number of energy conversion systems are in use in transportation. We shall now briefly describe two major types: the internal combustion engine and the gas turbine. Figure 4.8 shows a schematic of a spark ignition internal combustion engine cycle. This cycle is usually referred to as the Otto cycle after Nikolaus Otto, who first built this four-stroke engine in 1876. The cycle begins when the intake valve opens and a mixture of fuel and air enters the cylinder during the intake stroke. The intake valve closes when the piston reaches the bottom of the stroke, and as the piston moves upward, the mixture is compressed. As the piston nears the top of the cylinder, a spark plug ignites the fuel-air mixture. The thermal energy from the combustion of the fuel-air mixture forces the piston down, and the rotating crankshaft does work. After the piston reaches the bottom of its travel, the exhaust valve opens, and the piston again moves upward, displacing the gases from the cylinder. At the top of the cylinder, the exhaust valve closes, the intake opens, and the cycle repeats. During the cycle, the chemical energy of the fuel is converted to thermal energy during combustion. This thermal energy is converted to useful work by the piston. Most of the thermal energy is lost from the cylinder when the exhaust valve opens. Typically, only 25% of the chemical energy available in the fuel-air mixture ever produces useful work.

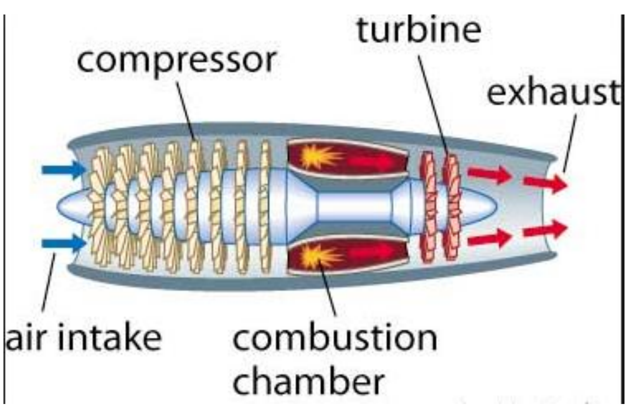
Figure 4.8

Combustion in an automobile engine.
(One cylinder of a typical automobile engine shown)



A schematic of a gas turbine is shown in Figure 4.9. Gas turbines develop their power by expanding a high-pressure high-temperature gas as in an Otto cycle. Air enters the engine from the left and is compressed in a rotating compressor. Air leaving the compressor at a high pressure and temperature has fuel injected into it in the combustion chamber. The fuel burns, and the high-energy gases expand through a rotating turbine, which is used to provide power for the compressor. The gases then further expand in the nozzle to a high exit velocity leaving the engine. The change in momentum of the gases passing through the engine produces net thrust, which is used to propel the aircraft. In a shaft power machine, instead of expanding in a nozzle, the gases are further expanded in another turbine, producing rotary or shaft output power.

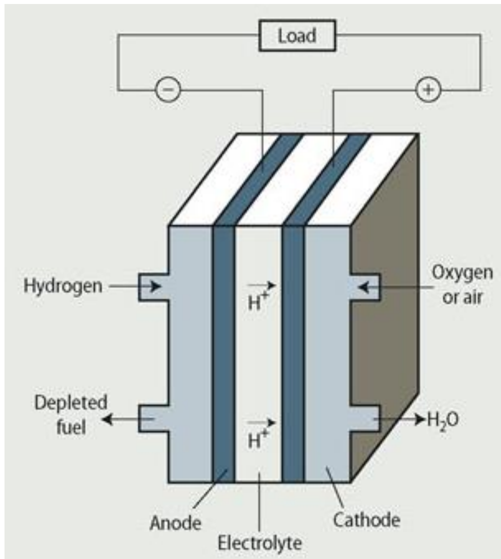
Figure 4.9
Schematic of a gas turbine engine



4.4.2 Unconventional Energy Conversion Systems

One reason for the present interest in direct or unconventional energy conversion systems is the potential they offer for higher-energy conversion efficiencies –thus reducing waste energy. Also, many times particular configurations of these systems have been developed as the only possible energy-producing device available for a particular job. For example, the Apollo space mission’s power requirements were uniquely suited for fuel cell applications. In the next few paragraphs we shall confine our brief discussion to three direct energy conversion systems that have received much notice: fuel cells, magnetohydrodynamic (MHD) generators, and thermionic energy converters.

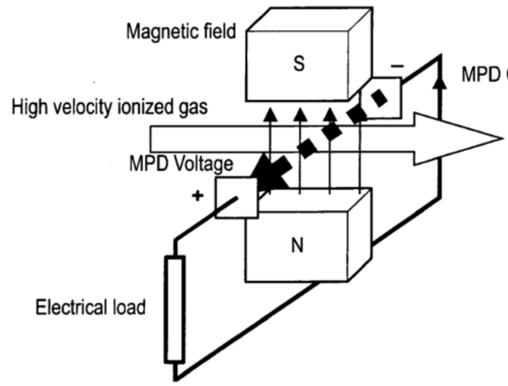
Figure 4.10
Basic Fuel Cell



A fuel cell is a direct energy conversion device that continuously converts chemical energy into electrical energy. A schematic of a typical fuel cell is shown in Figure 4.10. This device converts the energy in hydrogen or other fuels directly into electricity by a chemical reaction (of the same form as a combustion reaction) inside porous electrodes. The oxidizer is usually oxygen. However, current research is directed toward the development of fuel cells that use hydrocarbon fuels and air. Fuel cells are especially attractive since they are not theoretically limited to lower conversion efficiencies like heat engines and could conceivably have efficiencies as high as 90%, although today their actual efficiencies range between 50 and 60%. Recently, engineers have proposed the use of fuel cells for central power generation; however, the economic and technological problems to be overcome for this type of application appear formidable. As an interesting side note, in many ways the human body itself is a fuel cell system: food in blood, which is an electrolyte, is oxidized catalytically by enzymes to produce energy, part of which is electrical.

In MHD energy conversion systems, thermal energy is directly converted to electrical energy by using the scientific principle that a liquid metal or ionized gas will generate electric power when flowing through a magnetic field. Like the fuel cell, the MHD converter is an especially attractive system since it has no moving parts. In its simplest form, the MHD flow channel has electrical insulators on two opposite walls and power-removing conductors or electrodes on the other two walls (see Figure 4.11). The testing and development of MHD energy converters have been mainly confined to the laboratory with the exception of some fairly large power generation installations in Russia and Japan. Several U.S. power companies have funded design work for a peak-load MHD electrical generating station. The extreme temperatures required for efficient operation of MHD systems cause severe materials problems as well as some unique air pollution problems. If MHD technology can be developed, it should be possible to build fossil fuel power plants with efficiencies of 45 to 50% or higher if combined with conventional Rankine cycle systems.

Figure 4.11
MHD Generator



Analogous to heat engine systems, the thermionic generator uses electrons as a working fluid instead of a vapor or gas. Electrons are driven by thermal energy across a voltage difference to produce electrical energy. In the thermionic generator, electrons are first evaporated from a heated cathode and are then condensed or collected on a cooler anode. These electrons flow through an external circuit back to the cathode. Thus, in a thermionic generator, thermal energy is converted directly into electricity through a process similar to that in a steam power plant where water is evaporated in a boiler and then condensed after doing useful work in an engine.

As with many of our so-called new energy conversion systems, the thermionic energy converter represents a new approach to an old discovery. It was Thomas Edison who first observed an electric current between an incandescent filament and a cold electrode in an evacuated tube, but not until recently has there been active development of thermionic generators. With the discovery of materials that provide adequate electron emission rates without melting and by the addition of vapors to reduce the space charge effects, the performance of these systems have been greatly improved. Such systems have been designed for space power applications where high-temperature operation is advantageous. In addition, thermionic generators are well suited for use with nuclear reactors or radioisotope heat sources.

4.5 ENVIRONMENTAL ASPECTS OF ENERGY CONVERSION SYSTEMS

It is possible for energy conversion systems to impose health or safety hazards. The problems of environmental health should be faced today since they will require much more attention as space, air, water, and energy demands increase with the world's population and economic growth.

Whenever man uses energy, he pollutes his environment in some form. The severity of the problem is related to the type of pollution involved, the location of the pollution, and the quality of pollutants emitted. Our increasing environmental burden is related to energy utilization in each of the following three ways, and we must address ourselves to each of them in order to alleviate the problem:

1. The extent of energy use is increasing.
2. The location of the energy use and its related pollution is critical.
3. The pollution per unit of energy used must be considered.

We have previously discussed the first point. Basically, this increase in energy consumption is due to two factors. First, the standard of living is increasing and this requires more energy consumption by increased industrialization. The second factor is that, in addition to increasing our standard of living, we are also increasing our population. A significant point when looking at both these factors is that, in most of the world, the total increase in energy use is much greater than just the population increase. For example, in the 10-year period from 1958 to 1968 in the United States, total energy consumption increased by 50.5%, while the population increased by only 15.5%.

Also, along with increasing consumption, the type of energy needs can have important effects on the environment. In the United States in 1970, household and commercial energy consumption amounted to 22% of the total; industrial consumption was 30%, transportation was 24%, and electrical power generation was 24%. Although all the energy modes will increase in the future, Figure 4.4 shows that electrical power is growing at the fastest rate. As we have already seen, less than half of the energy that is consumed for electrical power generation ever finds its way into doing useful work. This shift to electrical energy consumption will have profound impact on the energy use and environmental pollution of the country.

This leads to an example of the second point to be considered –the location of the environmental pollution source. Under the provisions of the Clean Air Act of 1970 the Environmental Protection Agency has set national air quality standards for air pollution. Under these standards the atmospheric concentrations of various air pollutants will be limited to a level that is not hazardous to human health. With uniform standards throughout the United States it is safe to assume that those locations having the largest energy use will have the highest concentrations of pollution. It is these areas in which the most restrictive controls must be imposed. The location of pollution is as significant as the amount of pollution produced. Most energy utilization occurs near man, and consequently most pollution occurs near man. The greater the population density, the greater the energy utilization. Man has congregated himself in sprawling urban environments with the consequence that his own welfare is threatened. In these urban centers we find man's use of transportation increasing as he moves from his home to his work.

All energy utilization does not have to be near man. This is especially true of electrical power generation. In the past the economics of electricity distribution has dictated locating power plants near the areas where the power is to be used. This concept is changing. The Four Corners Power Plant in the southwestern United States was located far from the population centers it was built to serve. Efficient power transmission lines are used to transport the energy to the marketplace. The impact of the National Air Quality Standards Act may also severely limit other energy utilization in urban areas. Transportation use in the urban areas may have to be restricted in order to meet the standards. It is possible to foresee a time in urban areas when most energy used will be from electrical power that is generated far from the urban center. This may not be as efficient an energy use as it is today, but would produce reduced local environmental consequences.

The third point is that the pollution that is produced per unit of energy use must be reduced also. At the present time, as can be seen in Figure 4.3, fossil fuel combustion accounts for over 95% of our energy resource. Combustion produces air pollution, and with most of the combustion involved in heat engine applications thermal pollution can be significant. Combustion processes must be cleaned up to reduce pollution. The air pollution potential of the combustion will be discussed in Section 4.5.1. Following that thermal pollution will be discussed.

4.4.1 Air Pollution

Energy utilization produces most of the air pollution in this country. Table 4.5 gives the air pollution burden for the United States for 1969. Three subject areas –transportation, stationary sources, and industrial processes– are the primary energy utilization sectors of society. Seventy-five percent of the pollutants formed are a result of energy utilization.

Transportation with its total reliance on fossil fuel consumption is the largest single contributor to atmospheric emissions. It contributes about 51% of the total tonnage emitted annually. Following transportation are stationary sources with 16% of the total emissions and then industrial processes with 12%. It is quite evident from looking at these figures that sources should be controlled based on the tonnage emission rates.

Table 4.5
1969 Estimated Nationwide Emissions
United States (millions of tons/year)

Source	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation	1.1	.8	111.5	19.8	11.2
Fuel combustion in stationary sources	24.4	7.2	1.8	.9	10.0
Industrial processes	7.5	14.4	12.0	5.5	.2
Solid waste disposal	.2	1.4	7.9	2.0	.4
Miscellaneous	.2	11.4	18.2	9.2	2.0
Total	33.4	35.2	151.4	37.4	23.8

We can get some insight into the emissions problem if we consider the combustion process itself. In normal combustion processes, oxidation is the primary reaction. In many reactions, however, intermediate products are produced, some of which remain when the combustion process is complete. Theoretically, combustion reactions should go to completion perfectly. In practice this seldom occurs because of incomplete mixing, high-temperature chemical equilibrium, improper fuel-air ratio, or flame quenching. The net result is that intermediate products and/or incomplete combustion products are formed in most combustion reactions. This process is schematically illustrated in Figure 4.12.

Figure 4.12
Fuel combustion process

Hydrocarbon fuel + Air $\longrightarrow$ Combustion $\longrightarrow$ Products of combustion

$$C_xH_7 + O_2 + N_2 \longrightarrow CO_2 + H_2O + n_2 + O_2 + N_2$$
$$+ CO + NO + NO_7 + C_AH_A + C_nH_n + \ldots$$
(pollutants)

Combustion reactions are usually categorized as being either premixed or unmixed, depending on whether the fuel and air are mixed before or during the combustion process. Most energy conversion devices utilizing combustion are unmixed, and therefore mixing plays a very important role in the extent of the completion of the reaction. For example, in the combustion of coal as in a power plant, the fuel is solid and reacts with oxygen in the air as mixing makes it available. Equilibrium considerations then enter the picture because as carbon is oxidized the product is initially carbon monoxide rather than carbon dioxide. Later, further oxygen, if available, completes the reaction of carbon monoxide to carbon dioxide. These reactions are strongly temperature-dependent and the rate of the reaction also depends on other chemical species present. It should be pointed out that even in complete combustion reactions some carbon monoxide remains in the products.

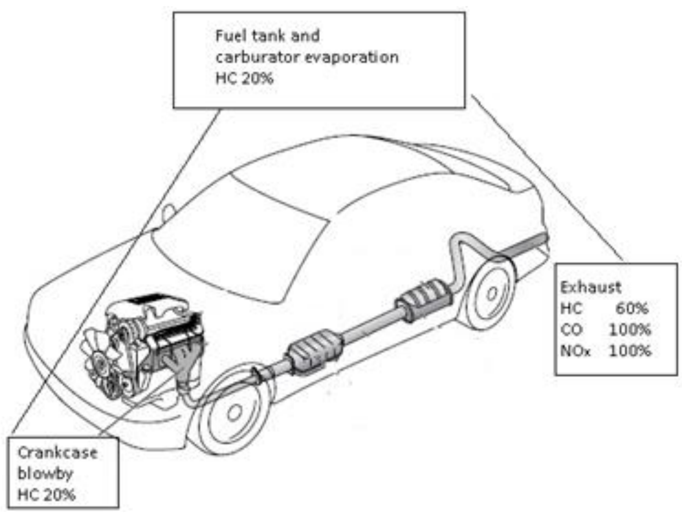
Other chemicals present in fossil fuels can also present problems. For example, sulfur present in the input fuel converts to about 98% SO_2 and 2% SO_3 during normal combustion. In gaseous form, these are ready to combine with water vapor in the exhaust gas or outside atmosphere to form acids. In fuel oils most of these sulfur oxides leave the stack, whereas in coal combustion a large percentage of the sulfur remains in the ash. Most of the particulates obtained from coal combustion are from the minerals present in the parent coal. Presently, both solid particulates and sulfur oxides can be removed from the exhaust gas with varying degrees of success.

Nitrogen oxides (NO, NO_2) form under conditions that we usually think of as perfect combustion, that is, complete mixing, high gas temperatures, and adequate excess air. NO_2 does not exist at these conditions, but combustion gas equilibrium at high temperatures with excess air forces the formation of NO. As the gas temperature increases, the concentration of NO increases. Power-plant furnaces are designed for high temperatures, and, under these conditions, the NO concentrations may be as high as 1000ppm. After the NO leaves the stack, atmospheric air and lower temperatures convert the NO to NO_2.

As you might have observed from this discussion, poor combustion produces excessive carbon monoxide, whereas good combustion produces nitrogen oxides. Finally, the sulfur in the fuel produces sulfur oxides. Current research in combustion processes is directed at reducing all three of these air pollutants simultaneously.

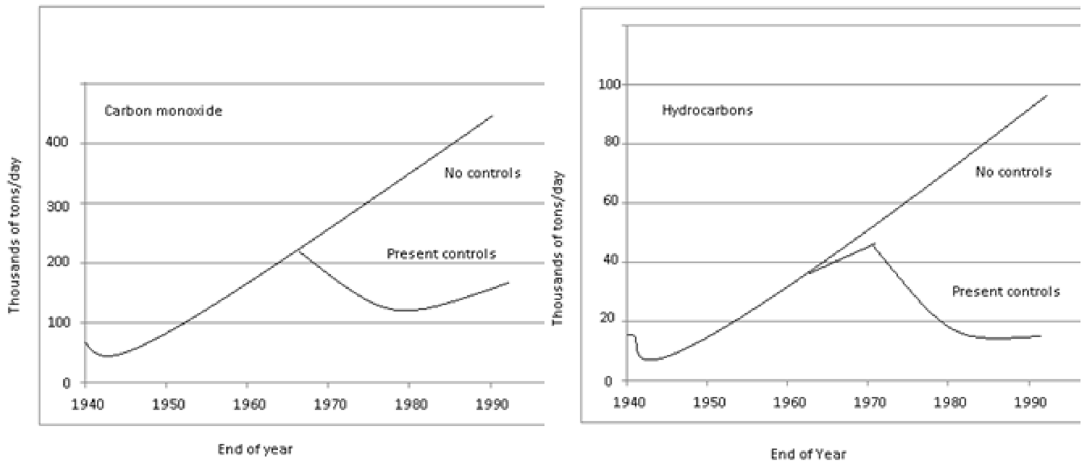
Although autos do no give the appearance of being as serious a polluter as power plants, their contribution to the air pollution problem is significant. The source of pollutants in cars is not completely from combustion of the fuels. In Figure 4.13 is shown the precontrol inventory of automotive emissions. In addition to the exhaust, fuel evaporation and crank case blowby have contributed to the hydrocarbon emissions. We should point out that the combustion process in internal combustion engines is different from the power-plant or space-heating furnace. Internal combustion engines are perhaps better characterized as intermittent combustion engines. A fuel-air mixture is produced and distributed usually nonuniformly to the cylinders of the engine. In the cylinder after compression the mixture is ignited and combustion proceeds. With changes in load produced by acceleration and deceleration the fuel-air ratio changes and less than ideal conditions are found in the engine for combustion. The walls of the combustion chamber quench the combustion reaction, and unburned or partially burned hydrocarbons appear in the exhaust.

Figure 4.13
Automobile emission inventory
(prior to 1981)



The internal combustion engine exhaust produces carbon monoxide, hydrocarbons, nitrogen oxides, and some particulates. One difficulty is that different modes of operation produce different emissions. Carbon monoxide is produced throughout the driving cycle, but oxides and/or nitrogen are generally produced during high power and acceleration conditions. Hydrocarbons are dominant during deceleration conditions or when the ignition system is malfunctioning. This type of characteristic makes the problem more difficult to correct. Since 1960 engine controls have been required by law to reduce emissions. Current legislation is directed at reducing emissions level for cars to one-tenth the level produced by cars in 1970. The impact of this legislation can be seen in Figure 4.14. With present controls, the emissions would reach a minimum in the early 1980s and would then increase again because of a predicted increase in the number of vehicles. With the 1976 controls this minimum would be lower and would occur about 1990, after which it could be expected to increase again.

Figure 4.14
Impact on automobile emission control



Diesel exhausts present similar problems except that the emissions are not so high. A more esthetic problem exists with diesel smoke and odor. Controls are also in progress here and some degree of control is being obtained. In the case of aircraft, the emissions problem is related to the location of the source –the airport– as well as the strength of the source. In combustion modification on jet aircraft, the smoke problem has been sharply reduced. Emissions from other stationary sources and industrial processes are strongly dependent on the type of process that is involved. Reduction of emissions from these processes necessitates an inventory of emissions based on ambient sampling and a careful analysis of the process in order to affect a degree of control.

The second law of thermodynamics limits the amount of energy that can be obtained from conventional electrical generating power plants based on the Rankine cycle. Thus, the problem of thermal pollution arises when we burn chemical or nuclear fuel and convert, on the average, one-third of the fuel energy into electric power and return two-thirds to a cooling source (such as a stream or a river). As society has expanded its production of electric power and increased its discharge of heated water into the aquatic environment, severe ecological problems have sometimes shown up. We should remember that the term thermal pollution applies only to situations where heated water conditions adversely affect the quality of water and aquatic life. In some situations, the addition of heat to water can have beneficial effects. For example, rejected power-plant heat has been used to grow oysters in Long Island Sound.

4.4.2 Thermal Pollution

The water temperature is a major consideration in determining the use of water. It plays a key role in the ability of the ecological system to maintain desirable characteristics throughout all biological stages. In addition to the direct lethal effects that temperature increases may have on biological systems, there may be effects on other potential water users, such as industries or municipalities. For example, higher temperatures lower the capacity of the water to hold oxygen and increase sedimentation (settling) rates. Chemical composition and acidity of the water may also change. In many ways, discharges of heated water are equivalent to placing organic wastes in a stream; that is, the absorbing capacity of a stream is reduced. It is beyond the scope of our brief discussion here to go into all ecological effects of thermal pollution; however, we must be aware that many scientists are presently engaged in research in this area.

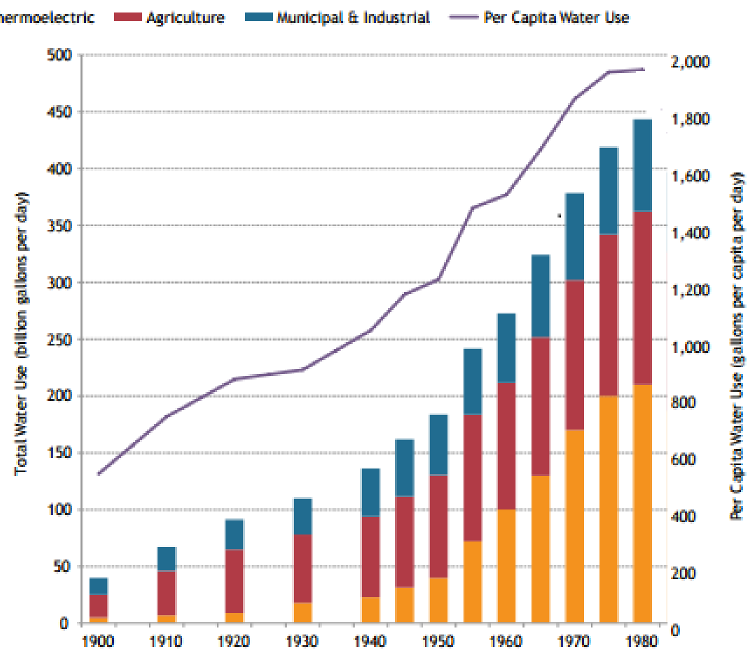


Figure 4.15
Water uses in U.S.

The major users of water include farmers (irrigation), municipal governments (sewage treatment), industrial organizations, and electric power plants (see Figure 4.15). Electric power production accounts for more than four-fifths of the total cooling water use and for about one-third of the total water use. In general the problems associated with cooling water discharges from electrical generating power plants far exceed the problems from industrial sources. It is estimated that by 1980, primarily because of increased power demands, the power industry will use one-fifth of the total freshwater runoff of the United States for cooling. Also, the increase in size of individual plants and the lower efficiency of present nuclear power plants have made a large difference in the intensity of the problem. (For example, the maximum size of steam-electric power plants has risen from about 200 to over 1,000 MW in the last 15 years.) Even though the total amount of heat rejected to the environment may not increase when a single plant replaces two or more, the ecological impact is much greater locally.

At the present time, technological solutions to thermal pollution problems have not kept pace with the increased production of power. The solutions of which most people are aware fit into the following six categories:

1. Methods to minimize the effect of waste heat on the environment.
2. Means to reduce waste heat in conventional power plant.
3. Uses for waste heat.
4. Shifting the path of heat rejection directly to the atmosphere.
5. New, nonpolluting methods of power generation.
6. Less consumer use of electricity.

The possibilities opened up by this list are boundless, and it should be noted that many engineers are engaged in various phases of all categories. Another key point to be made in concluding this section is that we cannot continue to double the generation of electricity every 10 years or so without taking into account the possible worldwide climate changes caused by heat rejection. Presently, we are probably safe since the solar energy input to earth is about 200,000 times greater than the worldwide energy conversion for electric power. However, as we have pointed out, local concentrations of reject heat can become significant.

4.4.2 SUMMARY

In this chapter we have shown that demands will be placed on our energy supplies by increasing population and industrialization of all the countries of the world. The governing laws (conservation of mass and the first and second laws of thermodynamics) that engineers use to analyze energy conversion systems were introduced. Environmental consequences of energy conversion were discussed, and it was pointed out that these problems are influenced by the increasing use of energy, the location of the energy use, and the pollution per unit of energy for the specific energy conversion process.

EXERCISES

1. In recent years, to stimulate the U.S. economy, economic measures have been enacted that will stimulate the sales of new U.S. automobiles. Your problem is to determine the amount of energy required to produce an average-sized U.S. automobile. You may express the energy required in consistent natural resource units such as tons of coal and barrels of oil. Be sure to state all your references and assumptions as you develop the problem solution.

2. The following list of projected technological breakthroughs during the next 25 years was published in the July 1970 of *Power*. Using available literature (be sure to cite your references), write a brief description (not more than 1,000 words) of any two subjects on the list.
   1970 – Economic atomic power generation
   1971 – Activated carbon absorption for water pollution control
   1972 – Inexpensive soundproofing materials
   1973 – Inexpensive sulfur removal from flue gases
   1974 – Inexpensive reuse of water from municipal and industrial discharges
   1975 – External combustion engines for automobiles
   Nonpolluting automotive emissions
   Cheap catalyst preventing release of noxious gases into atmosphere
   Molten-salt absorption for air pollution control
   Inexpensive water desalting
   General use of cryogenics methods
   Inexpensive method for extracting oil for oil shale
   1976 – Inexpensive method for extracting sulfur from coal
   Manned permanent sea-bottom station
   1977 – Scientific methods for removing solid waste from cities
   Fuel cells for utilities
   1978 – Selective chromatic recovery for industrial air pollution control
   New alloys –stronger, lighter, and more corrosion-resistant
   Petroleum-based fuel cell
   1979 – Widespread use of underground cables, except for HVC cross-country
   1980 – Permanent lunar base
   Electric car and gas-turbine-powered car
   Compact total-energy plant for the home
   Steam turbine-generators of 2,000-MW capacity
   1983 – Controlled thermonuclear power
   1985 – Commercial application of fast-breeder reactors
   1988 – Electrogasdynamics applications
   1989 – Cryogenic electric cables in and out of cities
   1990 – Magnetohydrodynamics applications
   1995 – Earth-weather control
   Commercial application of fusion reactor

3. During the past year there has been considerable interest in the problem of recycling waste materials, such as glass. Your problem is to determine the relative merits, on an energy basis, of glass recycling. Therefore, for a representative sample, say a quart bottle, compare the energy required to manufacture the bottle with the energy required to recycle the bottle or the energy required to reuse the bottle. Be sure to state all your assumptions and sources of data in your problem solution.

4. You, as a university student, have been asked to participate in the environmental cleanup program. As your first contribution, you are asked to calculate the amount (by weight) of sulfur dioxide (SO_2) given off as a result of your use of energy on the campus. For purposes of calculation you assume that your share of energy is supplied by the burning of coal (from the university power plant and outside electrical companies) divided by the total number of students. Using sound scientific principles, calculate the number of pounds of SO_2 that you are responsible for during the first semester here.

5. An interesting alternative to the problem of thermal pollution is the use of systems that use low-grade energy. For example, one might propose the use of such energy to grow aquacultural or agricultural crops. Your problem is to define (using a schematic drawing) a system that you might propose to use the reject heat from a typical electrical power plant, with a 1-MW power output. Be sure to include a basic mass and energy balance in your analysis.

6. In the text the Four Corners Power Plant was mentioned as an example of an efficient energy conversion system. However, its construction and operation have not been free from controversy. Discuss some of the environmental burdens that it imposes.

7. Rest rooms are found to contain both paper towels and heaters for drying hands. Find an electric hand dryer, and determine the amount of energy required to dry hands during one cycle of operation. Compare this figure with your estimated energy requirement to produce the paper towels. Discuss which hand dryer should be used.

8. In examining Figure 4.1 it is seen that a correlation seems to exist between GNP and energy consumption per capita for nations of the world. However, if only the highly developed countries with a GNP around $1,500/capita are considered, it is seen that a wide range of energy consumption levels are found. Discuss some of the reasons for the variation observed.

9. Verify the statements given in the text pertaining to energy growth prediction; i.e., at a 3% annual increase in energy consumption 75*Q* will be consumed by 2050 and at 5% 275*Q* will be consumed.

The predicted coal reserves for the United States are presently (1968) 2 X 10^{11} tons. If energy consumption increases at a rate of 3%/yr. above the current level of 9 x 10^{15} Btu/yr., when will this coal be depleted? Coal has a heating value of 14,000 Btu/lb.

EXPRESIONES DE TIEMPO

EJERCICIO 6.2

The following sentences are extracted from the text in exercise 6.1. Find them in the text (the page where each sentence appears is provided), and fill in the blanks with the missing TIME RELATIONSHIPS expressions. Translate the resulting sentences.

1) _______________ passing through the expander, heat is rejected as the working fluid passes through the condenser. (pág. 19)

………..

………..

2) Reciprocating steam engines were used in large numbers as locomotive power sources _____________ replaced by more compact and efficient diesel engines in the 1950s. (pág. 19)

………..

………..

3) The cycle begins ______________ the intake valve opens and a mixture of fuel and air enters the cylinder during the intake stroke. (pág. 20)

………..

………..

4) The gases _______________ further expand in the nozzle to a high exit velocity. (pág. 21)

……

………

5) _______ the piston nears the top of the cylinder; a spark plug ignites the fuel-air mixture. (pág. 20)

……

………

EXPRESIONES DE CAUSA-EFECTO

EJERCICIO 7.1

Translate the following sentences which show examples of CAUSE AND EFFECT expressions:

1) Fuel cells are especially attractive <u>since</u> they are not theoretically limited to lower conversion efficiencies.

………..

………..

2) The electrons flow through an external circuit back to the cathode. <u>Thus</u>, in a thermionic generator, thermal energy is converted directly into electricity.

……

……

3) Basically, this increase in energy consumption is <u>due to</u> two factors.

……

……

4) Most energy utilization occurs near man, and <u>consequently</u> most pollution occurs near man.

……

……

5) In practice this seldom occurs <u>because of</u> incomplete mixing, high-temperature chemical equilibrium, improper fuel-air ratio, or flame quenching.

……

……

6) Most energy conversion devices utilizing combustion are unmixed, and <u>therefore</u> mixing plays a very important role in the extent of the completion of the reaction.

……

……

EXPRESIONES DE CONTRASTE U OPOSICIÓN

EJERCICIO 8.1

The following sentences are extracted from the text in exercise 6.1. Find them in the text (the page where each sentence appears is provided), and fill in the blanks with the missing CONTRAST AND OPPOSITION expressions. Translate the resulting sentences.

1) It was Thomas Edison who first observed an electric current between an incandescent filament and a cold electrode in an evacuated tube, _________ not until recently has there been active development of thermionic generators. (pág. 23)

……

……

……

2) ____________ particular components in such systems have changed with time, in this type of energy conversion system; thermal energy is converted into mechanical energy by an appropriate heat engine. (pág. 19)

………..

………..

3) In a shaft power machine, _______________ expanding in a nozzle, the gases are further expanded in another turbine, producing rotary or shaft output power. (pág. 21).

………..

………..

4) The oxidizer is usually oxygen. ______________, current research is directed toward the development of fuel cells that use hydrocarbon fuels and air. (pág. 22)

………..

………..

5) Recently, engineers have proposed the use of fuel cells for central power generation; _____________, the economic and technological problems to be overcome for this type of application appear formidable. (pág. 22)

………..

………..

………..

6) Poor combustion produces excessive carbon monoxide, __________ good combustion produces nitrogen oxides. (pág. 26).

………..

………..

7) _____________ autos do no give the appearance of being as serious a polluter as power plants; their contribution to the air pollution problem is significant. (pág. 26)

………..

………..

8) _____________ the total amount of heat rejected to the environment may not increase when a single plant replaces two or more, the ecological impact is much greater locally. (pág. 28)

………..

………..

EXPRESIONES DE EJEMPLIFICACIÓN, CONTINUIDAD, SIMILITUD

EJERCICIO 9.1

Translate the following sentences and notice the relationships expressed by the words written in *italics* and their similarities with the other words given in each group. Underline the corresponding Spanish words.

<u>*Showing examples*</u>

1) Many systems have been developed as the only possible energy-producing device available for a particular job. *For example,* the Apollo space mission's power requirements were uniquely suited for fuel cell applications.

………..

………..

………..

2) Three subject areas, *such as* transportation, stationary sources, and industrial processes, are the primary energy utilization sectors of society.

………..

………..

3) Mixing plays a very important role in the extent of the completion of the reaction. *For instance*, in the combustion of coal as in a power plant, the fuel is solid and reacts with oxygen in the air as mixing makes it available.

………..

………..

………..

4) Other chemicals present in fossil fuels can also present problems (e.g. sulfur).

………..

<u>*Showing the continuity of the same idea*</u>

5) In a ten-year period, the total energy consumption increased by 50.5% while the population increased by only 15.5%. *Furthermore*, along with increasing energy consumption, the type of energy needs can have important effects on the environment.

………..

………..

………..

6) Thermionic generators have been designed for space power applications. *Besides*, such systems are well suited for use with radioisotope heat sources.

……..

……..

7) The source of pollution in cars is not completely from combustion of the fuels. *In addition to* the exhaust, fuel evaporation and crank case blowby have contributed to the hydrocarbon emissions.

……..

……..

8) The exhaust products from the combustor may present a potential air pollution problem. *Moreover,* the heat rejected may pose another potential harm to the environment, so-called thermal pollution.

……..

……..

……..

Showing similarities

9) *Like* the fuel cell, the MHD converter is an especially attractive system since it has no moving parts.

……..

……..

10) *As* with many of our so-called new energy conversion systems, the thermionic energy converter represents a new approach to an old discovery.

……..

……..

11) Thermal energy is converted directly into electricity *just as* in a steam power plant water is evaporated in a boiler and then condensed after doing useful work in an engine.

……..

……..

12) Does the manufacture of a quart bottle require *the same* amount of energy *as* the recycling of the bottle?

……..

……..

PALABRAS INTERROGATIVAS

EJERCICIO 10.1

Fill in the blanks with the corresponding QUESTION WORDS (in English) according to the answers given after each question. Then, translate the questions.

1) ________________ first observed an electric current between an incandescent filament and a cold electrode in an evacuated tube?

………

………

Thomas A. Edison

2) ________________ device is used to ignite the fuel-air mixture in a four-stroke engine?

………

A spark plug

3) ________________ is energy produced from food in blood?

………

Food in blood is oxidized catalytically by enzymes to produce energy.

4) ________________ were reciprocating steam engines replaced as locomotive power sources by more compact and efficient diesel engines?

………

………

In the 1950s.

5) ________________ of those crankshafts is heavier?

………

The crankshaft that you see at your right.

6) ________________ spark plugs are those?

………

They are Richard’s spark plugs.

7) ________________ can I leave this connecting rod?

……

On that table, please.

8) ________________ did it take to replace that compressor?

……

It took about 8 hours.

9) ________________ does the valve close when the piston reaches the bottom of the stroke?

……

Because the mixture must be compressed in the next stroke.

10) ________________ types of direct energy conversion systems do you know?

……

Only three types

EJERCICIO 10.2 (Home assignment)
Answer (in Spanish) the following questions about the text on Exercise 6.1. Also write down the page and the paragraph from which you obtained the information.

1) **Who** are continually aiming to increase the efficiency and power output of energy conversion devices?

……

……

2) **Why** are fuel cells especially attractive?

……

……

3) **Where** is the heat rejected in a typical heat engine system?

……

……

4) **Which** of the three direct energy conversion systems mentioned is very appropriate for space power applications where high-temperature operation is advantageous?

………

………

5) **How much** did the total U.S. energy consumption increase from 1958 to 1968?

………

………

6) **When** was the first manned permanent sea-bottom station supposed to be settled?

………

………

7) **How** do gas turbines develop their power?

………

………

8) **How many** types of thermodynamic power cycles account for the vast majority of power produced by heat engine systems?

………

………

9) **When** do car engines produce oxides and nitrogen in the exhaust?

………

………

10) **What** direct energy conversion system was chosen by several American power companies to design a peak-load power station?

………

………

EJERCICIO 10.3
Describe the Otto cycle (in Spanish). Also make and label (in Spanish) the necessary drawings to reinforce your description.

EJERCICIO 10.4
Explain how the gas turbine works (in Spanish). Also make and label (in Spanish) a schematic of a gas turbine

CAUSE + INFIVITIVO

EJERCICIO 11.1
Choose "True" or "False" according to the text from exercise 6.1 (write down the page, paragraph and line from which you obtained the information) and translate. Underline the forms in Spanish which correspond to the "CAUSE + INFINITIVE" forms used in English.

1) [_____] The future of electrical generation increase **may cause** the worldwide climate **to change** because of heat rejection.

Page………. Paragraph………. Line……….

……

……

2) [_____] The discharge of heated water always **causes** the aquatic environment **to affect** the quality of water and aquatic life.

Page………. Paragraph………. Line……….

……

……

3) [_____] Further oxygen **causes** the carbon monoxide **to become** carbon dioxide as mixing makes it available.

Page………. Paragraph………. Line……….

……

……

4) [_____] We saw that in the four-stroke engine the ignition of the fuel-air mixture **caused** the piston **to move down** as the intake valve opened.

Page………. Paragraph………. Line……….

……

……

5) [_____] In the thermionic generator thermal energy **causes** electrons **to flow** across the voltage difference to produce electrical energy.

Page………. Paragraph………. Line……….

……

……

EJERCICIO 11.2

Choose “True” or “False” according to the text from exercise 6.1 (write down the page, paragraph and line from which you obtained the information) and translate. Translate the sentences that are TRUE and justify the FALSE ones

1) The greater the population density, the greater the energy utilization.

[_____] Page………. Paragraph………. Line……….

……..

……..

2) Sulfur present in fossil fuels becomes gaseous after combustion and combines with water vapor to form acids.

[_____] Page………. Paragraph………. Line……….

……..

……..

3) The increase in the world energy use is growing at about the same rate as the population grows.

[_____] Page………. Paragraph………. Line……….

……..

……..

4) Transportation is the most important contributor to atmospheric emissions and it entirely relies on fossil fuels.

[_____] Page………. Paragraph………. Line……….

……..

……..

5) Although automobiles do not give the appearance of being as serious a polluter as power plants, with the present controls their emission level is expected to increase in the U.S. after 1990.

[_____] Page………. Paragraph………. Line……….

……..

……..

6) When the combustion process takes place with a complete mixing, high gas temperatures, and the proper excess air, nitrogen oxides (NO, NO_2) form in the stack.

[_____] Page………. Paragraph………. Line……….

…….

…….

7) Electrical power generation accounts for over 80% of the total cooling water use.

[_____] Page………. Paragraph………. Line……….

…….

8) Oxidation is the primary reaction in any normal combustion process and some intermediate products are also produced which last as long as the process continues.

[_____] Page………. Paragraph………. Line……….

…….

…….

9) The Four Corners Power Plant in the southwestern United States is an example of the economics of electricity distribution which dictates the convenience of locating power plants close to the consumption areas.

[_____] Page………. Paragraph………. Line……….

…….

…….

………

USOS DE PRONOMBRES "THAT" y "THOSE"

EJERCICIO 12.1

Fill in the blanks with the pronouns "THAT" or "THOSE" as required and write (within parentheses) the word/s in English substituted by those pronouns. Next, translate the sentences and underline the words in Spanish which correspond to "THAT" or "THOSE".

1) Efficiencies of present nuclear power plants are lower than ______________ of other power plants.

[_______________________________________]

…….

…….

2) The following list of projected technological breakthroughs is similar to _______________ given in the first chapter.
[____]

………

………

3) The capacity of low-temperature water to hold oxygen is not the same as _______________ of high--temperature water.

[____]

………

………

4) When fuel-air ratios are far from _______________ considered as ideal, unburned or partially unburned hydrocarbons appear in the exhaust.

[____]

………

………

………

5) It was pointed out that the combustion process in internal combustion engines is different from _______________ of a space-heating furnace.

[____]

………

………

………

VOZ PASIVA + INFINITIVO

EJERCICIO 13.1

Translate the sentences below written in the "PASSIVE VOICE" being very careful to give the equivalent forms most commonly used in Spanish.

1) He **was allowed to fly** that jet aircraft.

………..

2) **Were** you **asked to participate** in the environment cleanup program?

………..

3) It **is said to have** a slow sedimentation rate.

………..

4) You **are supposed to know** the current legislation which is directed at reducing the emission levels for cars.

………..

………..

5) Rest rooms **are found to contain** both paper towels and heaters for drying hands.

………..

LOS TIEMPOS PERFECTOS (presente, paasado y future)

EJERCICIO 14.1

Translate the following sentences and underline the different "PERFECT TENSES" forms in Spanish.

1) In combustion modification on jet aircraft, the smoke problem **has been** sharply **reduced**.

………..

………..

2) As society **has expanded** its production of electric power, severe ecological problems **have** sometimes **shown up**.

………..

………..

3) Somebody found that the chemical composition and acidity of the water **had changed**.

………..

………..

4) Rejected power plant heat **has been used** to grow oysters in Long Island Sound.

……

5) No one **had told** us that the increase in size of individual plants **had made** a large difference in the intensity of the problem.

……

……

6) There **has not been** much research on methods to minimize the effect of waste heat on the environment.

……

……

7) We **shall have finished** our report by the time he brings the available data on cryogenic electric cables.

……

……

8) **Had** she **verified** the statements given in the text pertaining to energy growth prediction?

……

……

9) **Have** you ever **thought** that sooner or later coal reserves will be depleted?

……

……

10) However, by the end of this century the controversy about its construction and operation **will have ended**.

……

……

EJERCICIO 15.1

Read the following extract. If the new words are not included in the glossary, look them up in a dictionary.

12.3
CONSERVATION OF ENERGY AND THE FIRST AND SECOND LAWS OF THERMODYNAMICS

In many ways, the principles and techniques developed from a thorough understanding of thermodynamics are required in other different areas of chemical engineering –energy balances, stage operations. The science of thermodynamics originated almost simultaneously with the development of the steam engine –in fact the word *thermodynamics* means "heat in motion".

Almost all engineering disciplines use thermodynamics. Thermodynamics is a study of the application of three basic "laws". The first law is an energy balance and is a statement of the conservation of energy. The second law concerns availability of energy –a simple example arising from it is the well-known fact that heat will flow *spontaneously* from a high temperature region to a low temperature region. The third law states that at absolute zero temperature (about – 460°F) molecular motion ceases.

From the three laws of thermodynamics one can derive a host of useful ideas and concepts that will enable us to predict directions of chemical reactions, determine the feasibility of new processing routes, predict thermochemical data (e.g. heat capacities), and so forth. The ideas most pertinent to the purposes of this chapter are the energy balance (a use of the first law), the concept of an ideal power cycle (a use of the second law), and vapor-liquid equilibrium (a use of the second law).

The energy balance simply states that energy is neither created nor destroyed. This brief statement ignores the possibility of nuclear fission reactions in which matter is converted to energy. In order to apply the energy balance, *all* forms of energy must be accounted for and expressed in the same units (Btu's, foot pounds, etc.). Different types of energy that are commonly encountered include heat, work, potential energy, kinetic energy, and internal energy. An example of a less common form of energy would be surface energy.

The Law of Conservation of Energy may be generally written as shown in the following equation.

Rate of accumulation of internal, potential and kinetic energy in the system	=	Net rate of internal, potential and kinetic energy into the system	+
		Net rate of heat addition to system	-
		Net rate of work done by the system on surroundings	

This transport of energy is shown schematically in Figure 12.1.

This equation asserts there are three different types of energy that must be considered: internal energy, potential energy, and kinetic energy. The Law of Conservation of Energy also asserts an interchangeability between energy and work, that is, that work is a form of energy. Note that the last two terms in the equation (the heat being transferred to the system and the work being done by the system) are states of energy in *transition*. This energy cannot be accumulated by the system in this fashion, but rather must be stored as either internal energy, potential energy, or kinetic energy.

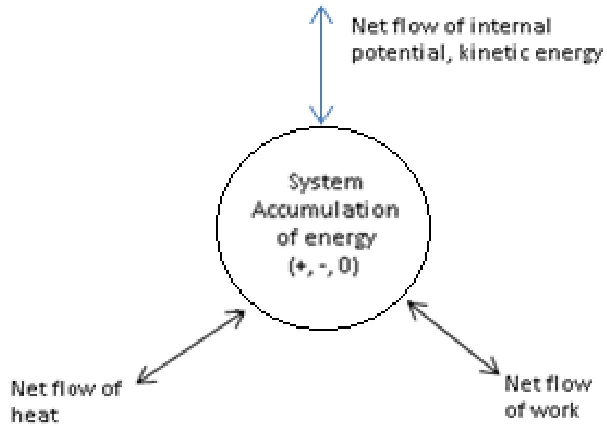


Figure 12.1
Balance of energy into and out of a system

Energy is a very essential factor in carrying out processes important to man, including chemical processing and environmental applications. The combustion process (e.g., burning coal) can transform fuel into light and heat. The heat can then be transferred to water, and this water can store energy at a higher internal energy level as steam. The stored energy from the fuel (steam) may be used to drive mechanical equipment (releasing energy as work) or **it** may be used to heat buildings through steam radiators (releasing energy as heat). The input of heat into a river would be stored as an increased temperature of the water; consequently, any fish in the river may be adversely affected by this stored energy (that is, by the higher temperature of the stream). If the combustion process is required to provide some specific amount of heat, this heat can be related to the amount of fuel that is required. Thus, the amount of pollutants that will be entering the atmosphere from this combustion process can be calculated and pollution control devices selected accordingly.

12.3.1
Internal Energy

Energy may be stored in a system in the form of internal energy. To understand how this energy is stored, we must recall that there are several sub-particles making up any substance; for example, a glass of water contains many individual water molecules and these water molecules in turn contain sub-particles (neutrons, protons, and electrons). The internal energy of this glass of water is determined in part by the movement of the sub-particles within the water. The molecular constituents are continually moving in translational motion, rotational motion, and vibrational motion. If the temperature of the water is increased, this component of the internal energy, represented by the movement of the molecules, increases. At high temperatures the molecular particles are moving much more rapidly than at low temperatures. Other forms of internal energy are also present. There are electrical and magnetic interactions between the sub-particles which contribute to this other component of internal energy. The total internal energy of a system is generally not known; however, for our purposes we can simply consider the internal energy of the substance relative to a reference state. For example, we can fully characterize the internal energy of the glass of water by defining **its** temperature, say 100°F, relative to some standard of reference temperature, let us say 0°F. Because of the internal energy term arising from the interaction of the molecules, we must also specify the state of the substance in the reference condition; for example, **it** may be water at 0° or solid crystalline ice at 0°.

12.3.2

Kinetic Energy

Another important form of energy (called kinetic energy) is **that** due to movement of the mass as a whole, rather than the molecular constituents of that substance described in Section 12.3.1. Kinetic energy is generally defined on a relative basis also, using the motion of one mass relative to another. We normally assume that the motion of a body may be considered relative to **that** of the motion of the earth, which is taken to be zero on a relative basis. Consequently, fundamentals of physics can define the kinetic energy of a moving body by the following equation

$$\text{K.E.} = 1/2\, mv^2 \qquad (12.2)$$

where m is the mass of the system and v is the velocity of the system. This suggests that a baseball thrown by a pitcher possesses internal energy (which is measured in part by the temperature of the baseball) and kinetic energy (which is measured in part by **its** velocity relative to the earth). If this baseball has been thrown at 60 mph (2860 cm/sec) and the baseball has a mass of 400 gms, then the kinetic energy of this baseball would be shown by the following equation

$$\text{K.E.}=1/2\ \left(400\ gms\right)\left(2680\ \frac{cm}{sec}\right)^2 = 14.3x\ 10^2\text{g-cm}^2/\text{cm}^2 \qquad (12.3)$$

12.3.3
Potential Energy

The potential energy of a substance is defined as the potential of that mass for doing work. Any two masses are known to exert an attraction on one another. A baseball thrown straight up in the air is attracted back towards the earth by the gravitational force of the earth. Consider this baseball when **it** reaches the apex of its travel up into the air. At this instant of time, the baseball contains a potential energy which is measurable relative to that of the earth. The potential energy of any mass is generally expressed by the following equation

$$\text{P.E.} = mZ \qquad (12.4)$$

where the distance *Z* is the height of that mass, *m*, above the surface of the earth. In the case of the baseball, this potential energy is achieved as a result of the expenditure of energy. Consequently, when a pitcher throws a baseball at a velocity of 60 mph as it leaves the pitcher’s hand (and if there is no frictional work done on the atmosphere by the baseball’s passing through the atmosphere), then we can calculate the ultimate height the baseball will achieve by combining equations (12.3) and (12.4). Let us consider a few simple examples:

Example 12.1: A 500 pound block is raised 50 feet. What is the change in potential energy?

$$\text{P.E.} = (500)$$
$$= \frac{(500)(50)}{778}\ \text{Btu}$$
$$= 32.1\ \text{Btu}$$

Example 12.2: If the block from Example 12.1 is allowed to drop from rest 50 feet to the ground, what is **its** kinetic energy just before striking the ground (neglecting any air friction)?

$$\text{P.E.} = (500)\ (50)\ \text{foot-pounds}$$

$$\text{K.E.} = \frac{mv2}{2gc}$$

To use the above relationship, we need to know the final velocity. Fundamental physics relationships tell us that

$$v^2 = V^2 + 2as$$

$$V = \text{initial velocity} = 0$$

$$a = \text{acceleration}$$

$$s = \text{distance}$$

$$v^2 = (2)\,(32.2)\,(50)$$

$$\text{K.E.} = \frac{(2)(32.2)(50)(500)}{(2)(32.2)(778)}\ \text{Btu}$$

$$\text{K.E.} = 32.1\ \text{Btu}$$

Note that we can obtain the same answer by simply equating the K.E. and P.E. terms as Equation (12.1) suggests. (Compare results of Examples 12.1 and 12.2)

The second law of thermodynamics concerns itself with the availability of energy, and was first conceived in terms or power cycles (steam engines, boiler plants, etc.) The first law does not tell us anything about the direction in which energy is transferred, the minimum work required to perform separations, the maximum theoretical work from a power plant cycle, etc…The second law is a statement of these limitations. There are many ways of expressing the second law – for our purposes we will use the following.

1. A device (machine, etc.) cannot convert all heat solely into work (some of the heat must be wasted).

2. It is impossible for heat to flow spontaneously from a low temperature to a high temperature (without, for example, the addition of work).

To illustrate the second law, let us consider a simple power plant cycle which is sketched in Figure 12.2. Water is pumped into a boiler at a relatively high pressure (say 1000 psi) where **it** is vaporized into superheated steam. This steam leaves the boiler at a high pressure and is used to drive a turbine by allowing the steam pressure to decrease to some low value near atmospheric pressure; the steam at this point is called exhaust steam. The turbine operates basically on the same principle as a paddle wheel on a boat, the steam pressure is used to turn the turbine blades which are connected to a rotating shaft. This shaft drives an electric generator. The exhaust steam leaving the turbine is condensed in a water (or air) cooled condenser. The condensed water is then pumped back to the boiler for reuse.

The diagram shows the pressures, temperatures and heats of vaporization and condensation for the appropriate points in the process. Note from Figure 12.2 that the heat of vaporization of water at 1000 pounds per square inch is much less than at atmospheric pressure.

If we call the boiler temperature T_H and the condenser temperature T_C, the second law of thermodynamics tells us that the efficiency of the power cycle is approximately

$$\text{Eff} = \frac{T_H + T_C}{T_H}$$

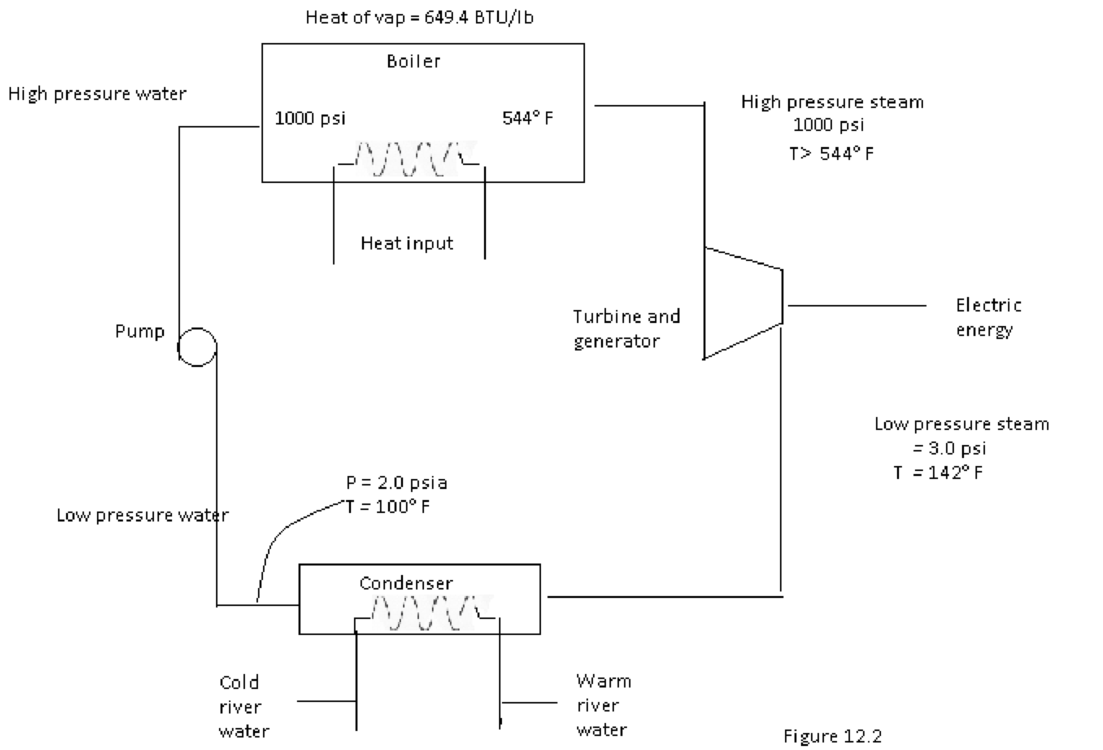


Figure 12.2
Schematic diagram of a power plant

The above expression is strictly true only for a Carnot cycle (a special form of a power cycle), but we will use **it** as an estimate of actual power plant efficiency. The high temperature depends upon the pressure at which the steam is generated –the higher the pressure, the higher the temperature. Table 12.1 shows the vapor pressure of water as a function of temperature.

Table 12.1
Vapor Pressure of Water

Temperature. ° F	Pressure, Psia
32	0.0886
40	0.1217
60	0.2561
80	0.5067
100	0.9487
150	3.716
200	11.525
212	14.696
250	29.82
300	67.01
400	247.25
500	680.80
600	1543.2
700	3094.1

The low temperature depends upon the temperature at which the heat can be rejected in the condenser, i.e., either the air or water (river) temperature. Let us assume that the two temperatures are 500° F (680 psia) and 90° F respectively. Then the efficiency is 5

$$\text{Eff} = \frac{(500+460)-(90+460)}{(500+460)}$$

$$\text{Eff} = \frac{(960-550)}{(960)} = 0.427 \text{ or } 42.7\%$$

Note that degrees absolute are used for the temperatures –degrees absolute are degrees Fahrenheit plus 460 or degrees Centigrade plus 273. The efficiency of 42.7% tells us that (100 -42.7) or 57.3% of all heat produced will be rejected into the river.

Let us now use the concept of an energy balance and the second law of thermodynamics to calculate the fuel requirements for a 800 megawatt power plant. A power plant of this size is typical of those currently under construction, although there are plans to build much larger plants. What we wish to calculate is the amount of fuel required and the amount of heat rejected to the river (thermal pollution). In the previous section on material balances we used this same example to estimate the SO_2 and particulate emissions.

We require 800 megawatts of power or

$$\text{Power} = \frac{(800{,}000{,}000)\text{ watts}}{(746\text{ watts}} \text{ x HP x } \frac{42.4}{\text{HP}}\frac{\text{Btu}}{\text{min}} \text{ x } \frac{60\text{ min}}{\text{hr}}$$

$$\text{Power} = 2.73 \text{ x } 10^9 \text{ Btu/hr.}$$

But this figure is the power generated and does not take into account the efficiency of converting heat to work.

The actual heat release in the boiler must be, for 42.3% efficiency,

$$\text{Heat} = -\frac{2.73 \text{ x } 10^9}{0.423}$$

$$\text{Heat} = 6.45 \text{ x } 10^9 \text{ Btu/hr.}$$

If we assume that the heating value of the coal is 11,500 Btu/lb., then we require

$$\text{Coal} = -\frac{6.45 \text{ x } 10^9}{1.15 \text{ x } 10^9} = 560{,}000\text{lbs/hr of coal}$$

or 280 tons per hour of coal

The heat release to the river is

$$\text{Thermal Pollution} = (6.45 - 2.73) \text{ x } 10^9$$
$$= 3.72 \text{ x } 10^9\text{Btu/hr.}$$

Or 3.72 billion Btu/hr. of heat

One Btu is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit, so this heat will raise the temperature of 372 million pounds power per hour of water about 10 degrees Fahrenheit. These heat quantities are truly stupendous, yet **they** refer to only one 800 megawatt (approximately) power plant. The annual electrical energy consumption in the United States is approximately 1640 million megawatts per year (1970). It is estimated that consumption will increase to 3240 million megawatts in 1980 and to 6072 million megawatts by 1990.

12.4 KINETICS AND CHEMICAL EQUILIBRIUM

Kinetics may be considered as a study of the rate and mechanism by which one chemical species is converted to another. The terms "rate" and "mechanism" are discussed below in some detail. To illustrate the discussion of kinetics, we will once again talk in terms of an air pollution problem, viz. the removal of SO_2 and NO_x from power plant stack gases.

It has been estimated that there are some 60 to 70 different processes or methods under investigation for the removal of SO_2 and/or NO_x from stack gases. One possible process utilizes a reaction of carbon monoxide with each pollutant (sulfur dioxide and nitric oxide) to produce harmless compounds.

$$2CO + SO_2 \rightleftharpoons 2CO_2 + 1/2\ S_2$$

$$CO + NO \rightleftharpoons CO_2 + 1/2\ N_2$$

There is also a side reaction that can occur between sulfur (one of the products) and CO to form carbonyl sulfide (COS).

$$CO + 1/2\ S_2 \rightleftharpoons COS$$

There are three questions we wish to answer concerning the above reactions.

1. Given the stack gas composition and temperature (i.e., percent SO_2, CO, CO_2, N_2, etc.) what is the maximum theoretical conversion of the SO_2 to S_2?
   Suppose we have a vessel at 1000° F to which is added gas of composition typical of a power plant stack -76% N_2, 14% CO_2, 1000 ppm SO_2, 500 ppm CO, and the balance H_2O and O_2. If this mixture is allowed to react and we let **it** sit sufficiently long in the vessel (at 1000° F) so that there eventually is no further change in composition, what will be the final concentrations of CO, SO_2, COS, S_2, etc.? This resulting point is called *chemical equilibrium* and may be calculated using thermodynamic principles.
2. How long, starting from the same initial composition as in (1), will it take to reach chemical equilibrium? (The answer may be years).
   The equilibrium concentration of SO_2 might be 800 ppm (for an initial SO_2 concentration of 1000 ppm). We may also wish to know how long it will take to reach 80% of the equilibrium conversion (80% x (1000 – 800) or 840 ppm SO_2. In other words, we want to know the rate of chemical reaction.
3. By what reaction path does the SO_2 react with CO to form CO_2 and S_2, i.e., what is the mechanism? For example, do both species absorb on a catalyst and react on its surface; are there intermediate products, e.g., radicals, formed?

Both these latter questions pertaining to reaction rates and mechanisms fall in the domain of kinetics. Typically the chemical engineer is more concerned with reaction rates than with reaction mechanisms, because the rate data are of vital importance in the design and operation of a chemical reactor to carry out a given conversion. The subject of kinetics is also intimately involved with the subject of catalysis. Many chemical reactions proceed very slowly unless a catalyst is present in which case the *rate* of reaction may be increased manifold.

For purposes of illustration we will use the reaction

$$CO + NO \rightleftharpoons CO_2 + 1/2\ N_2$$

and assume that there are no other reactions to consider. Suppose the initial concentrations of the reactants are:

CO 0.1 moles
NO 0.2 moles

and the temperature is 1000° F. We want to find the chemical *equilibrium* composition of the mixture. Thermodynamics allows us to define an equilibrium constant for the reaction which, for the present illustration, is taken to be

$$K_{eq} = \frac{a_{co,}\, a_N^{\frac{1}{2}}}{a_{co}\, a_{NO}}$$

Where K_{eq} is the equilibrium constant and a_{N2}, a_{CO2}, a_{CO}, are the "activities" of the chemical species. For gases at low pressures the activity is nearly always equal to what is called the partial pressure. The partial pressure is defined as

$P_1 = y_1 P_{tot}$

P_1 = partial pressure of component *i*

y_1 = mole fraction of component *i*

P_{tot} = total pressure

The equilibrium constant is found both theoretically and experimentally to vary with temperature as indicated in Figure 12.3.

Suppose we let x denote the number of moles of NO which react. Then the moles of NO remaining will be $(0.2 - x)$. Similarly, the equilibrium concentrations of the other components will be

NO	$(0.2 - x)$
CO	$(0.1 - x)$
CO_2	x
N_2	$0.5x$
The total is	$(0.3 - 0.5x)$

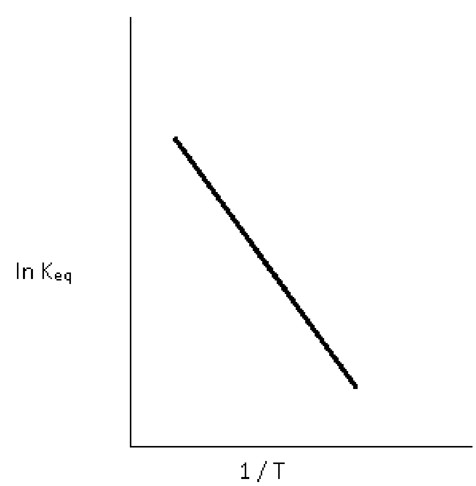


Figure 12.3

and the partial pressures become

$$P_{NO} = \frac{(0.2 - x)}{(0.3 - 0.5x)} P_{tot}$$

$$P_{CO} = \frac{(0.1-x)}{(0.3-0.5x)} P_{tot}$$

$$P_{CO1} = \frac{x}{(0.3-0.5x)} P_{tot}$$

$$P_{CO1} = \frac{(0.5x)}{(0.3-0.5x)} P_{tot}$$

The expression for the equilibrium constant is then

$$K_{eq} = \frac{P_{co2}\, P_{N}^{\frac{1}{2}}}{P_{co}\, P_{NO}}$$

$$= \frac{\frac{x}{(0.3-0.5x)} \mathrm{Ptot} \sqrt{\frac{(0.5x)}{(0.3-0.5x)} \mathrm{Ptot}}}{\frac{(0.2-x)}{(0.3-0.5x)} \mathrm{Ptot} \frac{(0.1-x)}{(0.3-0.5x)} \mathrm{Ptot}}$$

Using a value for K_{eq}, we then determine the equilibrium mixture, since only x is unknown.

12.4.2
Reaction Kinetics

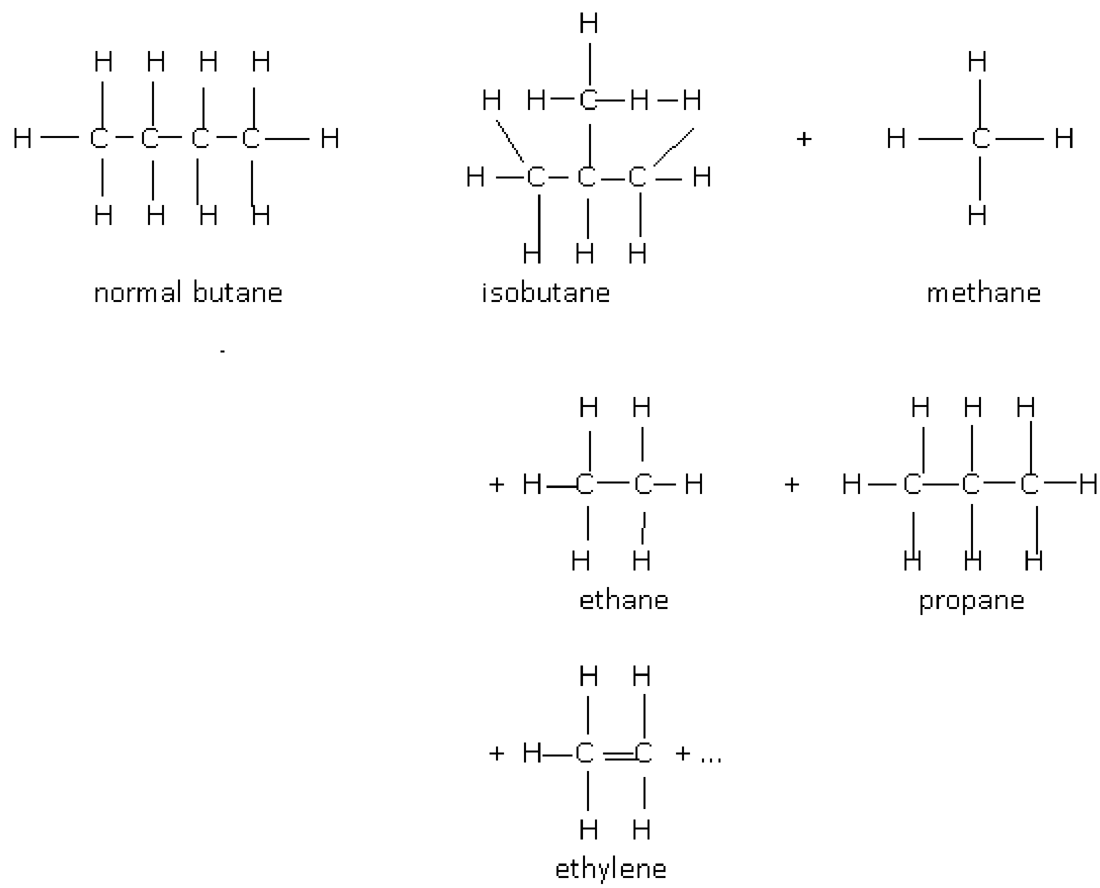
Whereas thermodynamics provides us with information as to how far a reaction could go if given an infinite time to react, reaction kinetics provides information concerning the actual rate at which a reaction proceeds. We are familiar with a variety of very rapid reactions, for example the reaction of hydrogen and oxygen in the inverted beaker observed in high school chemistry. In the presence of a flame, this reaction proceeds so rapidly that a loud pop is heard. Thermodynamics says that this reaction will go completely to water at room temperature. However, it is not until a burning ember is inserted into the mixture that the reaction takes place. A slower reaction with which we are familiar is the rusting of iron, particularly in the presence of water. Most reactions that we are concerned with in industrial practice occur at rates between **those** of the hydrogen-oxygen reaction and the iron-oxygen reaction.

The applications of kinetics in the United States economy are very broad. Chemical reaction kinetics play a major role in producing goods worth more than 100 billion dollars per year. This represents products accounting for 1/6 of the value of all goods manufactured in the United States. In general, these reactions are utilized to convert a low value raw material into a high value product. Examples wherein reactions are used to produce a valuable product are tabulated below.

1. Gasoline from crude oil
2. Jet fuel from crude oil
3. All drugs and pharmaceuticals
4. All heavy chemicals (acetic acid, fertilizers, etc.).
5. All plastics (telephone, wire coating, intrauterine devices, hula hoops, etc.)
6. All synthetic fibers for clothing (nylon, Dacron, etc.)
7. Food stuffs (cheese, beer, clarified apple juice, ethanol, etc.)
8. Solution to environmental problems (removal of nitric oxide, sulfur dioxide, etc.)

One of the great efforts in the general field of chemical engineering kinetics of the last few decades has been to find new catalysts which cause a reaction to proceed at relatively less severe conditions and to proceed more completely to the desired product, but without themselves being consumed by the reaction. These catalysts are characterized by being able to form a chemical intermediate which is not readily formed in the absence of the catalyst and which then can react to easily form the desired product. For example, without a catalyst, normal butane cannot readily be transformed to isobutene. Conversion of normal butane to isobutene is desirable because the isobutene is more useful in the production of gasoline.

We can force this reaction to proceed if we raise the temperature high enough. In such a case, the high temperature would transmit such high energies to the normal butane molecule that **it** would ultimately rearrange and fly apart as shown below.



It is apparent that we do get some isobutene, as desired, but we also may obtain many other nondesired products due to the severe reaction conditions required.

In the presence of a catalyst, however, which, in this case, is simply a solid material that is contacted with the normal butane at a moderately high temperature, the following reaction sequence proceeds:

> The normal butane becomes attached to the catalyst.
>
> The catalyst removes a hydrogen atom from the normal butane leaving a positive charge in its place on the normal butane. This positively charged ion then readily becomes rearranged to a more stable form of an isobutene ion.
>
> This isobutene ion then recovers the hydrogen picked up by the catalyst to produce isobutane and the fresh regenerated catalyst. This catalyst can then repeat the reaction sequence by picking up additional normal butane. Hence, we see a reaction sequence that more efficiently gives isobutene through the action of the catalyst, and, in addition, the catalyst is unchanged as a result of the reaction.

We must also be able to predict the rate of reaction –the rate at which the reactants disappear, the rate at which products form, and the rate of reaction between products formed and other reactants to form various by-products. This information will enable us to calculate the size of the reactor needed to remove a specified amount of reactants or to form a specified amount of products.

For the reaction

$$CO + NO \rightleftharpoons CO_2 + 1/2\ N_2$$

the expression for the rate of formation of CO_2 could be

$$\Gamma = k \text{ [concentration NO] [concentration CO]}$$

where k is the rate constant. We do not know without experimental data what the rate expression will be. For example, the rate of formation of CO_2 could be given by

$$\Gamma = k \text{ [concentration NO]}$$

i.e., independent of the CO concentration.

To illustrate the magnitude of a chemical reactor required for our stack gas problem, let us assume that we calculate from the rate equations that 90 percent of the SO_2 and NO_x will be removed in 0.1 seconds. This percent removal is about what is required to meet typical air pollution standards.

From the section on material balances, the volume of stack gas produced is 98,163,000 cubic feet per hour, or 27,200 cubic feet per second. The volume of the reactor is then

$$27{,}200 \frac{ft^3}{sec} \text{ x } 0.1 \text{ sec}$$
$$= 2720 \text{ ft}^3$$

If we were to assume that the height is three times the diameter then the reactor size would be

$$\left(\frac{D^3}{4} \text{ x } 3\text{ D}\right) = 2720$$
$$= 15.1 \text{ ft.}$$

and the dimensions of the reactor are 15 feet diameter by 45 feet high.

12.5
HEAT TRANSFER

The transfer of heat occurs in practically every engineering process and is encountered in everyday life in countless situations –e.g., car radiators, air conditioners, home furnaces, etc. There are three modes of heat transmission: conduction, convection, and radiation.

Conduction is the transfer of heat from one part of a body to another or between two bodies in actual physical contact.

Convection is the transfer of heat from one point within a fluid to another point within a fluid. Convection can be further subdivided into natural and forced convection. In natural convection the heat transfer occurs solely as a result of density differences resulting from temperature differences. In forced convection, the fluid is in motion.

Radiation is the transfer of heat by radiant energy. Electromagnetic waves are radiated by all bodies in all directions at all temperatures. These electromagnetic waves carry energy. When this energy strikes (contacts) another body, a part of **it** will be absorbed, a part reflected, and a part transmitted.

In many actual cases, heat transfer will occur by more than one of these means simultaneously. The rate of heat transfer (amount of heat transferred per unit time) is proportional to a driving force (temperature difference),

$$\text{rate} \ \infty \ \ \Delta T$$

or

$$\frac{dQ}{dt} \infty \quad \Delta T$$

The proportionality constant is known as the heat transfer coefficient –in the case of pure conductivity the coefficient is known as the thermal conductivity of the material. Excellent heat transfer materials such as copper have high thermal conductivities; excellent insulators, such as fiber glass, air, and asbestos, have low thermal conductivities.

As an example of the use of heat transfer concepts, combined with energy balances, let us consider what happens to the heat discharged from a power plant to a river. The reader will recall that not all the energy produced from the fuel combustion is converted into electrical energy (in fact most of **it** is not).

In writing an energy balance for a thermally polluted river, some of the terms which must be considered are discussed below.

Q_{sn} net short wave radiation flux delivered through the water surface air interface after losses by absorption and scattering in the atmosphere and by reflection at the surface

Q_{st} net atmospheric long wave radiation flux delivered through the interface

Q_{BR} long wave water surface back radiation to the atmosphere

Q_E energy loss by evaporation

Q_C convective energy flux between the water surface and the overlying air mass. This energy may either flow from the air to the water or from the water to the air depending upon the temperatures of each.

We will briefly describe the various terms above, **their** significance and relative magnitudes.

Net Short Wave Radiation

The net short wave radiation passing through the air-water interface may be described generally as the extraterrestrial radiation flux entering at the top of the atmosphere less losses incurred by scattering and absorption in the atmosphere and by reflection from the water surface. The rate is obviously a complicated function of many variables such as time of year, time of day, material in the atmosphere which can cause scattering and/or absorption, cloud cover, weather conditions (rain, snow), etc.

Atmospheric Radiation

A part of the long wave radiation which is emitted by solid or liquid bodies at the earth's surface is absorbed by water vapor and ozone in the surrounding atmosphere. These constituents, in turn, radiate back to the ground or into space.

Long Wave Back Radiation

This is essentially self-explanatory and is the radiation leaving the river surface.

Evaporation

Evaporation is one of the most important terms in the particular energy balance –**its** presence attests to the fact that cooling ponds may be used as a method of eliminating thermal pollution. When water evaporates from the surface of the river (or lake) into the air, it changes from a liquid to a vapor; for each pound of water vaporized approximately 970 Btu of heat are required. The only source of heat is the river itself and hence, the temperature of the river water will tend to decrease as evaporation is taking place. Water can evaporate into the air as long as the air is not saturated –or in perhaps more familiar terms as long as the relative humidity is less than 100%. The rate of evaporation depends upon the driving force which depends upon the relative humidity of the air. Also cold air can hold less water than warm air, i.e., one pound of cold air will contain less water at 100% relative humidity than one pound of warmer air also at 100% relative humidity.

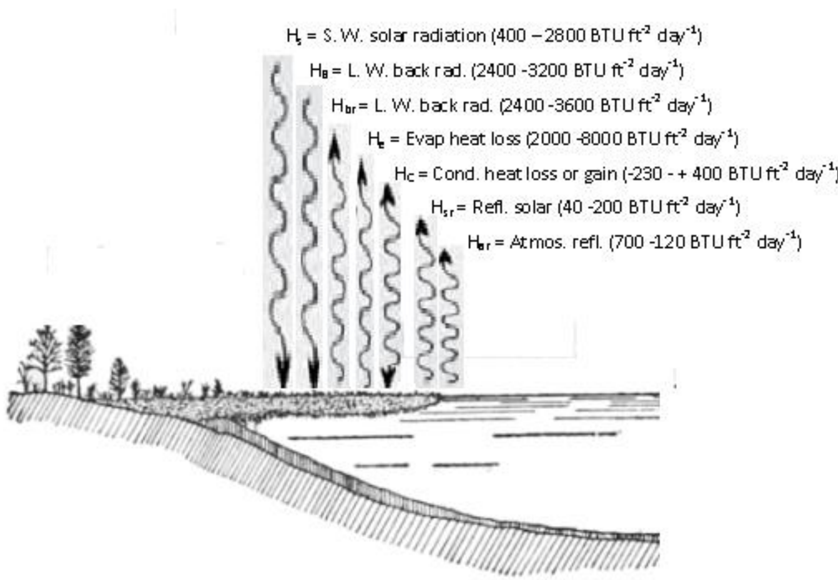
Convection

In the case of thermal pollution heat transfer, the term advection is often used rather than convection. Advection refers to the same mechanism of heat transfer, but implies that the transfer is in a horizontal direction, i.e., that the wind blows parallel to the river surface.

In order to carry out the energy balance for the thermal pollution of a river, we must be able to estimate the magnitude of each of the above terms. In addition, there are other means by which energy might leave the river, viz. conduction to the river bed or to the river banks. It has also been reported that rocks in the river are capable of absorbing significant quantities of radiant energy and can act as “hot spots”, particularly in late afternoon and evening.

What are the magnitudes of each of the above terms? Some reasonably careful estimates have been made of each and the numbers shown below in Figure 12.4 are typical of those either measured or generally accepted as being reliable estimates.

Figure 12.4
Mechanisms of heat transfer across a water surface

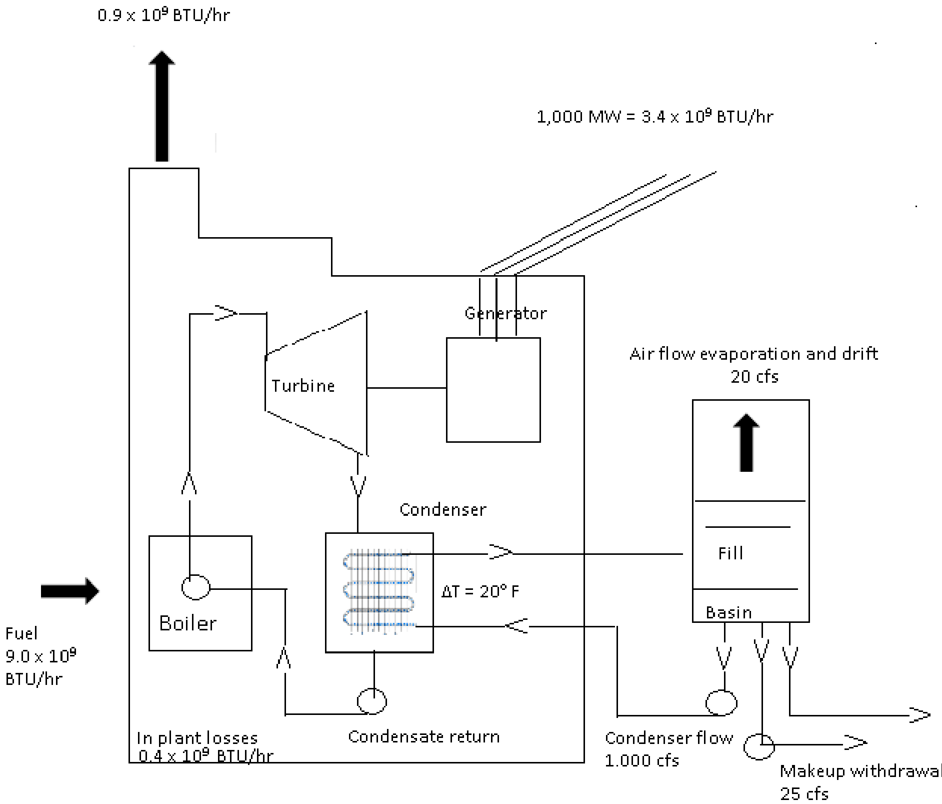


Jimeson and Adkins have presented a typical heat balance for a 1000 megawatt power plant, which is reproduced below in Figure 12.5.

The authors state that a 1,000 megawatt power plant operating with a 15°F increase in water temperature in the condenser requires about 1,400 cubic feet per second of water. If a cooling tower is employed for an 800 megawatt power plant, the tower will be approximately 400 feet in diameter and 450 feet high. These towers cool the water by allowing a portion of it to evaporate into the air passing through the tower. The heat required to evaporate the water will result in a decrease in water temperature.

Figure 12.5
Heat balance of 1,000 megawatt fossil steam plant

operating at full load



Jimeson and Adkins have also given the following costs of cooling water systems for steam electric plants:

Type of system	Investment cost $/KW
Once through	2.00 – 3.00
Cooling Ponds	4.00 – 6.00
Evaporative Cooling Tower	
Natural Draft (no fans)	6.00 – 9.00
Mechanical draft (fans)	5.00 – 8.00

The cooling costs correspond roughly to 0.2 to 0.4 mils/kw hr. (one mil is 0.1 cent).

EJERCICIO 15.2

Answer the following question (in Spanish) according to the text in Exercise 15.1.

1) A 600 pound metal ball was pushed horizontally along a distance of 100 feet. Then it was lifted 60 feet. Neglecting any friction, what was the final change in potential energy (expressed in Btu)?

………

………

………

2) What is the name of that form of energy which is due to movement of the mass as a whole?

………

………

3) What do each of the three laws of thermodynamics state?

………

………

………

4) A 2,000 pound rock is allowed to drop from rest 10,000 feet to the ground. Estimate the temperature rise (°F) it would produce if it fell into a pool containing 15,000 pounds of water and assuming that all the striking potential energy is converted into heat?

………

………

………

5) How do we characterize the internal energy of a glass of water?

………

………

………

EL CONDICIONAL (simple y perfecto)

EJERCICIO 16.1
Fill in the blanks with the SIMPLE CONDITIONAL TENSE FORMS of the verbs given in parentheses. Then translate and underline the corresponding forms in Spanish.

1) The input of heat into a river _______________ stored as an increased temperature of the water; consequently, any fish in the river may be adversely affected by this stored energy (be)

……

……

……

2) A host of useful ideas and concepts _______________ us to predict the directions of chemical reactions, determine the feasibility of processing routes, and so forth. (enable)

……

……

3) The energy balance _______________ that energy is neither created nor destroyed. (state)

……

……

4) This brief statement _______________ the possibility of nuclear fission reactions in which matter is converted to energy. (ignore)

……

……

5) An example of a less common form of energy _______________ surface energy. (be)

……

……

6) _______________ electrical and magnetic interactions between sub-particles which contribute to this other component of internal energy. (there be)

……

……

7) We __________ normally __________ that the motion of a body may be considered relative to that of the motion of the earth. (assume)

…….

…….

8) I knew that the first law _______________ us anything about the direction in which energy ________________ transferred. (tell, neg.) (be)

…….

…….

9) He said that he _______________ any air friction in the example where a 500 pound block was allowed to drop from rest 50 feet to the ground. (neglect)

…….

…….

10) It was understood that a glass of water _______________ many individual water molecules and these molecules in turn _________________ sub-particles. (contain) (contain)

…….

…….

EJERCICIO 16.2

Fill in the blanks with the PERFECT CONDITIONAL TENSE FORMS of the verbs given in parentheses. Then translate and underline the corresponding forms in Spanish.

1) It ___________________________ accumulated in this fashion as either, internal energy, potential energy, or kinetic energy. (be)

…….

…….

2) The amount of pollutants that ___________________________ the atmosphere from that combustion process ___________________________ calculated. (enter) (be)

…….

……..

3) We ____________________________ the state of the substance in the reference condition (e.g., water at 0° or solid crystalline ice at 0°). (specify)

……

……

4) This fact ____________________________ that a baseball thrown by a pitcher possessed internal and kinetic energy. (suggest)

……

……

5) To use the above relationship, we ________________________ to know the final velocity. (need).

……

……

EJERCICIO 17.1

Read pages 49 (from line 11) to 52 from the text in Exercise 15.1 and answer the following questions.

1) What does the boiler temperature depend on?

……

……

……

2) Describe the power plant cycle sketched in Fig. 12.2.

……

……

……

……

3) What is the efficiency of a power cycle plant operating at a boiler pressure of 65.01 psia if the air temperature at the air-cooled condenser is 75° F?

……

……

……

4) Find the amount of coal required by a 500 megawatt power plant station running at the conditions stated in the previous question.

………

………

………

5) Explain what a catalyst does in a chemical reaction.

………

………

………

VERBOS MODALES

EJERCICIO 18.1

Translate the following sentences and underline the forms in Spanish which correspond to COULD, MIGHT or SHOULD = OUGHT TO.

1) Water **should** be pumped into a boiler at a relatively high pressure (say 1000 psi) to be vaporized into a superheated steam.

………

………

2) The above expression is true only for a Carnot cycle, but we **could** use it as an estimate of actual power plant efficiency.

………

………

3) An efficiency of 42.7% **might** tell us that 53.3% of all the heat produced would be lost.

………

………

4) The diagram **ought to** show the heats of vaporization and condensation for the appropriate points in the process.

………

………

5) Note that the heat of vaporization of water at 1000 pounds per square inch **should** be much less than at atmospheric pressure.

……

……

6) This figure of the power generated **might** not take into account the efficiency of converting heat to work.

……

……

7) **Could** that amount of heat raise the temperature of 372 million pounds per hour of water about 10 degrees Fahrenheit?

……

……

8) I didn't know that "kinetics" **ought to** be considered as a study of the rate and mechanism by which one chemical species is converted to another.

……

……

9) There was also a side reaction that **could** occur between sulfur and CO to form carbonyl sulfide (COS): $CO + 1/2\ S_2 \rightleftarrows COS$

……

……

10) The equilibrium concentration of SO_2 **might** be 800 ppm (for an initial SO_2 concentration of 1000).

……

……

EJERCICIO 19.1

Read pages 53 to 56 (line 14) from the text in Exercise 15.1 and answer the following questions.

1) What has been one of the great efforts in the general field of chemical engineering kinetics of the last few decades?

………

………

………

2) Describe the reaction of hydrogen and oxygen in the presence of a flame in the inverted beaker.

………

………

………

3) How does a catalyst act on butane in the process to obtain isobutane?

………

………

………

4) Could you give examples of slow and fast reactions commonly found in industrial practice?

………

………

………

5) Estimate the approximate value (in dollars) of all goods manufactured in the United States in a year.

………

………

………

LOS CONDIOCIONES (tipo 1, 2 y 3)

EJERCICIO 20.1
Translate the following CONDITIONAL sentences

CASE 1

1) **If** the combustion process **is required** to provide some specific amount of heat, this heat **can be related** to the amount of fuel.

………

………

2) **If** the temperature of the water **is increased**, this component of the internal energy **increases**.

………

………

3) **If** we **call** the boiler temperature T_H and the condenser T_C, the second law of thermodynamics **tells** us the efficiency is as follows.

………

………

4) He **will see** that the turbine operates on the same principle of a paddle wheel of a boat, **if** he **compares** them.

………

………

CASE 2

5) You **could illustrate** the second law, **if** you **considered** a simple power plant cycle.

………

6) **If** an infinite time **were given**, this reaction **would** go completely to water at room temperature.

………

………

7) **If** we **wanted** to define an equilibrium constant, we **would need** the composition of the mixture.

………

………

8) **If** I **did not know** the number of moles, I **could not follow** the process of those chemical species.

…….

…….

CASE 3

9) If they **had calculated** the size of the reactor correctly, the specific amount of reactants **would have been removed**.

…….

…….

10) The rate at which various by-products disappeared **would have increased**, if another catalyst **had been used.**

…….

…….

11) **If** we **had not seen** the experimental data, we **would not have believed** it.

…….

…….

12) You **would have remembered** the meaning of that word, if you **had studied** a little more.

…….

…….

EJERCICIO 20.2
Translate the following sentences and notice they also express CONDITIONAL

1) **Should** the transfer of heat occur solely as a result of density differences resulting from temperature differences, the process is known as *natural convection*.

…….

…….

2) **Were** fans used in that cooling tower, its capacity would be increased.

…….

…….

3) **As long as** the air is not saturated, water can evaporate from the surface.

……..

……..

4) **Had** I **known** the definition of *Long Wave Back Radiation,* I would have explained it to him.

……..

……..

5) **Unless** there is a brief description of the various terms above, their significance and relative magnitudes will not be fully understood.

……..

……..

6) There will be convection **provided** a fluid exists between both bodies.

……..

……..

7) The main question is not **whether** an insulator will be used but **whether** it will reflect the incoming radiation.

……..

……..

8) **Should** the air be colder, it will hold less water.

……..

9) **Were** we to assume that the height is three times the diameter then the reactor size would be 15 feet diameter by 45 feet high.

……..

……..

10) The energy balance will not be complete **unless** the conduction to the river bed or to the river banks is considered.

……..

……..

EJERCICIO 21.1

Read pages 57 (from line 12) to 59 from the text in Exercise 15.1 and answer the following questions.

1) What does *Net Short Wave Radiation* mean?

………

………

………

2) What is the difference between *convection* and advection*?*

………

………

………

3) How does a cooling tower work?

………

………

………

4) Explain how heat transfer takes place through radiation.

………

………

………

5) Estimate the cost of a mechanical-draft evaporative cooling tower for a 1,000 megawatt power plant.

………

………

………

EJERCICIO 21.2

According to the text in exercise 15.1, decide whether the following statements are TRUE or FALSE. Write down the page and line numbers where you located the necessary information. Then translate the sentences that are TRUE or explain your decision (in Spanish) for the false ones.

1) It would not be possible to manufacture an engine that could convert all heat solely into mechanical power.

(__________) page………. line……..

………

………

2) The efficiency of the power cycle of a system operating at a boiler pressure of 1543.2 pounds per square inch and a condenser temperature of 110° F is approximately 55%.

(__________) page………. line……..

………

3) If an object with mass of 600 gms were thrown straight up in the air at a speed of 100 miles per hour, it would have a kinetic energy of about 60 x 10^{-8} gms-cm^2/sec^2.

(__________) page………. line……..

………

………

4) No engineering process involves more than one means of heat transfer.

(__________) page………. line……..

………

5) In analyzing the second law of thermodynamics we may deal with the concept of an ideal power cycle.

(__________) page………. line……..

………

………

6) The greater the temperature differences between two bodies, the greater the amount of heat transfer.

(__________) page………. line……..

………

………

7) The rate of accumulation of internal, potential, and kinetic energy in a system is equal to the sum of the net rate of flow of internal, potential and kinetic energy into the system.

(_________) page………. line……..

……..

……..

8) If you had had to raise the temperature of 1000 pounds of water 75°F, you would have needed to burn approximately 3 kilograms of coal.

(_________) page………. line……..

……..

……..

9) The first law does not apply for nuclear fission reactions in which matter is converted to energy.

(_________) page………. line……..

……..

……..

10) Reaction kinetics gives us information as to the actual rate at which a reaction proceeds.

(_________) page………. line……..

……..

……..

11) Mechanical work would be done provided that a higher internal energy level state (such as coal) were available.

(_________) page………. line……..

……..

……..

12) If 10 percent of SO_2 and NO_x remained in the stack gas, the combustion products thrown to the atmosphere would meet typical air pollution standards.

(_________) page………. line……..

……..

……..

13) Winds remove heat from a river by means of a heat transfer process known as advection.

(__________) page………. line……..

………

………

14) The rate of reaction of many chemical reactions may be slightly increased by using a catalyst.

(__________) page………. line……..

………

………

15) The net rate of heat addition to a system and the net rate of work done by the system on the surroundings would be transitional states of energy.

(__________) page………. line……..

………

………

16) The heat transfer due to solar radiation through the surface of a river may vaporize between ½ and 5 pounds of water per day per square foot.

(__________) page………. line……..

………

………

17) In order to vaporize 500 pounds of water 470,000 Btu are required.

(__________) page………. line……..

………

………

18) All of the extraterrestrial radiation flux entering at the top of the atmosphere finally reaches the surface of the earth.

(__________) page………. line……..

………

………

19) The kinetic energy of a substance is basically due to the movement of the molecular constituents.

(__________) page………. line……..

………

………

20) The higher the pressure, the less the heat of vaporization of water.

(__________) page………. line……..

………

EJERCICIO 22.1
Translate the following sentences and underline the equivalent forms in Spanish of the <u>FUTURE WITH "TO BE GOING TO"</u>.

1) Both species *are going to adsorb* on a catalyst and react on its surface.

………

………

2) The resulting point is called "chemical equilibrium" and *is going to be* calculated using thermodynamic principles.

………

………

3) We may also wish to know how long it *is going to take* to reach 80% of the equilibrium conversion.

………

………

4) By what reaction path *is* the SO_2 *going to react* with CO to form $CO_2$and S_2?

………

………

5) We *are not going to force* this reaction to proceed if we do not raise the temperature high enough.

………

………

EJERCICIO 22.2

Translate the following sentences and underline the equivalent forms in Spanish of <u>“TO BE ABLE TO”</u> (= CAN).

1) We *must* also *be able to predict* the rate of reaction –the rate at which the reactants disappear and the rate at which products form.

………

………

2) I *was not able to carry out* the energy balance for the thermal pollution of a river.

………

………

3) In addition, we *shall be able to estimate* the magnitude of each of the above terms.

………

………

4) He *has been able to design* a cooling tower for an 800 megawatt power plant.

………

………

5) You *would have been able* to give those thermal conductivities, if you had read this chapter.

………

………

EJERCICIO 22.3

Translate the following sentences and underline the equivalent forms in Spanish of the <u>“TO HAVE TO”</u> (= MUST).

1) The reader *will have to recall* that not all of the energy produced from the fuel is converted into electrical energy (in fact most of it is not).

………

………

2) The net short wave radiation passing through the air-water interface *should have to be described.*

……..

……..

3) He *has to understand* the meaning of “net atmospheric long wave radiation delivered through the interface”.

……..

……..

4) It *does not have to be emitted* by solid bodies at the earth’s surface.

……..

……..

5) These constituents, in turn, *would have to radiate back to* the ground or into space.

……..

……..

EJERCICIO 23.1

Refer to the text in Exercise 15.1 and complete the following statements. The locating clues within brackets indicate: page and line number.

1) (p. 47 line 9) it refers to ……………………………………………………………………………………..

2) (p. 47 line 29) its refers to ……………………………………………………………………………………..

3) (p. 47 line 32) it refers to ……………………………………………………………………………………..

4) (p. 48 line 1) that refers to ……………………………………………………………………………………..

5) (p. 48 line 4) that refers to ……………………………………………………………………………………..

6) (p. 48 line 9) its refers to ……………………………………………………………………………………..

7) (p. 48 line 16) it refers to ……………………………………………………………………………………..

8) (p. 48 line 28) its refers to ……………………………………………………………………………………..

9) (p. 49 line 12) it refers to ……………………………………………………………………………………..

10) (p. 50 line 2) it refers to …………………………………………………………………………………….

11) (p. 51 line 17) they refers to ……………………………………………………………………………………..

12) (p. 52 line 16) it refers to ……………………………………………………………………………………..

13) (p. 54 line 12) those refers to ……………………………………………………………………………………..

14) (p. 55 line 2) it refers to ……………………………………………………………………………………..

15) (p. 56 line 25) it refers to ……………………………………………………………………………………..

16) (p. 57 line 9) it refers to ……………………………………………………………………………………..

17) (p. 57 line 19) their refers to ……………………………………………………………………………………..

18) (p. 57 line 30) its refers to ……………………………………………………………………………………..

GLOSARIO GENERAL

Palabra	Función	Significado		Otra función y significado	
A					
A.D	expr	Año después de Cristo (Latín: Anno Domini = año del Señor)			
about	prep	acerca de, sobre, alrededor de			
above	prep	arriba, por encima de			
absence		¿?			
absorb	v	absorber			
abstractly	adv.	Abstractam*ente			
access	v	acceder			
according to	adv	de acuerdo con, según			
accordingly	adv	así			
account for		¿?			
accuracy	s	exactitud			
achieve	v	lograr			
acidity	s	acidez			
act	s	ley, acta, acto		v	actuar
activate	s	activar			
active	adj	activo			
actual	adj	actual, verdadero, real			
add	v	agregar, sumar			
addition	s	adición, agregado	in addition (to) = además (de)		
address	v	dirigir, remitir		s	dirección
adequate	adj	adecuado			
adjust	v	ajustar			
admittance	s	admitancia			
advance	s	adelanto, anticipación		v	adelantar
advantage	s	ventaja			
advantageous	adj	ventajoso			
advection	s	advección			
adverse	adj	adverso			
aerospace	adj	aeroespacial			
affect	v	afectar			
after	prep	después			
afternoon	s	tarde			
again	adv	otra vez, nuevamente			
against	prep	contra			
age	s	era, edad			
agent	s	agente			
ago	adj	hace	a year ago = hace un año		
agree	v	estar/ponerse de acuerdo, acordar			
aim		¿?			
air	s	aire			
aircraft	s	aeronave			
airport	s	aeropuerto			
alike		¿?			
all	adj	todos/as			
alleviate	v	aliviar			
allow	v	permitir			
alloy	s	aleación			
almost	adv	casi			
alone	adj	solo			
along	prep	a lo largo de			
already		¿?			
also	adv	también			
alternatively	adv	inversamente			
although	conj	aunque (también though)			
always	adv	siempre			
amazing	adj	sorprendente			

among	prep	entre		
amount	s	cantidad	v	valer
ampere	s	¿?		
amphoteric	adj	anfotérico		
analogous	adj	análogo		
analysis	s	análisis		
analyze	v	analizar		
and so forth	conj	etc.		
angry	adj	enojado		
another	adj	otro		
any	adj	cualquier (afir), algún (interr), ningún (neg)		
anybody/anyone	adj	cualquiera (afir), alguien (interr), nadie (neg)		
anything	adj	cualquier cosa (afir), algo (interr), nada (neg)		
anywhere	adj	cualquier lugar (afir), algún lugar (interr), ningún lugar (neg)		
apart	adv	aparte, separadamente, por separado		
apex	s	cima, cúspide, ápice, vértice (de un triángulo)		
appear	v	aparecer		
appearance	s	apariencia		
apple	s	manzana		
apply	v	aplicar		
arm	s	brazo		
arise	v	levantarse, elevarse, surgir (irreg. arose, arisen)		
arrange	v	arreglar, disponer		
arrangement	s	arreglo, disposición		
array	s	colección, serie, formación		
as long as		¿?		
as short as	expr	tan corto como		
as to	expr	en lo que se refiere a		
as well as		¿?		
as	adv	como, a medida que	conj	como
asbestos		¿?		
ash	s	ceniza		
ask	v	preguntar		
ask for	v	pedir		
assembly	s	montaje		
assert	v	afirmar, mantener, sostener, hacer valer		
assign	v	asignar		
assignment	s	tarea (asignada)		
associate	v	asociar		
assume	v	suponer		
assumption		¿?		
at least	expr	por lo menos, al menos		
attach		¿?		
attempt	s	intent		
attest	v	atestiguar, testimoniar		
automotive		¿?		
auxiliary	adj	auxiliar		
availability	s	disponibilidad		
available	adj	disponible		
avenue	s	avenida		
average	s	promedio, medio		
aware	adj	consciente de	to be aware of =: darse cuenta de	
away	adv	afuera, dirección contraria		
axis	s	eje		

B

B.C.	abrev	antes de Cristo (Before Christ)		
back	adv	de nuevo, nuevamente	to place it back = colocarlo de nuevo	adj posterior, trasero
background	s	antecedente, fondo, experiencia, conocimientos		
bad	adj	malo		
bail	s	barra de sujeción		
balance	s	equilibrio, balance	v	equilibrar, balancear

ball	s	bola, pelota, bolilla		
bank	s	banco, orilla (de un río)		
bar	s	barra, bar		
barrel	s	barril		
base	v	basar/se, fundamentar		
baseball	s	pelota de baseball		
basic	adj	básico		
basin	s	pileta, piletón, batea, palangana		
basis	s	fundamento, base		
be able to	v	ser capaz de		
beaker	s	cubeta de precipitación, jarra		
beam	s	haz, rayo, viga		
bearer	s	portador		
bearing	s	rodamiento, cojinete		
because	conj	porque		
become	v	hacerse, volverse, convertirse (irreg. became, become)		
bed	s	cama, lecho		
beer		¿?		
before	prep	antes de, delante de		
begin	v	empezar (irreg. began, begun)		
beginner		¿?		
beginning	s	comienzo		
belong (to)	v	pertenecer (a)		
behave	v	comportarse		
behavior	s	comportamiento		
behind	prep	detrás de		
being	s	ser		
believe	v	creer		
below	prep	por debajo de		
beside	prep	al lado de, junto a		
benzene	s	benceno, bencina		
beside	prep	al lado de, junto a		
besides	adv	además (de)		
best	adj	mejor (superlativo de good)		
better	adj	mejor (comparativo de good)		
between	prep	entre		
beyond	prep	más allá		
billion	adj	billion (USA : mil millones)		
blade	s	hoja, aspa, álabe		
blank	s	espacio en blanco		
block	s	bloque		
blood	s	sangre		
blow		¿?		
blowby	s	barrido		
blowdown	s	derrame		
blue	s	azul		
body	s	cuerpo		
blueish		¿?		
boil	v	hervir		
boiler		¿?		
book	s	libro		
bone	s	hueso		
borrow		¿?		
both	adj	ambos	pron	ambos, tanto… como…
bottle	s	botella		
bottom	s	parte inferior, fondo		
bracket	s	corchete		
branch	s	rama, sucursal		
break	v	romper, quebrar (irreg. broke, broken)	s	pausa, descanso
breakdown	s	división, desglose, ruptura, disrupción		
break through	s	ruptura, adelanto, avance		
break up	v	separar		
breeder reactor	s	reactor autorregenerador		

brief	adj	breve		
bright		¿?		
bring	v	traer (irreg. brought, brought)		
bring together	v	reunir		
brittle	adj	frágil, quebradizo		
broad	adj	ancho, amplio		
broadcasting	s	transmisión		
bromine		¿?		
Btu	abrev	British thermal unit = unidad térmica británica (unidad de cantidad de calor)		
build	v	construir (irreg. built, built)		
burden	s	carga		
burdensome	adj	pesado, oneroso		
burn	v	quemar		
but	conj	pero, sino	prep	excepto
by	prep	por by bus = en ómnibus		
by product	s	subproducto, producto secundario		

C

calculate	v	calcular		
call	v	llamar/se		
campus		¿?		
can	v. modal	poder		
capability	s	capacidad		
capable	adj	capaz		
capacity	s	capacidad		
carbon	s	carbono		
carburator	s	carburador		
careful	adj	cuidadoso		
carefully	adv	cuidadosamente		
carrier	s	portador/a		
carry	v	llevar, portar		
carry out		¿?		
case	s	caso		
catalysis	s	catálisis		
catalyst	s	catalizador		
catalytical	adj	catalítico		
categorize	v	clasificar/se		
category	s	categoría		
cathode		¿?		
cause	v	causar, hacer (que)		
cease	v	cesar		
cent	s	centavo		
century	s	siglo		
certain	adj	cierto		
challenging	adj	desafiante, exigente		
chamber	s	cámara		
change	v	cambiar, variar	s	cambio
channel	s	canal		
chaos	s	caos		
chapter	s	capítulo		
character	s	caracter (letra), carácter		
characterize	v	caracterizar		
charge	s	carga	v	cargar
cheap	adj	barato		
check	v	controlar, verificar, revisar	s	chequeo
cheese	s	queso		
chemical	adj	químico		
chemist	s	químico (la persona)		
chemistry	s	química		
chief	s	jefe	adj	principal
choice	s	eleccción		
choose	v	elegir (irreg. chose, chosen)		

circulate	v	circular		
cite	v	citar		
clarify	v	clarificar		
classify	v	clasificar		
clean	adj	limpio	v	limpiar
cleansing	s	purificación, limpieza		
cleanup	s	limpieza		
clear	adj	claro		
close	adj	cercano	v	cerrar
close to	adv	cercano a		
clothing	s	ropa, vestimenta		
cloud	s	nube		
coal	s	carbon (mineral)		
coating	s	recubrimiento		
coaxial	adj	coaxil		
coke	s	coque (carbón)		
cold	adj	frío		
collect	v	recoger, captar, cobrar		
colon	s	dos puntos (:)		
color	v	colorear	s	color
combine	v	combinar		
combustor	s	cámara de combustión		
comma	s	coma (,)		
command	s	comando, orden	v	ordenar
comment	s	comentario	v	comentar
common		¿?		
commonplace	adj	común, corriente		
compass	s	brújula		
compact	adj	compacto		
compare	v	comparar		
comparison	s	comparación		
complete	v	completar	adj	completo
completion	s	terminación, conclusión		
complex	adj	complejo		
complexity	s	complejidad		
complicated	adj	complicado		
compose	v	componer		
compound	v	componer, combinar, agravar		
comprehend	v	comprender		
conceivable	adj	concebible, imaginable		
conceive	v	concebir		
concentrate	v	concentrar		
concern	v	relacionar, ocuparse, preocuparse		
conclude	v	concluir		
condensate	s	condensado		
condense	v	condensar/se		
condenser	s	condensador		
conditioner		¿?		
conduction	s	conducción		
conductivity	s	conductividad		
confine	v	confinar, limitar		
confuse	v	confundir		
congregate	v	congregar, agrupar/se		
consenquent	adj	consecuente, consiguiente		
consider	v	considerar		
consist	v	consistir		
consistent	adj	consistente		
constituent	s	componente		
consume	v	consumir		
consumptive	adj	destructivo		
contact	v	contactar, poner en contacto	s	contacto
contain	v	contener		
container	s	contenedor, recipiente		

continue	v	continuar		
continuity	s	continuidad		
continuous		¿?		
contrasting	adj	contrastante		
contribute	v	contribuir		
contributor		¿?		
convective	adj	convectivo		
convenience	s	conveniencia		
convert	v	convertir		
converter	s	conversor, convertidos		
cool	v	enfriar	adj	frío, fresco
co-ordinate	v	coordinar		
copper	s	cobre		
copy	s	copia	v	copiar
corner	s	esquina		
correct	v	corregir		
correspond	v	corresponder		
corrode	v	corroer/se		
cost	s	costo		
could	v modal	podía (pret de can)	condicional = podría	
coulomb		¿?		
count	v	contar		
countless		¿?		
country	s	país, campo		
couple		¿?		
course	s	curso		
courtesy	s	cortesía		
cover		¿?		
crankcase	s	carter		
crankshaft	s	cigüeñal		
create	v	crear		
criterion	s	criterio		
critical	adj	crítico		
crop	s	cultivo, cosecha		
cross-sectional	adj	transversal		
crude	adj	crudo		
cryogenics	s	criogenia, ciencia de fenómenos a temperaturas cercanas a 0 absoluto		
crystalline	adj	cristalino		
current	s	corriente	adj	presente, actual
curve	s	curva		

D

daily		¿?		
dangerous	adj	peligroso		
dark		¿?		
datum	s	dato		
day	s	día		
deal		¿?		
debugger	s	depurador		
decade	s	década		
decide	v	decidir		
decision	s	decisión		
define	v	definir		
definite	adj	definitivo, definido		
deform	v	deformar/se		
degree	s	grado		
dehydrate	v	deshidratar		
deliver	v	entregar		
demand	s	demanda	v	demandar, exigir
denote	v	denotar, indicar		
depend	v	depender		
depend on/upon	v	depender de		

dependable	adj	confiable		
dependence	s	dependencia		
dependent	adj	dependiente		
deplete	v	agotar		
depth	s	profundidad		
derivative	s	derivada		
derive	v	derivar		
desalting	s	desalinización		
describe	v	describir		
design	s	diseño	v	diseñar
designer	s	diseñador		
desirable	adj	deseable		
desire	v	desear	s	deseo
despite	prep	a pesar de		
destroy	v	destruir		
detail	s	detalle		
determine	v	determinar		
develop	v	desarrollar		
development	s	desarrollo		
device	s	aparato, dispositivo, artefacto		
devise		¿?		
devote	v	dedicar		
dictate	v	dictar		
die	s	matriz	v	morir
differ		¿?		
difference	s	diferencia		
difficulty	s	dificultad		
direct	adj	directo	v	dirigir
direction	s	dirección		
disappear	v	desaparecer		
discharge	s	descarga	v	descargar
discover	v	descubrir		
discovery	s	descubrimiento		
discuss	v	discutir, tratar		
disk	s	disco		
disodium	adj	disódico		
disperse	v	dispersar		
displace		¿?		
display	v	mostrar, exhibir	s	muestra, exhibición
dissolve	v	disolver		
distinct	adj	distintivo		
distinguish	v	distinguir		
disturbance	s	perturbación		
diverse	adj	diverso		
divide	v	dividir		
do	v	hacer (irreg. did, done)		
domain		¿?		
dominant	adj	dominante, predominante		
door	s	puerta		
down	adv	hacia abajo		
draft	s	tiro, tiraje, corriente (de aire)		
drawing	s	dibujo		
drift	s	arrastre, deriva		
drill	s	ejercicio, taladro	v	taladrar
drive	v	conducir, impulsar, transmitir (irreg. drove, driven)	s	transmisión, propulsión
drop	s	caída, gota	v	dejar caer
drug	s	droga		
drum	s	tambor		
dry	v	secar	adj	seco
dryer		¿?		
ductile	adj	dúctil		
due to	expr	debido a		
dull	adj	apagado (color)		

during	prep	durante				
dyeing		¿?				

E

e.g.	abrev	por ejemplo (abr de exempli gratia)				
each	adj	cada	pron	cada uno		
early	adj	temprano, primitivo, primeros				
earth	s	tierra				
easy	adj	fácil				
east	s	Este				
echo	s	eco, repetición	v	producir eco		
economic/al	adj	económico				
edit	v	editar				
effect	s	efecto				
efficiency	s	eficiencia, rendimiento				
effort	s	esfuerzo				
either	expr	o… o…, tanto… como…				
either… or…	expr	tanto… como…				
elastic	adj	elástico				
elastically	adv	elásticamente				
elasticity	s	elasticidad				
electrical	adj	eléctrico				
electrogasdynamics	s	dinámica electrogaseosa				
electrolysis	s	electrólisis				
electrolyte	s	electrolito				
electromotive	adj	electromotriz				
eliminate	v	eliminar				
elongation	s	alargamiento				
ember	s	brasa, rescoldo				
embed	v	integrar, arraigar				
emetic	adj	emético, vomitivo				
emit	v	emitir				
emphasis	s	énfasis				
emphasize	v	enfatizar, destacar				
enable		¿?				
enact	v	promulgar				
encounter	v	encontrar				
engine	s	motor, máquina				
engineer	s	ingeniero				
enough	adv	suficiente(mente)				
environment	s	medio, medioambiente				
environmental	adj	ambiental				
equate	v	igualar				
escape	v	escapar/se				
essentially	adv	esencialmente				
establish	v	establecer				
esthetic	adj	estético				
estimate	v	estimar	s	estimación		
ethanol	s	etanol				
evacuate		¿?				
evaporate	v	evaporar				
evaporative	adj	evaporativo				
even	adv	incluso, aún	adj	parejo, par		
even as	expr	en cuanto	even so		adv	aún así
evening	s	noche				
ever		¿?				
every	adj	cada, todo, todos los/las				
everybody/one	pron	cada uno, todos, todo el mundo				
evident	adj	evidente				
examination	s	examen				
examine	v	examinar, evaluar				
example	s	ejemplo				

exceed	v	exceder			
excess	s	exceso			
exchange	s	intercambio, cambio			
exercise		¿?			
exert	v	ejercer			
exhaust		¿?			
exist	v	existir			
expand	v	expander/se			
expander	s	expansor (cámara de expansión)			
expect	v	esperar			
expenditure		¿?			
expensive	adj	caro			
experience	s	experiencia		v	experimentar
explain	v	explicar			
explanatory	adj	explicativo			
exploit	v	explotar			
exposure	s	exposición			
express	v	expresar			
extend	v	extender/se			
extent	s	extensión, punto	in the extent of = en el punto de		
extract	v	extraer			

F

face	v	enfrentar/se		s	cara
fact	s	hecho			
failure	s	falla, defecto			
faint		¿?			
fair		¿?			
fairly	adv	casi, bastante			
fall	v	caer/se		s	caída, catarata, otoño
false	adj	falso			
fan	s	ventilador			
farm	s	granja			
farmer	s	granjero			
fashion		¿?			
fast	adj	rápido			
feasibility	s	factibilidad			
feasible	adj	factible			
feature		¿?			
feedback	s	realimentación			
feel	v	sentir/se (irreg. felt, felt)			
fertilizer	s	fertilizante			
few	adj	pocos	a few = unos pocos		
fiber	s	fibra			
field	s	campo			
figure	s	figura, cifra		v	figurar, imaginar
file	s	archivo, lima		v	archivar, limar
fill	v	llenar, rellenar		s	relleno
fill in	v	completer			
find	v	encontrar (irreg. found, found)			
fine	adj	fino			
fire	v	alimentar, disparar		s	fuego
fireworks		¿?			
first	adj	primero			
fish	s	pez, pescado (plural =fish)			
fit		¿?			
fix		¿?			
flame	s	llama			
flash	s	destello		v	destellar
floor	s	piso			
flow	s	flujo		v	fluir
flue	s	chimenea			

flux	s	flujo (electrico, magnético o luminoso)		
fly	v	volar (irreg. flew, flown)	s	mosca
follow	v	seguir		
food	s	comida, alimento		
foot	s	pie		
for	prep	para, por	conj	pues, ya que, porque
force	s	fuerza	v	forzar
foregoing		¿?		
foresee	v	prever		
forever	adv	para siempre, por siempre		
form	v	formar	s	forma
formidable	adj	formidable, enorme		
forward	adj	inclinado, hacia adelante		
fossil	s	fósil	adj	fósil
fracture	v	fracturar		
free	adj	libre, gratis		
fresh	adj	fresco, nuevo, reciente		
freshwater		¿?		
from	prep	de, desde		
fuel	s	combustible		
fulfill	v	cumplir, llenar		
full	adj	lleno, completo		
fund	v	financiar, destinar fondos	s	fondo
furnace	s	horno		
further	adv	más, adicional		
furthermore	adv	además		

G

G.N.P/ CDP	abrev	Gross Domestic Product = PBI = Producto Bruto Interno		
gage (= gauge)	s	medidor pressure gage = manómetro		
gallon	s	galón (3,8 lts aprox)		
garlic		¿?		
gas	s	gas (a veces gasolina)		
gather	v	reunir, juntar		
generate	v	generar		
geothermal	adj	geotérmico		
get	v	obtener, conseguir, hacerse (irreg. got, got o gotten)		
get tired	v	cansarse		
get to	v	ir a		
give off	v	emitir		
give	v	dar (irreg. gave, given)		
glass	s	vidrio, vaso		
glow	s	brillo	v	brillar
glue		¿?		
go	v	ir (irreg. went, gone)		
good	adj	bueno		
goods	s	bienes, mercancía		
govern	v	gobernar		
governing		¿?		
government	s	gobierno		
grade		¿?		
grain	s	grano		
gram	s	gramo		
graphical	adj	gráfico		
graphite	s	grafito		
gravity	s	gravedad specific gravity 0 = peso específico		
gray	adj	gris		
great	adj	gran, grande		
green	adj	verde		
grind	v	moler (irreg. ground, ground)		
gross		¿?		
ground	s	tierra, suelo		

group	s	grupo		
grow	v	crecer (irreg. grew, grown)		
growth	s	crecimiento		
guide	s	guía	v	guiar
guideline	s	pauta, directiva		
gutter	s	alcantarilla		

H

half	s	mitad		
hand	s	mano		
handle	v	manejar, agarrar, sujetar		
happen	v	suceder		
hardening	s	endurecimiento		
hard		¿?		
harm	v	dañar		
hardness		¿?		
harmful	adj	prejudicial, dañino, nocivo		
have	v	tener (irreg. had, had)		
hazard	s	peligro		
hazardous		¿?		
health	s	salud		
head	s	cabeza		
hear		¿?		
heat	s	calor	v	calentar
heater	s	calefactor, calentador		
heavy	adj	pesado		
help	v	ayudar	s	ayuda
hence	adv	luego, por lo tanto		
here	adv	aquí, acá		
high	adj	alto		
hold	v	mantener, fijar (irreg. held, held)		
home	s	hogar, casa		
hoop	s	aro		
horse	s	caballo		
horsepower	s	caballo de fuerza		
host	s	anfitrión, montón		
hot	adj	caliente		
hour	s	hora		
household	adj	hogareño, domestic		
how	adv	como		
how long	adv	cuánto tiempo		
how many	adv	cuántos		
how much	adv	cuanto		
however	adv	sin embargo		
hula hoop	s	aro para hacer girar alrededor de la cintura		
human-like	adj	similar a un humano		
hundred	num	cien		
hydraulically	adv	hidráulicamente		
hydrolize		¿?		
hydrocarbon	s	hidrocarburo		
hydroelectric	adj	hidroeléctrico		

I

i.e.	adv	es decir (del Latin, abrev. id est: that is)		
if	conj	si		
ignite		¿?		
ignore	v	ignorar		
illustrate	v	ilustrar		
impetus	s	ímpetu		
imply	v	implicar		
impose	v	imponer		

improve	v	mejorar		
in addition (to)		¿?		
incredible	adj	increíble		
in front of	prep	en frente de		
in order to	expr	para (propósito)		
inadequate	adj	inadecuado		
inch	s	pulgada		
include	v	incluir		
income	s	ingresos		
incorporate	v	incorporar		
increase	s	aumento	v	aumentar
indicate	v	indicar		
industrialize	v	industrializar		
inexpensive		¿?		
influence	v	influir	s	influencia
inject	v	mejorar		
injure	v	herir		
input	s	entrada		
insert	v	insertar		
inside	adv	dentro de, adentro	adj	interior
insight		¿?		
insoluble	adj	insoluble		
instance	s	ejemplo		
instant	s	instante		
instruct	v	instruir		
insulator	s	aislante		
intake	s	admisión		
intead		¿?		
integer	s	entero (número entero)		
intensity	s	intensidad		
interchangerability		¿?		
interesting	adj	interesante		
interface	s	interface, superficie de contacto		
intermittant	adj	intermitente		
internal	adj	interno		
intimate		¿?		
into	prep	en, dentro de		
intrauterine	adj	intrauterino		
introduce		¿?		
inventory	s	inventario, cantidad		
invest	v	invertir		
investigation	s	investigación		
investment		¿?		
involve	v	implicar, involucrar, incluir		
ion	s	ion		
ionize	v	ionizar		
iron	s	hierro		
isobutane	s	isobutano		
issue	s	edición, publicación, salida, emisión, problema, cuestión	v	publicar, poner en circulación

J

jet	s	chorro		
job	s	trabajo		
join	v	unirse		
juice	s	jugo		
July	s	Julio		
just	adv	simplemente, sólo, recién	adj	justo
just as	adv	al igual que		

K

keep	v	mantener, conserver (irreg. kept, kept)		
key	s	llave, tecla, clave		
keypad	s	bloque de teclas, teclado		
keyword	s	palabra clave		
kinetic	adj	cinética		
kinetic	s	cinética		
knife	s	cuchillo		
knob	s	manija, perilla, picaporte		
know	v	saber, conocer (irreg. knew, known)		
knowledge	s	conocimiento		

L

label	v	identificar, rotular, etiquetar	s	rótulo, etiqueta
lake	s	lago		
land	v	aterrizar	s	tierra, territorio
language	s	idioma, lenguaje		
large	adj	grande		
last	adj	último	v	durar
late	adj	tarde		
later	adj	más tarde, después		
latter	adj	último		
law	s	ley		
lb	abrev	libra (unidad de peso del sistema inglés)		
lead	s	plomo	v	conducir
leaf	s	hoja		
learn	v	aprender		
leave	v	salir, dejar (irreg. left, left)		
left	s	izquierda	adj	izquierdo
lend		¿?		
length	s	longitud		
less	adj	menos (comparativo de little)	adj	menor
lesser		¿?		
let’s	expr	contracción de let us (imperativo que incluye a la primera persona = (let’s see = veamos)		
lethal	adj	letal		
letter	s	letra, carta		
level	s	nivel		
lever	s	palanca		
liberate	v	liberar		
lie		¿?		
life	s	vida		
lift	v	levantar	s	ascensor (UK)
light	adj	liviano, luminoso	s	luz
like	prep/conj	como	v	gustar
likely		¿?		
limit	v	limitar	s	límite
line	s	línea		
list	v	listar	s	lista
liter	s	litro		
litmus		¿?		
little	adv	poco		
living	s	vida		
load	s	carga	v	cargar
locate	v	ubicar, localizar		
location	s	ubicación, lugar		
locomotive	adj	locomotriz, motriz	s	locomotora
long	adj	largo		
look up	v	buscar		
look	v	mirar	s	apariencia
looking	s	apariencia		
lose		¿?		

loss		¿?		
lost		¿?		
loud		¿?		
low	adj	bajo		
lower	adj	inferior		
lump	v	agrupar		
lunar	adj	lunar		
luster	s	lustre, brillo		

M

machine	v	maquinar	s	máquina
magnet	s	imán		
magnetohydronamics	s	magnetohidrodinámica		
main	adj	principal		
mainstream	adj	prevaleciente, principal, establecido		
maintain	v	mantener		
major		¿?		
make sure	expr	asegurarse		
make up		¿?		
make	v	hacer (irreg. made, made)		
maker	s	fabricante		
makeup	s	reposición		
malfunction	v	funcionar mal		
man	s	hombre		
management	s	dirección, administración, gestión		
manifold		¿?		
mankind	s	humanidad		
manned	adj	tripulado		
manner	s	manera		
manufacture	v	fabricar		
manufacturer	s	fabricante		
manufacturing	adj	manufacturero		
many	adj	muchos/as		
mark	s	marca, símbolo	v	marcar
marketplace	s	mercado		
mass	s	masa		
master	v	dominar		
match		¿?		
matter	s	materia		
may	v. modal	puede que		
mean	v	significar, querer decir	s	media (en matemática)
meaning	s	significado		
means		¿?		
measurable		¿?		
measure	v	medir		
mechanical	adj	mecánico		
mechanism	s	mecanismo		
medicine	s	medicina, medicamento		
medium	s	medio		
meet	v	reunir, encontrar, satisfacer (irreg. met, met)		
melt	v	fundir/se, derretir/se		
memorize	v	memorizar		
microwave	s	microonda		
middle	s	mitad	adj	medio, central
might	v modal	podría (pret y condicional de may)		
mil	s	milésimo		
million	adj	millón		
mindless	adj	sin cerebro		
minimize	v	reducir, minimizar		
minor	adj	menor		
miscellaneous	adj	variado, diverso		
mix	v	mezclar		

mixture	s	mezcla		
mobile	adj	móvil		
mode	s	modo		
moderate	adj	moderado		
moisture	s	humedad		
mold	v	moldear, fundir en molde		
mole	s	mol		
molten	adj	fundido, derretido		
monoxide	s	monóxido		
more	adj	más	adv	más
moreover	adv	además		
most of	adj	la mayor parte de, la mayoría de		
most	adj	más		
mostly	adv	principalmente		
motion	s	movimiento		
mountainous	adj	montañoso		
move	v	mover/se		
movement	s	movimiento		
mph	abrev	miles per hour (millas por hora)		
much	adj	mucho		
multiplicity	s	multiplicidad		
must	v. modal	deber		

N

narrow	adj	angosto		
nationwide	adj	nacional, a escala nacional		
nature	s	natulareza		
near	v	acercarse	adv	cerca (de)
nearly	adv	casi, aproximadamente		
necessitate	v	necesitar		
necking	s	estrechamiento, reducción de la sección		
need	v	necesitar	s	necesidad
neglect	v	despreciar, no considerar		
neither… nor…	adv	ni… ni…		
net	adj	neto		
network	s	red (eléctrica), cadena (de emisoras)		
neutralize	v	neutralizar		
nevertherless		¿?		
next	adj	próximo, siguiente		
Nile	nombre propio	Nilo		
nitrate	s	nitrato		
nitric	adj	nítrico		
no one /nobody	pron	nadie		
no	adj	ningún		
nonmetal		¿?		
nonmetallic		¿?		
nonpoisonous		¿?		
nonrenewable	adj	no renovable		
nonuniform		¿?		
normality	s	normalidad		
north	s	Norte		
note	v	notar, observar	s	nota
nothing	s	nada		
notice	v	notar, observar	s	nota, anuncio
nowhere	adv	en ninguna parte		
noxious	adj	nocivo		
nucleus	s	núcleo		

O

obey	v	obedecer		
observe	v	observar		
obtain	v	obtener		

obvious	adj	obvio		
occupy	v	ocupar		
occur	v	ocurrir, producirse		
odor	s	olor		
of course	expr	por supuesto		
offer	v	ofrecer		
often	adv	a menudo		
oil	s	aceite, petróleo		
old	adj	viejo		
on	prep	sobre, en		
once through	expr	una vez terminado		
once	adv	una vez	conj	una vez que
only	adv	solo, solamente		
opaque	adj	opaco		
open		¿?		
operate	v	operar, funcionar, hacer funcionar		
opportunity	s	oportunidad		
opposite	adj	opuesto		
or so	expr	aproximadamente		
order		¿?		
ordinary	adj	común		
originate	v	originar/se		
other	adj	otro		
out	prep	afuera, fuera		
outer	adj	exterior		
output	s	salida, potencia efectiva, producción		
outside	adj	exterior, externo	s	exterior
outward		¿?		
over	prep	sobre		
overcome		¿?		
overlying	adj	sobrepuesta		
own		¿?		
ox	s	buey (pl : oxen)		
oxide	s	óxido		
oxidize	v	oxidar		
oxidizer	s	oxidante		
oyster	s	ostra		

P

pace	s	paso, ritmo		
paddle	s	paleta		
page	s	página		
pair	s	par		
paper	s	papel		
parent	s	padre, madre, origen		
part	s	parte, pieza		
particle	s	particula		
particulate	s	particula (en forma de partícula=		
pass	s	pase	v	pasar
passage	s	pasaje		
past	adj	pasado		
path	s	camino, recorrido, trayectoria		
pattern	s	patrón, modelo		
peak	s	pico, máximo		
people	s	gente, personas, pueblo		
per	prep	por		
percentage	s	porcentaje		
perform	v	realizar		
performance	s	actuación, rendimiento, funcionamiento		
perhaps		¿?		
period	s	período		
phase	s	fase		

physics	s	física		
picture	s	figura, cuadro, película	v	visualizar, imaginar
pig	s	cerdo pig iron = arrabio		
pile	s	pila, montón		
pipe	s	caño		
place	v	colocar	s	lugar
plan		¿?		
plane	s	plano, avión (airplane)		
play	v	jugar, tocar		
please	expr	por favor		
plug	s	enchufe, clavija spark plug = bujía de automóviles		
plus		¿?		
point out	v	señalar		
point	s	punto		
poison	s	veneno		
poisonous		¿?		
pole	s	polo, poste		
pollutant	s	contaminante		
pollute	v	contaminar		
polluter		¿?		
pollution	s	polución		
pond		¿?		
poor	adj	pobre		
pop		¿?		
population	s	población		
porous	adj	poroso		
pose	v	plantear		
pound	s	libra (450 gr); abrev lb		
powder	s	polvo		
power	s	potencia, poder		
powerful		¿?		
ppm	abrev	parte por millón		
practice	s	práctica	v	practicar
predict	v	predecir		
predefined	adj	predefinido		
prefer	v	preferir		
presence	s	presencia		
preserve	v	preservar		
press	v	presionar, oprimir, apretar, prensar	s	prensa
pressure	s	presión		
prevent	v	impedir, evitar		
previous	adj	previo		
primary	adj	primario		
principle	s	principio		
print	v	imprimir		
printer	s	impresora		
prior	adj	previo, anterior		
proceed	v	proseguir, continuar		
process	s	proceso		
processing	s	procesamiento		
profound	adj	profundo		
progressive	adj	progresivo		
proper	adj	apropiado, propio		
property	s	propiedad		
proportionality	s	proporcionalidad		
propose	v	proponer		
prove	v	probar		
provide	v	proveer, suministrar		
provided	conj	con tal que, a condición de que, siempre que		
provision	s	provisión, disposición		
psia	abrev	pounds per square inch absolute = libras por pulgadas cuadrada absoluta		
pull	v	tirar	s	tiro
pump	s	bomba	v	bombear

pure		¿?		
purify	v	purificar		
purpose	s	propósito, aplicación		
push	v	empujar	s	empuje
put	v	poner (irreg. put, put)		

Q

quality	s	calidad		
quantitative	adj	cuantitativo		
quantity	s	cantidad		
quart	s	cuarto de galóm (aprox. 1 litro)		
quenching		¿?		
question	s	pregunta		
quickly	adv	rápidamente		
quite	adv	bastante		
quotation mark	expr	comillas		
quote	s	comilla	v	citar

R

radiate	v	irradiar, radiar		
radiation	s	radiación		
radiator	s	radiador		
radical	s	radical (química)	adj	radical
radioisotope	s	radioisótopo		
radius	s	radio (de una circunferencia)		
rail	s	riel		
rain	s	lluvia		
raise	v	elevar		
range	v	oscilar, variar		
rapid	adj	rápido		
rat	s	rata		
rate	s	velocidad, ritmo, tarifa, índice	v	clasificar, tasar
rather	adv	mas bien		
ratio	s	cociente, relación		
raw		¿?		
ray	s	rayo		
reach		¿?		
react	v	reaccionar		
reactant	s	reactivo		
reader		¿?		
ready	adj	listo, preparado, rápido		
real	adj	real		
realgar	s	rejalgar (mineralogía)		
reality	s	realidad		
realize	v	darse cuenta		
rearrange		¿?		
reason	s	razón	v	razonar
recall	v	recordar		
recent	adj	reciente		
reciprocating	adj	alternativo		
recognize		¿?		
recover	v	recuperar		
recovery	s	recuperación		
red	s	rojo	adj	rojo
reddish		¿?		
reduce	v	reducir		
refer (to)	v	referirse, mencionar		
refine	v	refinar		
reflect	v	reflejar		
regarding	prep	con respecto a, relativo a		
regardless of	adv	independientemente de		
regionalized		¿?		

reinforce	v	reforzar			
reject	v	rechazar, desechar			
rejection	s	rechazo, desecho			
relate	v	relacionar			
relationship	s	relación			
relativity	v	relatividad			
release	v	liberar			
reliable	adj	confiable			
reliance	s	dependencia, confianza			
rely	v	depender, contar, confiar			
remain	v	permanecer			
remark	s	acotación, comentario			
remember	v	recordar			
remind	v	hacer recordar			
removal	s	remoción, extracción			
renewable	adj	removable			
repair	v	reparar			
replace	v	reemplazar			
report	v	informar, reportar		s	informe
reproduce	v	reproducir			
require	v	requerir			
requirement	s	requisito			
research	s	investigación			
researcher	s	investigador			
resemble		¿?			
reserve	s	reserva		v	reservar
resistance	s	resistencia			
resistor	s	resistor			
resource	s	recurso			
rest		¿?			
restrict	v	restringir			
return	v	volver		s	retorno
reuse		¿?			
review	s	repaso		v	repasar
right	s	derecha, derecho		adj	derecho, correcto
rigid	adj	rígido			
river	s	río			
roasting	s	calcinación, tostado, asado			
robotics	s	robótica			
rock	s	roca			
rocket	s	cohete			
rod	s	vara, varilla	connecting rod : biela		
role	s	rol, papel			
roll	v	rodar			
roof	s	techo			
room	s	habitación, ambiente			
rotating	adj	rotativo			
rough		¿?			
route	s	ruta			
row	s	fila			
rule	s	regla			
run	v	correr, ejecutar, hacer funcionar, andar (irreg. ran, run)		s	recorrido, tramo
runoff	s	circulación, caudal			
rust		¿?			

S

safe	adj	seguro	
safety	s	seguridad	
sale		¿?	
salt	s	sal	
same	adj	mismo	the same as = lo mismo que
sample	s	muestra	

sampling		¿?		
say	v	decir (irreg. said, said)		
scale	s	escala, balanza		
scatter	v	espacir, dispersar		
scene	s	escena		
schematic	s	esquema		
scientific	adj	científico		
scientist	s	científico (persona)		
scope	s	alcance		
score	s	puntaje	v	tener puntaje
screen	s	pantalla		
second	adj	segundo (número ordinal)		
see	v	ver (irreg. saw, seen)		
segregate	v	segregar		
seldom	adv	rara vez		
select	v	seleccionar		
selective	adj	selectivo		
self-	prefijo	auto-		
self-explanatory	adj	auto-explicativo		
semicolon	s	punto y coma (;)		
send	v	enviar (irreg. sent, sent)		
sentence	s	oración, sentencia		
separate	v	separar		
separator	s	separador		
serious		¿?		
serve		¿?		
server	s	servidor		
service	s	servicio		
sesquisulfide	s	sesquisulfuro		
shell		¿?		
set	s	juego, equipo, aparato, conjunto	v	colocar, fijar (irreg. set, set)
settling	s	decantación, asentamiento		
several	adv	varios		
severe	adj	severo, riguroso		
severity		¿?		
sewage	s	efluentes cloacales		
shaft		¿?		
shale	s	esquisto oil shale = esquisto bituminoso		
shall	verbo aux	se utiliza para indicar el tiempo futuro con las primeras personas I, we)		
shape	s	forma	v	dar forma
share		¿?		
sharp	adj	agudo, afilado, abrupto		
sheet	s	hoja, lámina, chapa		
shift	v	cambiar, conmutar	s	cambio, turno
shine	s	brillo	v	brillar
short	adj	corto, bajo		
should	v modal	debería (se utiliza para sugerencias)		
show up	v	aparecer		
show	v	mostrar (irreg. showed, shown)	s	espectáculo
side	s	lado, extremo, polo		
sign	s	signo, cartel	v	firmar
signal	s	señal		
significance	s	importancia		
significant		¿?		
silicone	s	silicio		
similarly	s	similitud		
simplicity	s	simplicidad		
simply	adv	simplemente		
since	conj	dado que, ya que	prep	desde
single	adj	único		
sit	v	sentarse, asentarse (irreg. sit, sit)		
size	s	tamaño, talle		
sketch	v	dibujar		

skill	s	habilidad		
sky	s	cielo		
slide	v	deslizar/se (irreg. slid, slid)	s	deslizamiento
slight		¿?		
slow	adj	lento		
small	adj	pequeño		
smoke	s	humo		
smooth	adj	liso, suave		
so as	expr	de modo de, de madera de		
so-called	expr	llamado		
soft	adj	suave		
softening		¿?		
solar	adj	solar		
solve	v	resolver, solucionar, disolver		
some	adj	algunos/as		
someone/somebody	pron	alguien	adj	algún, alguna, algunos/as
somehow	adv	de alguna manera		
something	pron	algo		
sometimes	adv	a veces, algunas veces		
somewhat	adv	algo, un poco		
somewhere	adv	en alguna parte		
soon	adv	pronto		
sort	s	especie, clase	v	brillar, elegir (irreg. shone, shone)
so that	conj	de manera que/ tal, para que		
sound	s	sonido, caleta (de mar)	adj	sólido
soundproofing	adj	insonoro, aislante acústico		
source	s	fuente		
south	s	Sur		
southwestern		¿?		
space	s	espacio	v	separar
space-heating	expr	calefacción de ambiente		
spark	s	chispa	v	encender
spark plug	s	bujía		
speaking	s	habla		
specialize	v	especializar/se		
species	s	especie, clase		
specify		¿?		
specimen	s	espécimen, probeta		
speculate	v	especular		
spend		¿?		
spot		¿?		
sprawl	v	extender		
sprinkler	s	rociador, pulverizador		
stable	adj	estable		
stack	s	chimenea		
stage	s	etapa		
stand for	v	representar, significar		
stand	v	quedarse, permanecer, pararse		
standard	adj	normal, común	s	norma
stannate		¿?		
statement	s	enunciado, oración		
station	s	estación power station = estación eléctrica		
stationary	adj	estacionario		
steady	adj	constante, permanente		
steam	s	vapor (de agua)		
steel	s	acero stainless steel = acero inoxidable		
step	s	paso step by step = paso a paso		
stick		¿?		
still	adv	aún, todavía		
stimulate	v	estimular		
stop	v	parar, detener	s	parada
store	v	acumular, almacenar	s	tienda, negocio
straight	adj	derecho, recto		

strain	s	deformación	v	estirar, tensar
stream		¿?		
street	s	calle		
strength	s	resistencia, fortaleza		
stress	s	esfuerzo, tensión	v	someter a esfuerzo
strick		¿?		
strike	v	pegar, golpear, alcanzar, chocar contra (irreg. struck, struck)		
striking	adj	sorprendente, asombroso		
string	s	cadena (en computación), cuerda		
stroke	s	golpe, recorrido, carrera (motores)		
strong	adj	fuerte		
structure	s	estructura		
study	v	estudiar	s	estudio
stuff	s	material, material, product		
stupendous	adj	estupendo, prodigioso, formidable		
style	s	estilo		
subject	v	someter	s	sujeto, tema
sublime	v	sublimar/se		
substitute	v	sustituir		
success	s	éxito		
successor	s	sucesor		
such that	expr	de tal manera que		
such	adj	tales, dichos such a (adj) = tal, dicho	such as (prep) = tal/es como	
suggest	v	sugerir		
suit		¿?		
sulfur	s	azufre		
summarize	v	resumir		
summary	s	resumen		
superheated	adj	sobrecalentado		
supervise	v	supervisar		
supply	s	suministro, fuente		
support	v	soportar	s	soporte
suppose	v	suponer		
sure	adj	seguro be sure = asegurarse		
surface	s	superficie		
surgery	s	cirugía		
surpass	v	sobrepasar, superar, aventajar		
surprise		¿?		
surround	v	rodear, circundar		
surroundings		¿?		
swimming pool	s	pileta de natación		
switch	s	interruptor (llave)	v	cambiar
synthetic	adj	sintético		

T

table	s	mesa, table (numérica)
tabulate	v	tabular
take for granted		¿?
take into account		¿?
take place	v (expr)	tener lugar, ocurrir
take	v	tomar, llevar (irreg. took, taken)
takeoff	s	despegue (aviación)
talk	v	hablar, conversar
tall	adj	alto
tank	s	tanque
tarnish	v	perder el brillo, empañarse, mancharse
task	s	tarea
teach	v	enseñar (irreg. taught, taught)
technique	s	técnica
tell	v	decir (irreg. told, told)
tend	v	tender
tendency	s	tendencia

tensile	s	tensión, tracción		
tension	s	tensión, tracción		
term	s	término, plazo		
terrain	s	terreno		
test	s	ensayo, prueba	v	ensayar, probar
than	conj	que (en comparativo)		
that is	expr	es decir		
that	adj dem	ese, esa, aquel, aquella	pron	eso, aquello , que
their	adj pos	su/s		
them	pron obj	los, las, les, ellos, ellas		
themselves	pron reflex	ellos mismos		
then	adv	luego, entonces	conj	entonces, en ese caso
theory	s	teoría		
there are	v	hay (presente del verbo “there be” usado delante de formas plurales)		
there is	v	hay (presente del verbo “there be” usado delante de formas singulares)		
thereby		¿?		
therefore	adv	por lo tanto		
thermal	adj	térmico		
thermodynamics	s	termodinámica		
thermionic	adj	termoiónico		
thermonuclear	adj	termonuclear		
these	adj dem	estos, estas	pron	éstas, estos
thick	adj	grueso, espeso		
thin	adj	delgado		
this	adj dem	este, esta	pron	esto
those	adj dem	esos, esas, aquellos, aquellas	pron	aquellos, aquellas
thourough	adj	completo, exhaustivo		
thousand	num	mil		
threat	s	amenaza		
threaten		¿?		
through (thru)	prep	a través de		
throughout	adv	completamente, por todos lados	prep	por todo, en todo
thrust	s	empuje, impulso		
thus far		¿?		
thus	adv	así		
tie	v	atar, ligar		
time	s	tiempo, hora, vez, momento		
tin	s	estaño		
to	prep	a		
today	adv	hoy		
together	adv	juntos		
tomorrow	adv	mañana	s	mañana
ton	s	tonelada		
tonnage		¿?		
tool	s	herramienta		
tooth	s	diente		
top	s	parte superior		
toward	prep	hacia		
towel	s	towel		
tower	s	torre		
tract	s	aparato (anatomía)		
transfer	s	transferencia	v	transferir
transform	v	transformar		
translate	v	traducir		
translation	s	traducción		
transport	v	transportar		
travel	v	viajar, recorrer, moverse		
treat		¿?		
treatment		¿?		
trend	s	tendencia		
truck	s	camión		
true	adj	verdadero		
try	v	probar, intentar		

tube	s	tubo		
turn off		¿?		
turn on		¿?		
turn		¿?		
twentieth	num	vigésimo		
type	v	escribir (a máquina), tipear	s	tipo

U

under	prep	bajo, debajo de		
undergo	v	sufrir, soportar (irreg. underwent, undergone)		
underneath	prep	debajo de, bajo	adv	debajo
understand	v	entender		
undesirable	adj	indeseable		
unify	v	unificar		
unite	v	unir/se		
unknown	dj	desconocido		
unless	conj	a menos que, a no ser que		
unlike	prep	a diferencia de, contrariamente a		
until	conj	hasta	prep	hasta
up to	prep	hasta		
up	adv	hacia arriba		
upon		¿?		
upper	adj	superior		
upward	adv	hacia arriba	adj	ascendente
us	pron obj	nosotros/as, nos		
use	s	uso	v	usar
useful	adj	útil		
useless	adj	inútil		
utility	s	instalación		
utilize	s	utilizar		

V

vacuum	s	vacío		
value	s	valor		
valuable		¿?		
valve	s	válvula		
vanish	v	desaparecer		
vaporize	v	vaporizar		
variety	s	variedad		
various	adj	diversos		
vary	v	variar		
vast	adj	vasto		
verify	v	verificar		
very	adv	muy		
vessel	s	recipiente, vasija, navío		
visualize	v	visualizar		
vital	adj	vital		
viz	abrev	es decir (del Latín videlicet) i.e = that is = namely		
voice	s	voz		
volatile	adj	volátil		
voltage	s	tensión, voltaje		

W

wall	s	pared		
want	v	querer		
warm	adj	caliente, cálido		
was	v	era/estaba (irreg. pret. de to be)		
waste	s	desperdicio, desecho	v	desperdiciar, perder
watch	v	observar, mirar, vigilar	s	reloj, vigilancia
water	s	agua		
waterwheel	s	rueda hidráulica		

wave	s	onda		
way	s	modo, manera, vía, camino		
weak	adj	débil		
weather	s	tiempo, clima		
week	s	semana		
weigh	v	pesar		
weight	s	peso		
weld	v	soldar		
welfare	s	bienestar		
well	s	pozo	adv	bien
were	v	eran/estaban, éramos/estábamos (irreg. pret. de to be)		
west	s	Oeste		
what	pron rel	lo que,	pron interr.	qué, cual
when	adv	cuando	pron interr.	cuando
whenever	adv/conj	cada vez que, cuando, en cualquier momento		
where	adv	donde, adonde		
whereas	conj	mientras que		
wherein	adv	en donde		
whether	conj	si		
which	pron	que, el cual/la cual	pron interr	cuál
while	conj	mientras (que)		
white	adj	blanco		
who	pron rel	quien	pron interr	quien
whole		¿?		
whose	pron rel	cuyo	pron interr	de quien
why	adv	por qué	pron interr	por qué
wide	adj	amplio, ancho		
widespread	adj	extendido		
width		¿?		
will	v. aux	se emplea para formar el futuro (no se traduce)		
wind	s	viento		
windmill	s	molino de viento		
wire	s	cable, alambre		
with	prep	con		
withdrawal	s	extracción, retiro, remoción		
within	prep	dentro		
without	prep	sin		
wood	s	madera		
work	v	trabajar, funcionar	s	trabajo
workplace	s	lugar de trabajo		
world	s	mundo		
worldwide	adj	mundial		
worry	v	preocuparse		
worse	adj	peor (comparative de bad)	adv	peor
worst	adj	peor (imperative de bad)	adv	peor
worth	prep	que vale, equivalente		
would	v modal	no se traduce, indica modo potencial		
write	v	escribir (irreg. wrote, written)		
write down	v	anotar, escribir		
wrong	adj	incorrecto, equivocado		
wrought iron	expr	hierro forjado, hierro dulce, hierro suave		

Y

year	s	año over the years = con el correr de los años		
yellow	s	amarillo	s	amarillo
yesterday	adv	ayer		
yet		¿?		
yield	v	producir		
yield point	expr	punto de fluencia, límite elástico		
yield strength	expr	límite elástico		
young	adj	jóven		
your	adj pos	su (de Ud., de Uds.)		