

Chapter 1: Introduction to the World of Energy

Goals of Period 1

- Section 1.1: To introduce The World of Energy
- Section 1.2: To define ratios and “per”
- Section 1.3: To review scientific notation
- Section 1.4: To introduce energy sources
- Section 1.5: To define and illustrate linear and exponential growth

1.1 Introduction to the World of Energy

The World of Energy courses explore the basic principles of physics in the context of energy use. The courses include practical examples from everyday life to help you use energy safely and wisely. They help prepare you to make rational, informed decisions regarding energy policy, the environment, and your own place in the changing World of Energy. The World of Energy courses, Physics 103 and 104, are a 10-credit hour, two-quarter sequence that fulfill the GEC physical science requirement for the Bachelor of Arts degree at The Ohio State University.

The World of Energy uses a hands-on approach to investigate physics concepts, energy use, and the effects of its use on our environment. Through class activities and demonstrations, the World of Energy gives students an opportunity to experience first hand the laws of physics. Physics concepts are conveyed by your instructor, this textbook, activity sheets completed during class, and weekly lecture videos.

Class Activities

During two 2-hour classes per week, your instructor will explain physics concepts, present demonstrations, and introduce hands-on activities to illustrate these concepts. To help organize, understand, and remember the information from the demonstrations and class activities, students complete and turn in activity sheets during each class. Students must be present for the full class period to receive credit for an activity sheet unless excused by the instructor. Activity sheets are found in Part I of the *Physics 103 Activity Book*.

Lectures

In addition to attending two 2-hour classes per week, students attend a 1-hour lecture. At most lectures, you will see a video or hear a speaker discussing energy use. These videos and lectures are an important part of the course. They explain physics principles and help relate these principles to the role of energy in everyday life. A list of questions for each video is included in Part II of the *Physics 103 Activity Book*. These questions help students identify important concepts in the videos. Answers to these video questions are not handed in. Instead, students write and turn in a summary of at least two paragraphs of each lecture video. The dates of the lectures are given in the course syllabus. Midterm and final exams will include questions based on the material in the lectures.

Examinations

The course examinations consist of two midterms of 30 questions each and a comprehensive final examination of 45 questions. All exam questions are multiple choice. Midterm exams are given during the lecture hour. The dates of the examinations are given in the course syllabus. **No** make-up examinations will be given. If you have a conflict with any of the exam times, notify your instructor immediately.

Students may use calculators during exams, but may not program them or use their graphing capabilities. Exams include a sheet with useful equations and constants. Equation sheets are provided because the World of Energy emphasizes understanding concepts, rather than memorizing equations and constants. However, it is essential that students understand the meaning of the equations, their symbols, and their units. Part III of the *Physics 103 Activity Book* contains six practice exams with equation sheets. The textbook provides help in understanding equations and solving problems in the Skills and Strategies and Concept Check solutions.

Textbook

Each chapter of this textbook corresponds to one class period. To get the most benefit from class, students should read the text prior to each class. The text contains Concept Check questions to check your understanding of the material. We suggest that students write answers to the Concept Check questions in the textbook. If you cannot answer a Concept Check question, reread the text, review the examples, and study the Skills and Strategies help boxes. Answers to the Concept Check questions are given in Appendix A.

Each chapter ends with Exercises and Review Questions. At the beginning of each class period, students turn in answers to selected Exercise questions. The course syllabus lists the questions assigned for each period and their due date. Prior to class, you should look over the all the Exercise and Review Questions and attempt to answer them, as your instructor will discuss these questions during class.

How to Succeed in The World of Energy

In the World of Energy, students learn physics concepts primarily by doing activities in class, observing instructor demonstrations, and participating in class discussions. While your textbook contains important information and should be read before each class, it does not provide all the information you will need – some physics concepts have been left for you to discover in your classroom activities. *Therefore, class attendance and active participation is very important.*

In the World of Energy we will explore different forms of energy and the many ways in which energy is used to do work. We begin by discussing some of the mathematical tools used in the course.

1.2 Ratios and “per”

To simplify comparisons among quantities, information is often presented as a ratio. A ratio is a fraction, or one quantity divided by another quantity. For example, to travel at a speed of 60 miles per hour means going a distance of 60 miles for each hour of travel, or 60 miles/1 hour, a fraction which is read as “60 miles per hour.” The word *per* means *for each* and designates a ratio. *Per* indicates division, and the meaning of the ratio depends on which quantity is the divisor.

(Example 1.1)

If gasoline costs \$1.25 per gallon,

$$\frac{\$1.25}{1 \text{ gal}} = \text{the cost of 1 gallon of gas and}$$
$$\frac{1 \text{ gal}}{\$1.25} = \frac{0.8 \text{ gal}}{\$1.00} = \text{the number of gallons purchased for \$1.00}$$

One common use of ratios is to represent the efficiency of an energy process. When coal is burned in a power generating plant, the energy stored in the coal is converted into electrical energy, which we call **electricity**. However, during the conversion process, some of the coal’s energy is converted into forms of energy other than electricity. This energy is wasted as far as production of electricity is concerned. The efficiency of an energy conversion process equals the ratio of the amount of energy of the desired type produced (the energy of the electricity) per total amount of energy put into the conversion process (the energy of the coal). Equation 1.1 describes this relationship.

$$\text{Efficiency} = \frac{\text{Useful Energy Out}}{\text{Total Energy In}} \quad \text{(Equation 1.1)}$$

Example 1.2 illustrates the calculation of energy efficiency using joules of energy, the usual unit of energy measurement.

(Example 1.2)

What is the efficiency of an energy conversion that requires 600 joules of energy to produce 200 joules of useful energy?

$$\text{Efficiency} = \frac{\text{Useful Energy Out}}{\text{Total Energy In}} = \frac{200 \text{ joules}}{600 \text{ joules}} = 0.33 = 33 \%$$

We have rounded the answer to two digits and converted from a decimal to a percent by multiplying by 100.

Another important use of ratios is to convert a quantity from one unit into another as explained in the Skills and Strategies hint below.

Skills and Strategies #1: Converting Units

To convert a quantity from one type of unit to another, for example from hours to minutes, use ratios to cancel the unit you wish to eliminate. Ratios can be formed from any two equivalent quantities, such as 60 min = 1 hour or 365 days = 1 year.

To convert hours into minutes, multiply by a ratio with units of hours in the denominator to cancel hours from the numerator.

$$3 \text{ hours} \times \frac{60 \text{ min}}{1 \text{ hour}} = 180 \text{ min}$$

To convert 20 minutes into hours, multiply by a ratio with units of hours in the numerator.

$$20 \text{ min} \times \frac{1 \text{ hour}}{60 \text{ min}} = \frac{20 \text{ hours}}{60} = \frac{1}{3} \text{ hour}$$

The same strategy can be used repeatedly to convert hours into seconds:

$$3 \text{ hours} \times \frac{60 \text{ min}}{1 \text{ hour}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 10,800 \text{ sec}$$

(Example 1.3)

There are 1,609 meters per 1 mile. Use ratios to convert 60 miles per hour into meters per second.

$$\frac{60 \text{ miles}}{1 \text{ hour}} \times \frac{1,609 \text{ meters}}{1 \text{ mile}} \times \frac{1 \text{ hour}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = \frac{27 \text{ meters}}{1 \text{ sec}}$$

To check your understanding of this material, write the answers to Concept Check 1.1 below. Solutions to the Concept Checks are given in Appendix A.

Concept Check 1.1

- a) What is the meaning of $\frac{52 \text{ weeks}}{1 \text{ year}}$? _____
of $\frac{1 \text{ year}}{52 \text{ weeks}}$? _____
- b) How many minutes are there in 7 hours? _____
- c) How many seconds are there in 30 days? _____

Skills and Strategies #2: Review of Algebraic Operations

The previous Skills and Strategies stated that a ratio can be written in two ways. For example, 1 day = 24 hours can be written as 24 hours/1 day or as 1 day/24 hours. Why can we invert the ratio? The answer is that we have made a ratio of equal quantities. Such ratios often involve the equalities 1 day = 24 hours, 1 minute = 60 seconds, or 1 mile = 1,609 meters.

To illustrate why we can write ratios as 1 day/24 hours or as 24 hours/1 day, we start with the equality, 24 hours = 1 day, and divide both sides of the equation by 1 day, canceling units.

$$\frac{24 \text{ hours}}{1 \text{ day}} = \frac{1 \text{ day}}{1 \text{ day}} \quad \text{or} \quad \frac{24 \text{ hours}}{1 \text{ day}} = 1$$

To invert the ratio, we make use of the fact that ***an equation is unchanged when we perform the same operation on each side of the equation.*** First we multiply both sides of the equation by 1 day and cancel:

$$1 \times 1 \text{ day} = \frac{24 \text{ hours}}{1 \text{ day}} \times 1 \text{ day}; \quad \text{or} \quad 1 \text{ day} = 24 \text{ hours}$$

Then we divide both sides of the equation by 24 hours and cancel:

$$\frac{1 \text{ day}}{24 \text{ hours}} = \frac{24 \text{ hours}}{24 \text{ hours}}; \quad \text{or} \quad \frac{1 \text{ day}}{24 \text{ hours}} = 1$$

Using the above algebraic operations, we have shown that a ratio of equal quantities is equal to its inverse: 24 hours/1 day is equal to 1 day/24 hours.

What about ratios of unequal quantities? When converting units, you might incorrectly choose ratios that give you the inverse of the answer you wanted. If so, you can get the ratio you want ***if you invert and divide the numerator by the denominator.***

For example, you are asked to find the gallons of gasoline used for every mile traveled (gallons/mile), but you have an expression in units of miles/gallon. To obtain the expression you want, invert the ratio and divide the numerator by the denominator.

$$\frac{17 \text{ miles}}{1 \text{ gallon}} = \frac{1 \text{ gallon}}{17 \text{ miles}} = \frac{1/17 \text{ gallons}}{\text{mile}} = \frac{0.059 \text{ gallons}}{\text{mile}}$$

1.3 Scientific Notation (Powers of Ten)

A number in ***scientific notation*** is written with one digit to the left of the decimal point times 10 raised to an exponential power. In scientific notation, 2,400 is written as 2.4×10^3 . The number raised to the exponential power is called the base.

Scientific notation uses the base 10 and is sometimes called **powers of 10**. Very large and very small numbers are more easily expressed and manipulated when written in scientific notation. For example,

The amount of energy used per day = 160,000,000 barrels of oil = 1.6×10^8 barrels.

The diameter of an atomic nucleus = 0.000 000 000 000 005 meters = 5.0×10^{-15} m.

To find the exponent, or power of base 10, count the number of places the decimal places is shifted to the left for positive exponents or shifted to the right for negative exponents. A positive exponent of 10 indicates how many times the base 10 is multiplied by itself. A negative exponent indicates how many times 1 is divided by 10. Any number to the power zero equals one.

$$10^3 = 10 \times 10 \times 10 = 1,000$$

$$10^2 = 10 \times 10 = 100$$

$$10^1 = 10$$

$$10^0 = 1$$

$$10^{-1} = 1/10 = 0.1$$

$$10^{-2} = 1/(10 \times 10) = 0.01$$

$$10^{-3} = 1/(10 \times 10 \times 10) = 0.001$$

Table 1.1: Rules for Using Scientific Notation

1. When multiplying powers of 10, add their exponents.

$$10^A \times 10^B = 10^{(A + B)}$$

$$10^5 \times 10^3 = 10^{(5 + 3)} = 10^8 = 100,000,000$$

$$10^2 \times 10^{-3} = 10^{(2 + (-3))} = 10^{-1} = 1/10 = 0.1$$

2. When dividing powers of 10, subtract their exponents.

$$10^A / 10^B = 10^{(A - B)}$$

$$10^4 / 10^6 = 10^{(4 - 6)} = 10^{-2} = 1/10^2 = 1/100 = 0.01$$

$$10^1 / 10^{-2} = 10^{(1 - (-2))} = 10^{(1 + 2)} = 10^3 = 1,000$$

3. When raising a power to of 10 to a power, multiply the exponents.

$$(10^A)^B = 10^{(A \times B)}$$

$$(10^4)^2 = 10^{(4 \times 2)} = 10^8 = 100,000,000$$

4. Any number raised to the power zero equals 1.

$$A^0 = 1 \quad 10^0 = 1; \quad 27^0 = 1; \quad 43,836^0 = 1$$

Skills and Strategies #3: Powers of Ten and Calculators

To enter a number in scientific notation, press the 10^X key and enter the exponent. If the 10^X symbol is above a key, press 2^{nd} F before pressing the 10^X key.

For example, to enter 8×10^{12} , press $\boxed{8} \boxed{\times} \boxed{10^X} \boxed{1} \boxed{2}$

To enter 3×10^{-6} , press $\boxed{3} \boxed{\times} \boxed{10^X} \boxed{+/-} \boxed{6}$

Some calculators use reverse notation in which the exponent is entered before the 10^X key is pressed. To enter 3×10^{-6} , press $\boxed{3} \boxed{\times} \boxed{6} \boxed{+/-} \boxed{10^X} \boxed{=}$

If your calculator has an EE or EXP key, press that key and then enter the exponent.

To enter 3×10^{-6} , press $\boxed{3} \boxed{\text{EE}}$ or $\boxed{\text{EXP}}$ and then $\boxed{+/-} \boxed{6}$

IMPORTANT NOTE: A calculator's y^x key does NOT give powers of 10.

For example, 3.4^8 is **NOT** the same as 3.4×10^8

Concept Check 1.2

- a) How much is $(2 \times 10^4) \times (5 \times 10^3)$? _____
- b) How much is $(6 \times 10^{-9}) / (3 \times 10^3)$? _____
- c) Which number is larger: 4.7×10^{-3} or 3.2×10^{-2} ? _____

Some powers of ten have common names:

one million	=	1,000,000	=	10^6
one billion	=	1,000,000,000	=	10^9
one trillion	=	1,000,000,000,000	=	10^{12}

Standard prefixes for powers of ten are shown in Table 1.2. For example, 5 nanoseconds = 5 nsec = 5×10^{-9} seconds.

Table 1.2: Standard Prefixes Denoting Powers of Ten

Prefix	Symbol	Factor	Prefix	Symbol	Factor
tera	T	10^{12}	deci	d	10^{-1}
giga	G	10^9	centi	c	10^{-2}
mega	M	10^6	milli	m	10^{-3}
kilo	k	10^3	micro	μ	10^{-6}
hecto	h	10^2	nano	n	10^{-9}
deka	da	10^1	pico	p	10^{-12}
			femto	f	10^{-15}

Concept Check 1.3

- a) How many grams are in 2 kilograms ? _____
- b) How many grams are in 5 milligrams ? _____
- c) Which is larger: one microsecond or one nanosecond ? _____

Fun with Physics

Use the prefixes in Table 1.2 to answer the riddles by finding an alternate name for their units.

1 million microphones = 1 _____ ?

10 cards = 1 _____ ?

1 millionth of a fish = 1 _____ ?

10 rations = 1 _____ ?

Answers to the riddles are given in Appendix A.

1.4 Energy Sources

As population has increased and societies have become more technologically advanced, energy requirements have increased rapidly. Development of clean, safe, and renewable energy sources will be one of the most challenging issues of the 21st century. To introduce our study of energy use, we first consider the energy content of some common fuels, given in joules of energy per kilogram of fuel (joules/kg).

Table 1.3: Energy Content of Fuels

Type of Fuel	Energy in joules/kg	Type of Fuel	Energy in joules/kg
Coal	2.9×10^7	Garbage and Trash	1.2×10^7
Crude Oil	4.3×10^7	Bread	1.0×10^7
Gasoline	4.4×10^7	Butter	3.3×10^7
Natural Gas	5.5×10^7	Nuclear fission with Uranium 235	$8.0 \times 10^{13} = 8,000,000 \times 10^7$
Wood	1.4×10^7		

(Example 1.4)

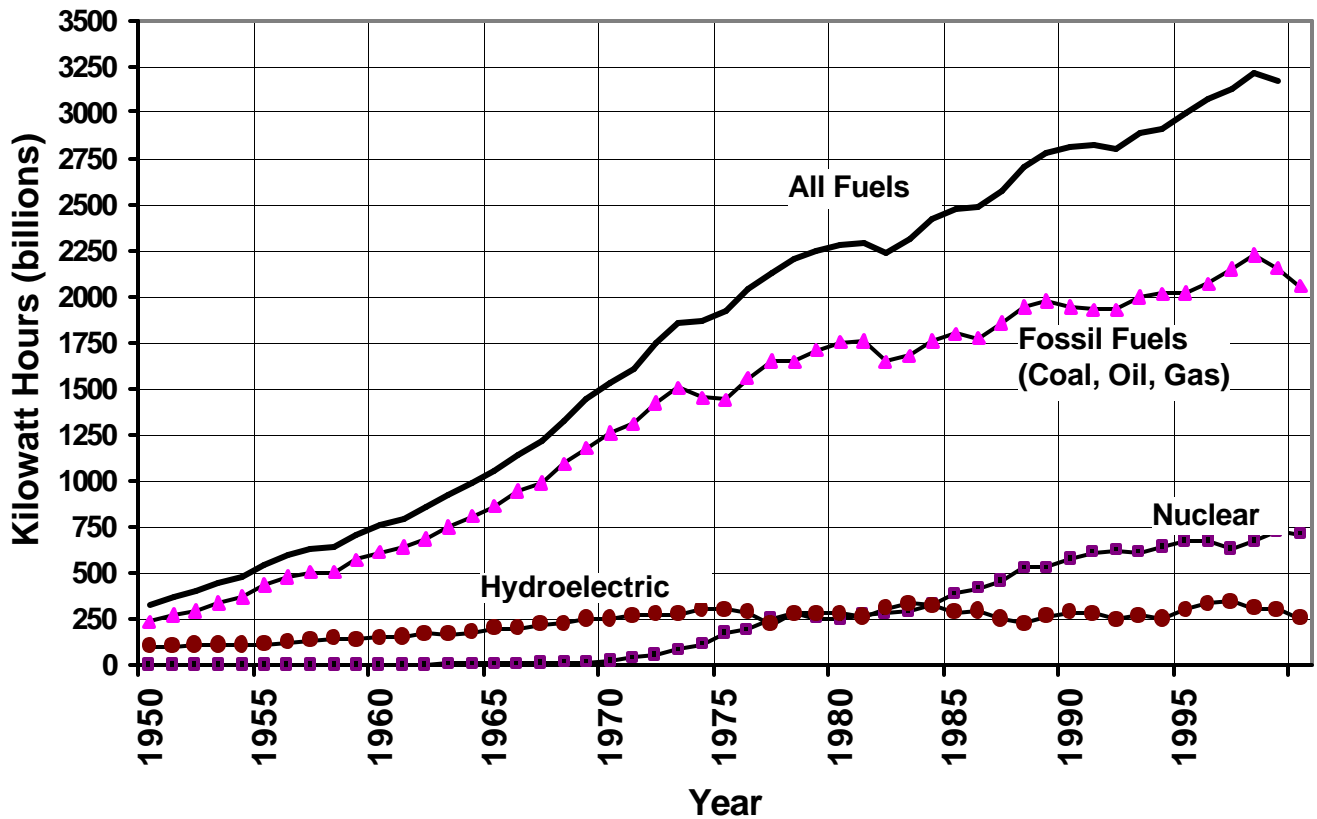
The energy content of the garbage and trash burned by a trash-powered generating plant to produce electricity is 1.2×10^7 joules/kg. The energy content of Uranium 235 used by a nuclear-powered generating plant is 8.0×10^{13} joules/kg. How many kilograms of trash are needed to produce the same amount of energy as 1 kilogram of Uranium 235?

Form a ratio of the energy content/kg and divide to find the number of kilograms of trash per 1 kilogram of Uranium 235. The cancellation of units of joules is shown in the second step of the solution, where the denominator of the ratio is inverted and multiplied by the numerator.

$$\frac{8.0 \times 10^{13} \text{ J/kg U 235}}{1.2 \times 10^7 \text{ J/kg trash}} = \frac{8.0 \times 10^{13} \cancel{\text{J}}}{1 \text{ kg U 235}} \times \frac{1 \text{ kg trash}}{1.2 \times 10^7 \cancel{\text{J}}} = \frac{6.7 \times 10^6 \text{ kg trash}}{1 \text{ kg U 235}}$$

Dependence on particular energy sources in the U.S. has changed over the past century. Figure 1.1 illustrates the growth of electrical energy production in the U.S. from 1950 to 2000 and the energy sources for this electricity.

Fig. 1.1: Annual Electricity Production in the U.S. by Type of Fuel



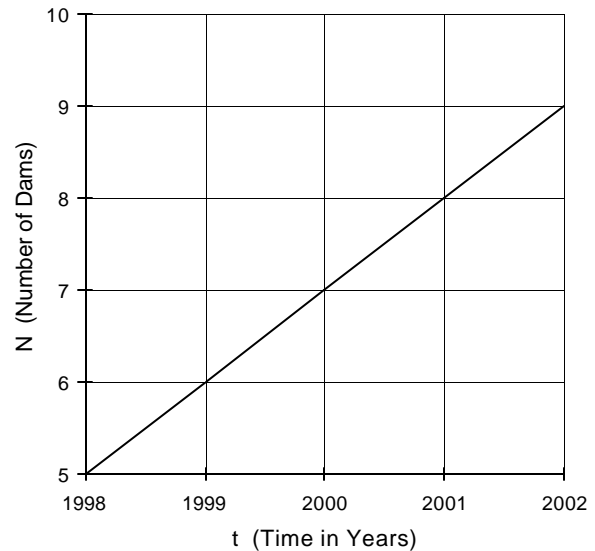
As we can see from Fig. 1.1, energy use often involves increasing quantities, such as the increase in electricity use during the past century. The rate of growth of the quantity is often of most interest. Therefore, we next turn our attention to a study of growth rates.

1.5 Linear and Exponential Growth

A growth rate is the ratio of the amount of increase to the time elapsed. We consider two common models for growth rates – linear and exponential growth – using sample data for the increase in the number of oil wells and hydroelectric dams in a hypothetical country. Figure 1.2 presents the data for dams.

Fig. 1.2: Linear Growth of Dams

Years	Time Periods	Dams
1998	0	5
1999	1	6
2000	2	7
2001	3	8
2002	4	9



The growth rate of dams producing hydroelectric power is called linear because the number of dams increases by a constant amount during each time period (1 dam/year). When graphed, linear data form a straight line as shown in Figure 1.2.

The equation describing linear growth uses the symbol **N** for the number of dams at a given time. This number depends on **B**, the initial number of dams (**B** = 5); **t**, the number of one-year time periods elapsed; and **A**, the amount of increase per time period. The value of **A** determines how steeply the straight graph line rises or falls and is known as the slope of the line. The relationship between **A**, **B**, **N**, and **t** is

$$N = A \times t + B$$

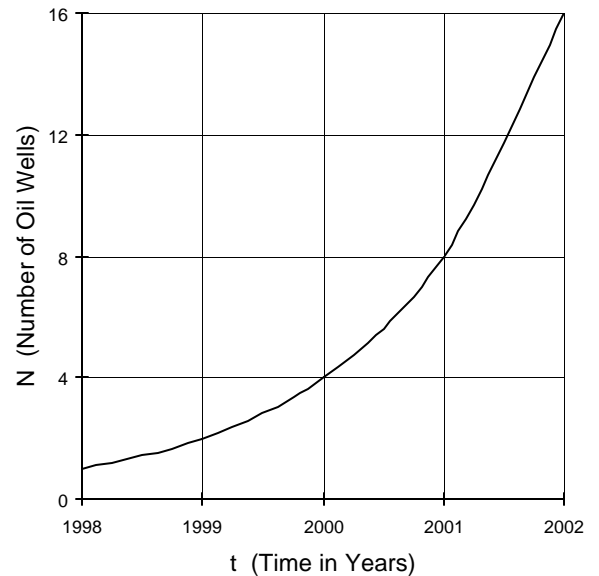
Applying the equation to the data in Fig. 1.2 verifies that the equation is correct.

$$\begin{array}{l}
 \text{In 1998, } N = 1 \times 0 + 5 = 5 \\
 \text{In 1999, } N = 1 \times 1 + 5 = 6 \\
 \text{In 2000, } N = 1 \times 2 + 5 = 7 \\
 \text{In 2001, } N = 1 \times 3 + 5 = 8 \\
 \text{In 2002, } N = 1 \times 4 + 5 = 9
 \end{array}$$

Next we consider a second type of growth rate called exponential growth. Figure 1.3 illustrates exponential growth using sample data for the increase in the number of oil wells in a hypothetical country.

Fig. 1.3: Exponential Growth of Oil Wells

Years	Time Periods	Oil Wells	Number of Wells as exponentials
1998	0	1	$1 = 2^0$
1999	1	2	$2 = 2^1$
2000	2	4	$4 = 2^2$
2001	3	8	$8 = 2^3$
2002	4	16	$16 = 2^4$



The graph of exponential growth is not a straight line because the amount of the increase per time period is not constant. Exponential growth is characterized by a doubling of the amount of the quantity during a fixed time period. Since the amount increases by a factor of two, exponential growth is described by base 2 raised to an exponential power that is equal to the number of time periods elapsed. The last column of Figure 1.3 illustrates this basis of exponential growth.

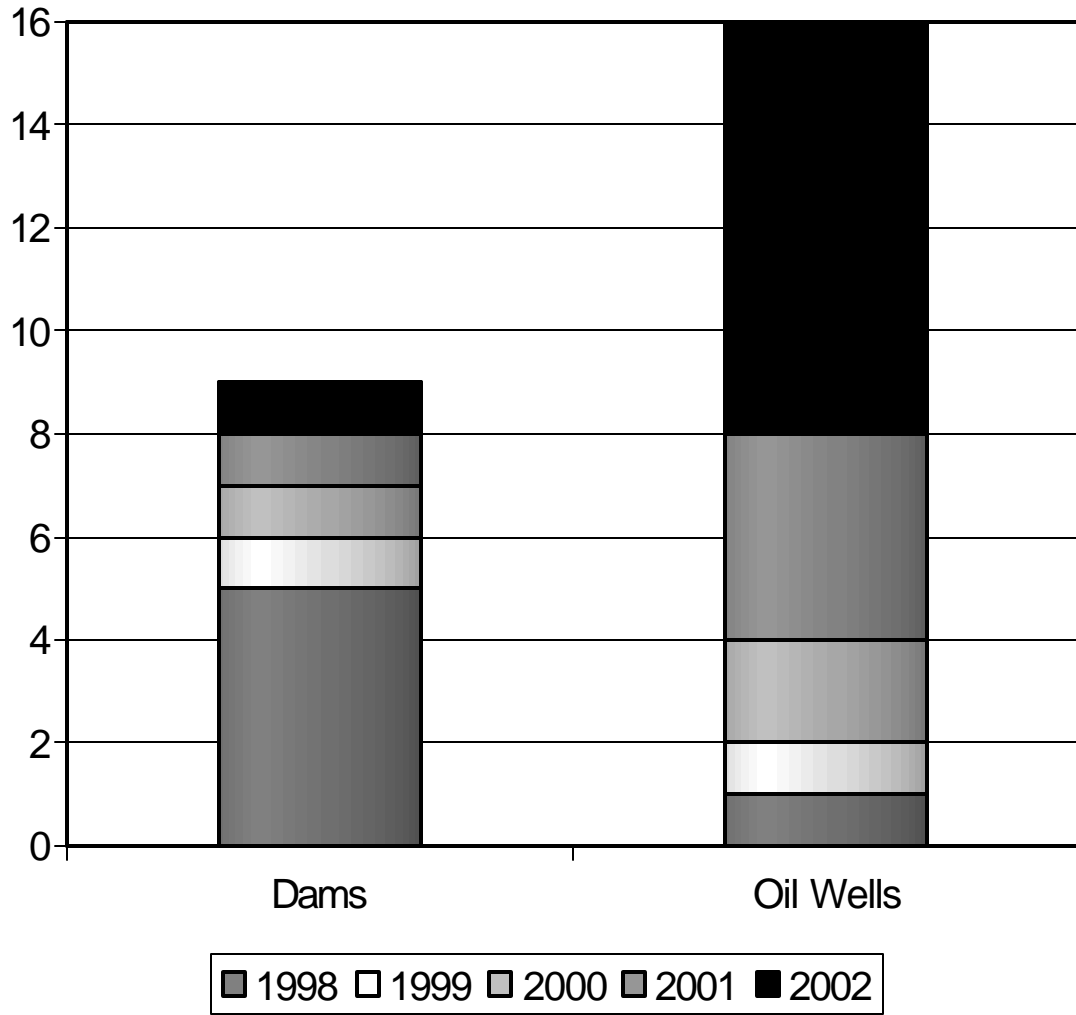
The equation for the exponential growth uses ***B*** for the initial amount of the quantity (***B*** = 1 oil well) and ***t*** for the number of one-year time periods elapsed. (We assume that there is only one doubling per time period.) ***N*** is the number of wells.

$$N = B \times 2^t$$

$$\begin{aligned} \text{In 1998, } N &= 1 \times 2^0 = 2^0 = 1 \\ \text{In 1999, } N &= 1 \times 2^1 = 2^1 = 2 \\ \text{In 2000, } N &= 1 \times 2^2 = 2^2 = 4 \\ \text{In 2001, } N &= 1 \times 2^3 = 2^3 = 8 \\ \text{In 2002, } N &= 1 \times 2^4 = 2^4 = 16 \end{aligned}$$

Figure 1.4 uses the sample data on dams and oil well to compare the rates of linear and exponential growth.

Figure 1.4 Increase in the Number of Dams and Oil Wells

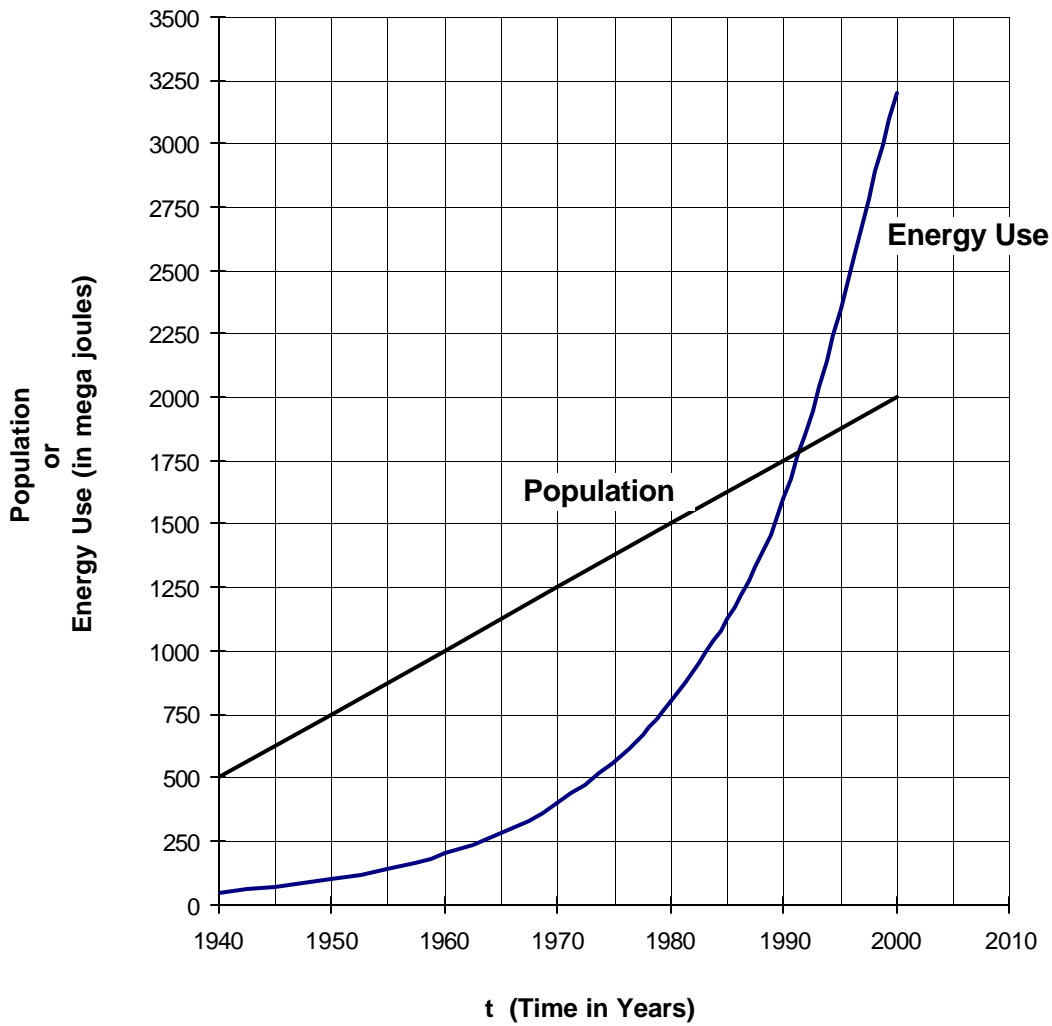


When studying energy, we may be interested in the amount of a quantity at a particular time, such the amount of electrical energy used in 1990. More often we are interested in the increase or decrease in a quantity over a period of time, such as the increase in energy use over the past 50 years. Table 1.4 presents sample data of the population of a town and energy used by that town from 1940 to 2000. Figure 1.5 graphs these data.

Table 1.4 Sample Data on Population and Megajoules (MJ) of Energy Use

Year	Population	Energy Use (MJ)	Year	Population	Energy Use (MJ)
1940	500	50	1980	1,500	800
1950	750	100	1990	1,750	1,600
1960	1,000	200	2000	2,000	3,200
1970	1,250	400	2010	?	?

Fig. 1.5 Sample Data on Population and Energy Use



As discussed earlier, the slope of a graph is the ratio of the amount by which it rises or falls to the elapsed period of time. In Figure 1.5, the graph of population is a straight line, which has a constant slope. Graphs with a constant slope represent **linear growth**. Linear growth is characterized by the addition of a constant amount during a fixed time period. In this example, the population grows by 250 every 10 years. The constant linear growth is independent of how long the population has been growing and is independent of the initial number of people. For example, if the town had 750 people in 1960, there would be $750 + 250 = 1,000$ people in 1970 and 1,250 in 1980. The population grows by 250 every 10 years, regardless of the size of the initial population and how long the population has been growing.

The graph of energy use is an example of **exponential growth** because the use of energy doubles during a fixed time period – in this example, every 10 years. In the case of exponential growth, the amount added during each time period depends on the amount of the quantity present at the beginning of that time period. Therefore, the amount to be added also depends on the number of elapsed time periods. For example, the town used 50 megajoules (MJ) of energy in 1940 and doubled its energy use to 100 MJ in 1950, an increase of 50 MJ in 10 years. But if the city had used 100 MJ in 1940 and doubled its energy use to 200 MJ by 1950, the increase would have been 100 MJ. The larger the initial amount, the greater the increase per time period.

With exponential growth, an amount is added during each time period to double the total quantity from the previous time period. The time between doublings is called the **doubling time**. In this example, the doubling time of energy use is 10 years. Between 1940 and 1950, energy use doubled from 50 MJ to 100 MJ – an increase of 50 MJ. Between 1950 and 1960, energy use doubled again from 100 MJ to 200 MJ, but during this 10-year period the amount of increase is 100 MJ. With exponential growth, the rate of change is not constant, but depends on the amount to be doubled at any given time, as well as the initial amount.

Concept Check 1.4

- a) If the growth of a town's population remains the same as shown in Table 1.3, what will the population be in 2010? _____
- b) If the growth of energy use remains the same, what will be the energy use in 2010? _____
- c) Add a data point to Figure 1.3 to represent the population in 2010. Where would a data point for energy use in 2010 be located?
- d) In Figure 1.5, what is the slope of the straight line representing population growth? _____

(Example 1.5)

A rapidly developing suburb had three gasoline station pumps in 2000. The number of gas pumps increases at the rate of 2 pumps per year. The number of vehicles driven by the suburb's residents was 5,000 in 2000. The number of vehicles grows exponentially with a doubling time of one year. How many gas pumps and vehicles will there be in 2003?

A data table simplifies the solution. Since the number of gas pumps grows linearly at the rate of two per year, we add 2 each year until 2003. The number of vehicles grows exponentially, beginning with 5,000 in 2000. Double the number of vehicles each year until 2003. In 2003, there will be 9 gas pumps and 40,000 vehicles.

Years	Pumps	Vehicles
2000	3	5,000
2001	5	10,000
2002	7	20,000
2003	9	40,000

Exponential growth rates have many applications in business and finance and in physical and biological systems. The length of time for a quantity to double, the doubling time, is particularly important. Table 1.5 gives the doubling time in years for various growth rates when compounded annually. As shown in the table, doubling times can vary substantially, but still represent exponential growth.

Table 1.5: Growth Rates and Doubling Times

Annual Growth Rate (in percent)	Doubling Time (in years)	Annual Growth Rate (in percent)	Doubling Time (in years)
0	Infinite	20	3.8
1	69.7	30	2.6
2	35.0	40	2.1
3	23.4	50	1.7
4	17.7	60	1.5
5	14.2	70	1.3
6	11.9	80	1.2
7	10.2	90	1.1
8	9.0	100	1.0
9	8.0	200	0.6
10	7.3	300	0.5
12	6.1	400	0.4
14	5.3	900	0.3
16	4.7	9900	0.15
18	4.2		

Concept Check 1.5

- a) If you invest \$1,000 at 10% interest compounded annually, how long will it take for your money to double to \$2,000? _____
- b) If a stock doubles in value every 2.1 years, what is its rate of growth? _____

Period 1 Summary

1.1: The World of Energy presents physics concepts in the context of energy use. The hands-on format of the course makes student class participation especially important.

1.2: The concept of *per* is represented by a ratio: one quantity divided by another quantity. When converting units, use ratios that allow cancellation of the unwanted units.

The efficiency of an energy conversion process equals the amount of energy of the desired type produced per total amount of energy put into the process.

$$\text{Efficiency} = \text{Useful Energy Out/Total Energy In}$$

1.3: Powers of 10 simplify calculations with very large or small numbers.

When multiplying powers of 10, add exponents.

When dividing powers of 10, subtract exponents.

1.4: Linear growth is expressed by $N = A \times t + B$

Exponential growth is expressed by $N = B \times 2^t$

where N = the amount of the quantity

A = the amount of increase per time period

B = the initial amount

t = the number of time periods elapsed

1.5: Linear growth rates add the same amount of a quantity during each time period.

The amount added is constant – it does not depend on the initial amount or on the number of time periods.

Exponential growth doubles the amount of the quantity during each time period.

The doubling time for exponential growth is the length of time required for the amount of a quantity to double.

The amount added varies for each time period – it depends on the initial amount and on the number of elapsed time periods.

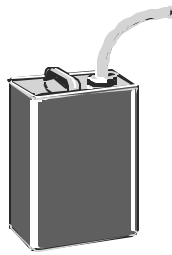
Growth rate tables (Table 1.5) provide an easy way to determine growth rates and doubling times.

Period 1 Exercises

E.1 The British thermal unit (BTU) is a common unit of measurement for thermal energy. If one gallon of gasoline contains 126,000 BTU's, what is the energy content of 10 gallons of gasoline?

- a) 1.26×10^4 BTU's
- b) 1.26×10^5 BTU's
- c) 1.26×10^6 BTU's
- d) 1.26×10^7 BTU's
- e) 1.25×10^8 BTU's

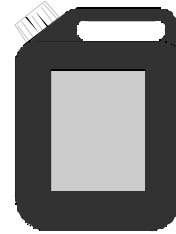
E.2 How much does the gasoline in each container cost per gallon?



(a) \$1.00 for 0.75 gallons



(b) \$10.00 for 8 gallons



(c) \$7.00 for 5 gallons

E.3 3×10^5 times 5×10^7 is between

- a) 10^{10} and 10^{11}
- b) 10^{11} and 10^{12}
- c) 10^{12} and 10^{13}
- d) 10^{13} and 10^{14}
- e) 10^{14} and 10^{15}

E.4 Which of the following expression(s) is/are correct?

- a) $10^A \times 10^B = 10^{A \times B}$
- b) $10^A / 10^B = 10^{A/B}$
- c) $10^A \times 10^{B/D} = 10^{[A \times B] / D}$
- d) $10^{A+B} \times 10^C = 10^{A+B+C}$
- e) None of the expressions is correct.

- E.5 What is the efficiency of an energy conversion process, which requires 1,200 joules of energy to produce 400 joules of useful energy?
- a) 8%
 - b) 33%
 - c) 50%
 - d) 75%
 - e) 300%
- E.6 Because of their large amounts, energy reserves are commonly expressed in a unit called the quad, for quadrillion. One quad is the equivalent of 10^{15} BTU's. If residential and commercial buildings annually use 30×10^{15} BTU's (= 3.0×10^{16} BTU's), how many quads of energy do they require?
- a) 3.0×10^1 quads
 - b) 3.0×10^2 quads
 - c) 3.0×10^0 quads
 - d) 1.5×10^1 quads
 - e) 1.5×10^2 quads
- E.7 The population of a certain country doubles every 30 years. If the population was 20 million in 1990, when will it reach 80 million, assuming that the doubling rate remains constant?
- a) 2020
 - b) 2050
 - c) 2080
 - d) 2110
 - e) 2140
- E.8 Use the data in Table 1.5 to find when a population of 1,000,000 people, with an annual growth rate of 16%, will reach 8,000,000.
- a) 4.7 years
 - b) 9.4 years
 - c) 14.1 years
 - d) 18.8 years
 - e) 23.5 years

Period 1 Review Questions

- R.1 When using ratios to convert a quantity from one unit to another, how do you decide which value to put in the numerator and which in the denominator of the ratio? Explain your answer with an example.
- R.2 State the rules of exponents you used to find the answer to exercise E.3.
- R.3 What is another name for:
- a) 2×10^{-2} meters ?
 - b) 6×10^{-6} seconds ?
 - c) 4×10^3 grams ?
- R.4 Explain how to tell whether a graph exhibits linear or exponential growth rates. Does every growth rate fit into one of these two types?
- R.5 What determines the amount added during each time period to a quantity that is growing linearly?
- R.6 What determines the amount added during each time period to a quantity that is growing exponentially?
- R.7 What is the doubling time of a quantity? How long will it take a stock, which increases in value at a rate of 10% per year, to double in value?

