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

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 1103 and 1104, are each a three-semester credit hour course that fulfills the GEC physical science requirement for the Bachelor of Arts degree at The Ohio State University. Physics 1103 and 1104 are non-sequential: students may take Physics 1104 without having taken Physics 1103.

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, and activity sheets completed during class.

Class Activities and Activity Sheets

During two 80-minute 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 on the course web site.

Homework Exercises

Following each activity sheet is a page of exercises to be completed and handed in. At the beginning of each class period, students turn in a completed Exercise sheet for the previous period. For example, at the beginning of the class when Period 2 will be taught, students turn in a completed Period 1 Exercise sheet.

Videos

Outside of class time, students will view six 50-minute videos related to the course material. These videos 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 on the course web site. These questions help students identify important concepts in the videos. DVDs of the videos are available on closed reserve at the OSU 18th Avenue Library. Midterm and final exams will include one question based on the material in each video.

Textbook

Each chapter of the textbook corresponds to one class period. The textbook chapters are available on the course web site. 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 at the end of each chapter.

Examinations

The course examinations consist of two midterms of 33 questions each and a comprehensive final examination of 50 questions. All exam questions are multiple choice. The dates of the examinations are given in the course syllabus. **No** make-up examinations will be given. Students who have a time conflict with any of the exam times should notify their instructor.

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. The course web site contains six practice exams with answer keys. The textbook chapters provide help in understanding equations and solving problems in the Skills and Strategies and Concept Check solutions. In addition to the sample exams, multiple choice questions with solutions for each textbook chapter are available on the course web site.

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 $4.25 per gallon,

$$\frac{\$4.25}{1 \text{ gal}} = \text{the cost of 1 gallon of gas and}$$

$$\frac{1 \text{ gal}}{\$4.25} = \frac{0.24 \text{ gal}}{\$1.00} = \text{the number of gallons purchased for \$1.00}$$

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.

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

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?

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

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.

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

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

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

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

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

(Example 1.3)

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

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

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. Common examples of such ratios are 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.

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

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:

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

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

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

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,

Barrels of crude oil used worldwide per day = 87,000,000 barrels = 8.7×10^{7} 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 point 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.

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

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

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

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

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

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

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

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

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

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

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

$$\mathbf{A^{0} = 1} \qquad 10^{0} = 1; \quad 27^{0} = 1; \quad 43{,}836^{0} = 1$$

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 [2nd F] before pressing the 10^X key.

For example, to enter 8×10^{12}, press [8] [X] [10^X] [1] [2]

To enter 3×10^{-6}, press [3] [X] [10^X] [+/-] [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 [3] [X] [6] [+/-] [10^X] [=]

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

To enter 3×10^{-6}, press [3] [EE] or [EXP] and then [+/-] [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 phones = 1 _________________ ?

1 millionth of a phone = 1 ___________________?

10 cards = 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
Hydrogen gas	14.2×10^7	Wood	1.8×10^7
Natural gas	5.5×10^7	Sugars/carbs/protein	1.7×10^7
Crude oil/gasoline	4.6×10^7	Household waste	0.8×10^7
Ethanol	3.0×10^7	Nuclear fission with Uranium 235	$8.0 \times 10^{13} = 8{,}000{,}000 \times 10^7$
Coal (bituminous)	2.4×10^7		

Source: Wikipedia.org/wiki/Energy-density

(Example 1.4)

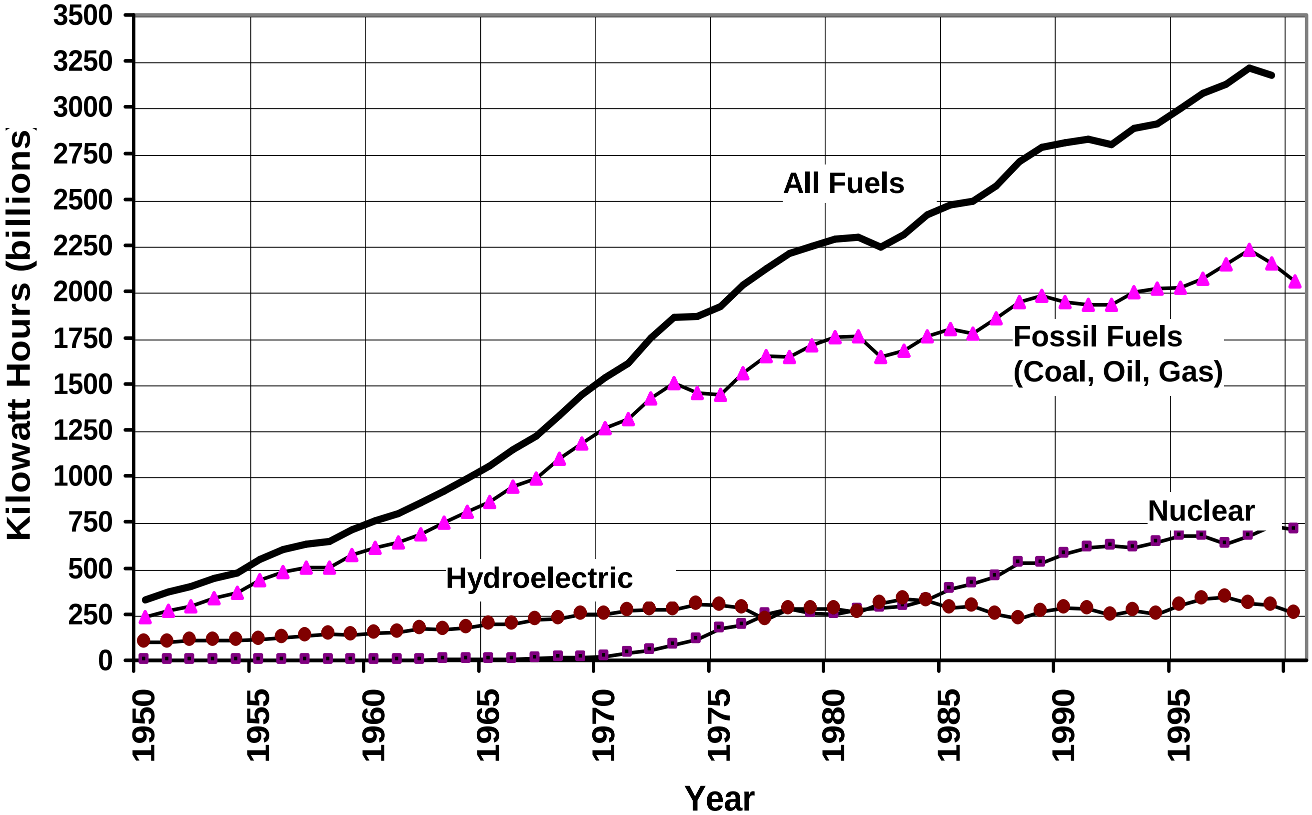
The energy content of the coal burned by a coal-fired generating plant to produce electricity is 2.4×10^7 joules/kg. The energy content of Uranium 235 used by a nuclear-powered generating plant is 8.0×10^{13} joules/kg. How many kilograms of coal are needed to produce the same amount of energy as 1 kilogram of Uranium 235?

Form a ratio of the joules of energy content per kilogram of fuel (J/kg) and divide to find the number of kilograms of coal 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.

$$\frac{8.0 \times 10^{13}\ \text{J/kg U 235}}{2.4 \times 10^{7}\ \text{J/kg coal}} = \frac{8.0 \times 10^{13}\ \cancel{\text{J}}}{1\ \text{kg U 235}} \times \frac{1\ \text{kg trash}}{2.4 \times 10^{7}\ \cancel{\text{J}}} = \frac{3.3 \times 10^{6}\ \text{kg coal}}{1\ \text{kg U 235}}$$

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



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.

When converting one form of energy into another form, some energy is wasted.

The efficiency of an energy conversion process tells what percent of the total energy put into the process is useful energy.

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.

Efficiency = 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.

When a power of ten is raised to a power, multiply the exponents.

When a number is raised to the zero power, the result equals one.

1.4: Table 1.3 gives the energy content of common fuels. Their values are in units of tens of millions of joules of energy per kilogram of fuel with one exception. Uranium-235, the fuel used in nuclear power plants, has an energy content per kilogram about one million times greater than the other fuels.

Solutions to Chapter 1 Concept Checks

1.1

a) 52 weeks/1 year is the number of weeks per each year

1 year/52 weeks is the number of years per 52 weeks

b)

$$7\ \cancel{\text{hours}} \times \frac{60\ \text{min}}{1\ \cancel{\text{hour}}} = 420\ \text{min}$$

c)

$$30\ \cancel{\text{days}} \times \frac{24\ \cancel{\text{hours}}}{1\ \cancel{\text{day}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{hour}}} \times \frac{60\ \text{sec}}{1\ \cancel{\text{min}}} = 2{,}592{,}000\ \text{sec}$$

1.2

a) $(2 \times 10^4) \times (5 \times 10^3) = (2 \times 5) \times 10^{3+4} = 10 \times 10^7 = 10^8$

b) $(6 \times 10^{-9}) / (3 \times 10^3) = (6 / 3) \times 10^{-9-3} = 2 \times 10^{-12}$

c) $4.7 \times 10^{-3} = 0.0047$; $3.2 \times 10^{-2} = 0.032$ 0.032 is larger than 0.0047

1.3

a) 1 kilogram = 1,000 grams, so 2 kilograms = 2,000 grams

b) 1 milligram = 10^{-3} grams or 0.001 gram, so 5 milligrams = 0.005 grams

c) 1 microsecond = 1×10^{-6} seconds; 1 nanosecond = 1×10^{-9} seconds, so 1 microsecond is larger than 1 nanosecond.

Fun with Physics

1 million phones = 1 megaphone

1 millionth of a phone = 1 microphone

10 cards = 1 deka cards (deck of cards)

10 rations = 1 deka ration (decoration)