Chapter 1

Foundations of Engineering Economy

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The need for engineering economy is primarily motivated by the work that engineers do in performing analysis, synthesizing, and coming to a conclusion as they work on projects of all sizes. In other words, engineering economy is at the heart of *making decisions.* These decisions involve the fundamental elements of *cash flows of money, time,* and *interest rates.* This chapter introduces the basic concepts and terminology necessary for an engineer to combine these three essential elements in organized, mathematically correct ways to solve problems that will lead to better decisions.

Purpose: **Understand and apply the fundamental concepts and terminology of engineering economy.**

LEARNING OUTCOMES

1. Determine the role of engineering economy in the decision-making process.	**Definition and role**
2. Identify what is needed to successfully perform an engineering economy study.	**Study approach and terms**
3. Perform calculations about interest rate and rate of return.	**Interest rate**
4. Understand what equivalence means in economic terms.	**Equivalence**
5. Calculate simple interest and compound interest for one or more interest periods.	**Simple and compound interest**
6. Identify and use engineering economy terminology and symbols.	**Symbols**
7. Understand cash flows, their estimation, and how to graphically represent them.	**Cash flows**
8. Formulate spreadsheet and calculator functions used in engineering economy.	**Spreadsheets/Calculators**
9. Describe the terms universal and personal morals, and professional ethics; understand the Code of Ethics for Engineers.	**Ethics and economics**

1.1 WHAT IS ENGINEERING ECONOMY?

Before we begin to develop the fundamental concepts upon which engineering economy is based, it is appropriate to define the term engineering economy. In the simplest of terms, *engineering economy* is a collection of techniques that simplify comparisons of alternatives on an *economic* basis. In defining what engineering economy is, it might also be helpful to define what it is not. Engineering economy is not a method or process for determining what the alternatives are. On the contrary, engineering economy begins only after the alternatives have been identified. If the best alternative is actually one that the engineer has not even recognized as an alternative, then all of the engineering economic analysis tools in this book will not result in its selection.

Engineering economic analysis is able to answer professional and personal financial questions. If you wish to evaluate the economics of purchasing a new home or leasing versus buying a new automobile for yourself, the techniques of engineering economy covered in this text are just as applicable as they are for determining if a replacement piece of equipment should be purchased by your employer.

While economics will be the sole criterion for selecting the best alternatives in this book, real-world decisions usually include many other factors in the decision-making process. For example, in determining whether to build a nuclear-powered, gas-fired, or coal-fired power plant, factors such as safety, air pollution, public acceptance, water demand, waste disposal, global warming, and many others would be considered in identifying the best alternative. The inclusion of other factors (besides economics) in the decision-making process is called multiple attribute analysis. This topic is introduced in Chapter 14.

1.2 PERFORMING AN ENGINEERING ECONOMY STUDY

In order to apply economic analysis techniques, it is necessary to understand the basic terminology and fundamental concepts that form the foundation for engineering-economy studies. Some of these terms and concepts are described below.

1.2.1 Alternatives

An *alternative* is a stand-alone solution for a given situation. We are faced with alternatives in virtually everything we do, from selecting the method of transportation we use to get to work every day to deciding between buying a house or renting one. Similarly, in engineering practice, there are always several ways of accomplishing a given task, and it is necessary to be able to compare them in a rational manner so that the most economical alternative can be selected. The alternatives in engineering considerations usually involve such items as purchase cost (first cost), anticipated useful life, yearly costs of maintaining assets (annual maintenance and operating costs), anticipated resale value (salvage value), and the interest rate. After the facts and all the relevant estimates have been collected, an engineering economy analysis can be conducted to determine which is best from an economic point of view.

1.2.2 Cash Flows

The estimated inflows (revenues and savings) and outflows (costs) of money are called cash flows. These estimates are truly the heart of an engineering economic analysis. They also represent the weakest part of the analysis, because most of the numbers are judgments about what is going to happen in the *future.* After all, who can accurately predict the price of oil next week, much less next month, next year, or next decade? Thus, no matter how sophisticated the analysis technique, the end result is only as reliable as the accuracy of the data that it is based on. This means that economic decisions about proposed alternatives are made under *risk,* that is, without certainty. Techniques that utilize sensitivity analysis, risk analysis, and multiple attribute analysis assist in understanding the consequences of variation in cash flow estimates.

1.2.3 Alternative Selection

Every situation has at least two alternatives. In addition to the one or more formulated alternatives, there is always the alternative of inaction, called the *do-nothing (DN)* alternative. This is the *as-is* or *status quo* condition. In any situation, when one consciously or subconsciously does not take any action, he or she is actually selecting the DN alternative. Of course, if the status quo alternative *is* selected, the decision-making process should indicate that doing nothing is the most favorable economic outcome at the time the evaluation is made. The procedures developed in this book will enable you to consciously identify the alternative(s) that is (are) economically the best.

1.2.4 Evaluation Criteria

Whether we are aware of it or not, we use criteria every day to choose between alternatives. For example, when you drive to campus, you decide to take the "best" route. But how did you define *best?* Was the best route the safest, shortest, fastest, cheapest, most scenic, or what? Obviously, depending upon which criterion or combination of criteria is used to identify the best, a different route might be selected each time. In economic analysis, *financial units* (dollars or other currency) are generally used as the tangible basis for evaluation. Thus, when there are several ways of accomplishing a stated objective, the alternative with the lowest overall cost or highest overall net income is selected.

1.2.5 Intangible Factors

In many cases, alternatives have noneconomic or intangible factors that are difficult to quantify. When the alternatives under consideration are hard to distinguish economically, intangible factors may tilt the decision in the direction of one of the alternatives. A few examples of noneconomic factors are safety, customer acceptance, reliability, convenience, and goodwill.

1.2.6 Time Value of Money

It is often said that money makes money. The statement is indeed true, for if we elect to invest money today, we inherently expect to have more money in the future.

If a person or company borrows money today, by tomorrow more than the original loan principal will be owed. This fact is also explained by the time value of money.

> **The change in the amount of money over a given time period is called the *time value of money;* it is the most important concept in engineering economy.**

The time value of money can be taken into account by several methods in an economy study, as we will learn. The method's final output is a *measure of worth,* for example, rate of return. This measure is used to accept or reject an alternative.

1.3 INTEREST RATE, RATE OF RETURN, AND MARR

Interest is the manifestation of the time value of money, and it essentially represents "rent" paid for use of the money. Computationally, interest is the difference between an ending amount of money and the beginning amount. If the difference is zero or negative, there is no interest. There are always two perspectives to an amount of interest—interest paid and interest earned. Interest is *paid* when a person or organization borrows money (obtains a loan) and repays a larger amount. Interest is *earned* when a person or organization saves, invests, or lends money and obtains a return of a larger amount. The computations and numerical values are essentially the same for both perspectives, but they are interpreted differently.

Interest paid or earned is determined by using the relation

$$\text{Interest} = \text{end amount} - \text{original amount} \qquad \textbf{[1.1]}$$

When interest over a *specific time unit* is expressed as a percentage of the original amount (principal), the result is called the *interest rate* or *rate of return (ROR).*

$$\textbf{Interest rate or rate of return} = \frac{\textbf{interest accrued per time unit}}{\textbf{original amount}} \times \mathbf{100\%} \qquad \textbf{[1.2]}$$

The time unit of the interest rate is called the *interest period.* By far the most common interest period used to state an interest rate is 1 year. Shorter time periods can be used, such as, 1% per month. Thus, the interest period of the interest rate should always be included. If only the rate is stated, for example, 8.5%, a 1-year interest period is assumed.

The term *return on investment (ROI)* is used equivalently with ROR in different industries and settings, especially where large capital funds are committed to engineering-oriented programs. The term *interest rate paid* is more appropriate from the borrower's perspective, while *rate of return earned* is better from the investor's perspective.

EXAMPLE 1.1

An employee at LaserKinetics.com borrows $10,000 on May 1 and must repay a total of $10,700 exactly 1 year later. Determine the interest amount and the interest rate paid.

Solution

The perspective here is that of the borrower since \$10,700 repays a loan. Apply Equation [1.1] to determine the interest paid.

$$\text{Interest paid} = \$10{,}700 - 10{,}000 = \$700$$

Equation [1.2] determines the interest rate paid for 1 year.

$$\text{Percent interest rate} = \frac{\$700}{\$10{,}000} \times 100\% = 7\% \text{ per year}$$

EXAMPLE 1.2

a. Calculate the amount deposited 1 year ago to have \$1000 now at an interest rate of 5% per year.

b. Calculate the amount of interest earned during this time period.

Solution

a. The total amount accrued (\$1000) is the sum of the original deposit and the earned interest. If X is the original deposit,

$$\text{Total accrued} = \text{original amount} + \text{original amount (interest rate)}$$
$$\$1000 = X + X(0.05) = X(1 + 0.05) = 1.05X$$

The original deposit is

$$X = \frac{1000}{1.05} = \$952.38$$

b. Apply Equation [1.1] to determine interest earned.

$$\text{Interest} = \$1000 - 952.38 = \$47.62$$

In Examples 1.1 and 1.2 the interest period was 1 year, and the interest amount was calculated at the end of one period. When more than one interest period is involved (e.g., if we wanted the amount of interest earned after 3 years in Example 1.2), it is necessary to state whether the interest is accrued on a *simple* or *compound* basis from one period to the next. Simple and compound interest will be discussed in Section 1.5.

Engineering alternatives are evaluated upon the prognosis that a reasonable rate of return (ROR) can be realized. A reasonable rate must be established so that the accept/reject decision can be made. This reasonable rate, called the *minimum attractive rate of return* (MARR), is the lowest interest rate that will induce companies or individuals to invest their money. The MARR must be higher than the cost of money used to finance the alternative, as well as higher than the rate that would be expected from a bank or safe (minimal risk) investment. Figure 1.1 indicates the relations between different rates of return. In the United States, the current U.S. Treasury bill rate of return is sometimes used as the benchmark safe rate.

For a corporation, the MARR is always set above its *cost of capital,* which is the interest rate a company must pay for capital funds needed to finance projects.

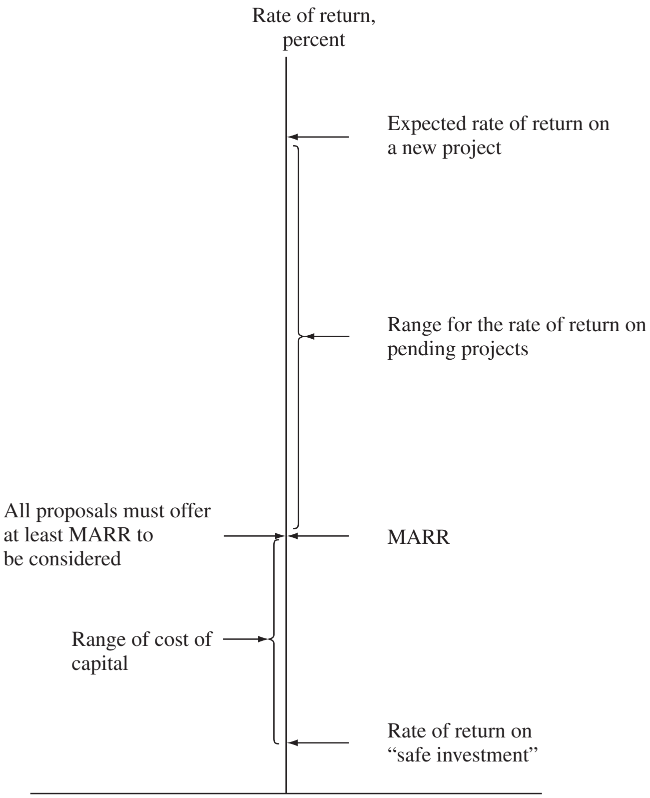


FIGURE 1.1
MARR relative to cost of capital and other rate of return values.

For example, if a corporation can borrow capital funds at an average of 5% per year and expects to clear at least 6% per year on a project, the MARR will be at least 11% per year.

The MARR is also referred to as the *hurdle rate;* that is, a financially viable project's expected ROR must meet or exceed the hurdle rate. Note that the MARR is not a rate calculated like the ROR; MARR is established by financial managers and is used as a criterion for accept/reject decisions. The following inequality must be correct for any accepted project.

$$\text{ROR} \geq \text{MARR} > \text{cost of capital}$$

Descriptions and problems in the following chapters use stated MARR values with the assumption that they are set correctly relative to the cost of capital and the expected rate of return. If more understanding of capital funds and the establishment of the MARR is required, refer to Section 13.5 for further detail.

An additional economic consideration for any engineering economy study is *inflation*. In simple terms, bank interest rates reflect two things: a so-called real rate of return *plus* the expected inflation rate. The safest investments (such as government bonds) typically have a 3% to 4% real rate of return built into their overall interest rates. Thus, an interest rate of, say, 9% per year on a government bond means that investors expect the inflation rate to be in the range of 5% to 6% per year. Clearly, then, inflation causes interest rates to rise. Inflation is discussed in detail in Chapter 10.

1.4 EQUIVALENCE

Equivalent terms are used often in the transfer between scales and units. For example, 1000 meters is equal to (or equivalent to) 1 kilometer, 12 inches equals 1 foot, and 1 quart equals 2 pints or 0.946 liter.

In engineering economy, when considered together, the time value of money and the interest rate help develop the concept of *economic equivalence,* which means that different sums of money at different times would be equal in economic value. For example, if the interest rate is 6% *per year,* \$100 today (present time) is equivalent to \$106 one year from today.

$$\text{Amount in one year} = 100 + 100(0.06) = 100(1 + 0.06) = \$106$$

So, if someone offered you a gift of \$100 today or \$106 one year from today, it would make no difference which offer you accepted from an economic perspective. In either case you have \$106 one year from today. However, the two sums of money are equivalent to each other *only* when the interest rate is 6% per year. At a higher or lower interest rate, \$100 today is not equivalent to \$106 one year from today.

In addition to future equivalence, we can apply the same logic to determine equivalence for previous years. A total of \$100 now is equivalent to \$100/1.06 = \$94.34 one year ago at an interest rate of 6% per year. From these illustrations, we can state the following: \$94.34 last year, \$100 now, and \$106 one year from now are equivalent at an interest rate of 6% per year. The fact that these sums are equivalent can be verified by computing the two interest rates for 1-year interest periods.

$$\frac{\$6}{\$100} \times 100\% = 6\% \text{ per year}$$

and

$$\frac{\$5.66}{\$94.34} \times 100\% = 6\% \text{ per year}$$

Figure 1.2 indicates the amount of interest each year necessary to make these three different amounts equivalent at 6% per year.

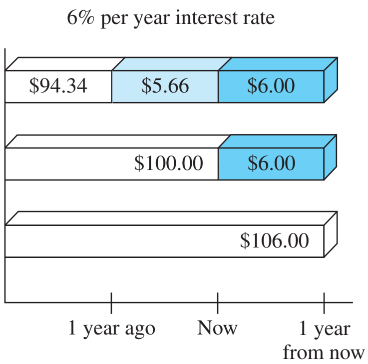


FIGURE 1.2
Equivalence of three amounts at a 6% per year interest rate.

EXAMPLE 1.3

AC-Delco makes auto batteries available to General Motors dealers through privately owned distributorships. In general, batteries are stored throughout the year, and a 5% cost increase is added each year to cover the inventory carrying charge for the distributorship owner. Assume you own the City Center Delco facility. Make the calculations necessary to show which of the following statements are true and which are false about battery costs.

a. The amount of \$98 now is equivalent to a cost of \$105.60 one year from now.
b. A truck battery cost of \$200 one year ago is equivalent to \$205 now.
c. A \$38 cost now is equivalent to \$39.90 one year from now.
d. A \$3000 cost now is equivalent to \$2887.14 one year ago.
e. The carrying charge accumulated in 1 year on an investment of \$2000 worth of batteries is \$100.

Solution

a. Total amount accrued $= 98(1.05) = \$102.90 \neq \$105.60$; therefore, it is false. Another way to solve this is as follows: Required original cost is $105.60/1.05 = \$100.57 \neq \$98$.
b. Required old cost is $205.00/1.05 = \$195.24 \neq \$200$; therefore, it is false.
c. The cost 1 year from now is $\$38(1.05) = \$39.90$; true.
d. Cost one year ago is $3000/1.05 = \$2857.14 \neq 2887.14$; false.
e. The charge is 5% per year interest, or $\$2000(0.05) = \$100$; true.

1.5 SIMPLE AND COMPOUND INTEREST

The terms *interest, interest period,* and *interest rate* were introduced in Section 1.3 for calculating equivalent sums of money for one interest period in the past and one period in the future. However, for more than one interest period, the terms *simple interest* and *compound interest* become important.

Simple interest is calculated using the principal only, ignoring any interest accrued in preceding interest periods. The total simple interest over several periods is computed as

$$\text{Interest} = (\text{principal})(\text{number of periods})(\text{interest rate}) \qquad [1.3]$$

where the interest rate is expressed in decimal form. Therefore, the total (future) amount accumulated after several periods is the principal plus interest over all n periods.

EXAMPLE 1.4

HP borrowed money to do rapid prototyping for a new ruggedized computer that targets desert oilfield conditions. The loan is \$1 million for 3 years at 5% per year simple interest. How much money will HP repay at the end of 3 years? Tabulate the results in \$1000 units.

Solution

The interest for each of the 3 years in \$1000 units is

$$\text{Interest per year} = 1000(0.05) = \$50$$

Total interest for 3 years from Equation [1.3] is

$$\text{Total interest} = 1000(3)(0.05) = \$150$$

The amount due after 3 years in \$1000 units is

$$\text{Total due} = \$1000 + 150 = \$1150$$

The \$50,000 interest accrued in the first year and the \$50,000 accrued in the second year do not earn interest. The interest due each year is calculated only on the \$1,000,000 principal.

The details of this loan repayment are tabulated in Table 1.1 from the perspective of the borrower. The year zero represents the present, that is, when the money is borrowed. No payment is made until the end of year 3. The amount owed each year increases uniformly by \$50,000, since simple interest is figured on only the loan principal.

TABLE 1.1 Simple Interest Computations (in \$1000 units)

(1) End of Year	(2) Amount Borrowed	(3) Interest	(4) Amount Owed	(5) Amount Paid
0	\$1000			
1	—	\$50	\$1050	\$ 0
2	—	50	1100	0
3	—	50	1150	1150

For *compound interest,* the interest accrued for each interest period is calculated on the *principal plus* the *total amount of interest accumulated in all previous periods.* Thus, compound interest means interest on top of interest. Compound interest reflects the effect of the time value of money on the interest also. Now the interest for one period is calculated as

$$\textbf{Interest} = \textbf{(principal + all accrued interest)(interest rate)} \qquad [1.4]$$

EXAMPLE 1.5 If HP borrows \$1,000,000 from a different source at 5% per year compound interest, compute the total amount due after 3 years. Compare the results of this and the previous example.

TABLE 1.2 Compound Interest Computations (in $1000 units), Example 1.5

(1) End of Year	(2) Amount Borrowed	(3) Interest	(4) Amount Owed	(5) Amount Paid
0	$1000			
1	—	$50.00	$1050.00	$ 0
2	—	52.50	1102.50	0
3	—	55.13	1157.63	1157.63

Solution

The interest and total amount due each year are computed separately using Equation [1.4]. In $1000 units,

Year 1 interest:	$1000(0.05) = $50.00
Total amount due after year 1:	$1000 + 50.00 = $1050.00
Year 2 interest:	$1050(0.05) = $52.50
Total amount due after year 2:	$1050 + 52.50 = $1102.50
Year 3 interest:	$1102.50(0.05) = $55.13
Total amount due after year 3:	$1102.50 + 55.13 = $1157.63

The details are shown in Table 1.2. The repayment plan is the same as that for the simple interest example—no payment until the principal plus accrued interest is due at the end of year 3. An extra $1,157,630 − 1,150,000 = $7,630 of interest is paid compared to simple interest over the 3-year period.

Comment: The difference between simple and compound interest grows significantly each year. If the computations are continued for more years, for example, 10 years, the difference is $128,894; after 20 years compound interest is $653,298 more than simple interest.

Another and shorter way to calculate the total amount due after 3 years in Example 1.5 is to combine calculations rather than perform them on a year-by-year basis. The total due each year is as follows:

$$\text{Year 1:} \quad \$1000(1.05)^1 = \$1050.00$$
$$\text{Year 2:} \quad \$1000(1.05)^2 = \$1102.50$$
$$\text{Year 3:} \quad \$1000(1.05)^3 = \$1157.63$$

The year 3 total is calculated directly; it does not require the year 2 total. In general formula form,

Total due after a number of years = principal (1 + interest rate)$^{\text{number of years}}$

This fundamental relation is used many times in upcoming chapters.

We combine the concepts of interest rate, simple interest, compound interest, and equivalence to demonstrate that different loan repayment plans may be equivalent, but they may differ substantially in monetary amounts from one year to another. This also shows that there are many ways to take into account the time value of money. The following example illustrates equivalence for five different loan repayment plans.

EXAMPLE 1.6

a. Demonstrate the concept of equivalence using the different loan repayment plans described below. Each plan repays a \$5000 loan in 5 years at 8% interest per year.

- **Plan 1: Simple interest, pay all at end.** No interest or principal is paid until the end of year 5. Interest accumulates each year on the *principal only.*
- **Plan 2: Compound interest, pay all at end.** No interest or principal is paid until the end of year 5. Interest accumulates each year on the total of principal *and* all accrued interest.
- **Plan 3: Simple interest paid annually, principal repaid at end.** The accrued interest is paid each year, and the entire principal is repaid at the end of year 5.
- **Plan 4: Compound interest and portion of principal repaid annually.** The accrued interest and one-fifth of the principal (or \$1000) is repaid each year. The outstanding loan balance decreases each year, so the interest for each year decreases.
- **Plan 5: Equal payments of compound interest and principal made annually.** Equal payments are made each year with a portion going toward principal repayment and the remainder covering the accrued interest. Since the loan balance decreases at a rate slower than that in plan 4 due to the equal end-of-year payments, the interest decreases, but at a slower rate.

b. Make a statement about the equivalence of each plan at 8% simple or compound interest, as appropriate.

Solution

a. Table 1.3 presents the interest, payment amount, total owed at the end of each year, and total amount paid over the 5-year period (column 4 totals). The amounts of interest (column 2) are determined as follows:

Plan 1 Simple interest = (original principal)(0.08)
Plan 2 Compound interest = (total owed previous year)(0.08)
Plan 3 Simple interest = (original principal)(0.08)
Plan 4 Compound interest = (total owed previous year)(0.08)
Plan 5 Compound interest = (total owed previous year)(0.08)

Note that the amounts of the annual payments are different for each repayment schedule and that the total amounts repaid for most plans are different, even though each repayment plan requires exactly 5 years. The difference in the total amounts repaid can be explained (1) by the time value of money, (2) by simple or compound interest, and (3) by the partial repayment of principal prior to year 5.

TABLE 1.3 Different Repayment Schedules Over 5 Years for $5000 at 8% Per Year Interest

(1) End of Year	(2) Interest Owed for Year	(3) Total Owed at End of Year	(4) End-of-Year Payment	(5) Total Owed after Payment
Plan 1: Simple Interest, Pay All at End				
0				$5000.00
1	$400.00	$5400.00	—	5400.00
2	400.00	5800.00	—	5800.00
3	400.00	6200.00	—	6200.00
4	400.00	6600.00	—	6600.00
5	400.00	7000.00	$7000.00	
Totals			$7000.00	
Plan 2: Compound Interest, Pay All at End				
0				$5000.00
1	$400.00	$5400.00	—	5400.00
2	432.00	5832.00	—	5832.00
3	466.56	6298.56	—	6298.56
4	503.88	6802.44	—	6802.44
5	544.20	7346.64	$7346.64	
Totals			$7346.64	
Plan 3: Simple Interest Paid Annually; Principal Repaid at End				
0				$5000.00
1	$400.00	$5400.00	$ 400.00	5000.00
2	400.00	5400.00	400.00	5000.00
3	400.00	5400.00	400.00	5000.00
4	400.00	5400.00	400.00	5000.00
5	400.00	5400.00	5400.00	
Totals			$7000.00	
Plan 4: Compound Interest and Portion of Principal Repaid Annually				
0				$5000.00
1	$400.00	$5400.00	$1400.00	4000.00
2	320.00	4320.00	1320.00	3000.00
3	240.00	3240.00	1240.00	2000.00
4	160.00	2160.00	1160.00	1000.00
5	80.00	1080.00	1080.00	
Totals			$6200.00	

TABLE 1.3 (Continued)

(1) End of Year	(2) Interest Owed for Year	(3) Total Owed at End of Year	(4) End-of-Year Payment	(5) Total Owed after Payment
Plan 5: Equal Annual Payments of Compound Interest and Principal				
0				$5000.00
1	$400.00	$5400.00	$1252.28	4147.72
2	331.82	4479.54	1252.28	3227.25
3	258.18	3485.43	1252.28	2233.15
4	178.65	2411.80	1252.28	1159.52
5	92.76	1252.28	1252.28	
Totals			$6261.41	

b. Table 1.3 shows that $5000 at time 0 is equivalent to each of the following:

Plan 1 $7000 at the end of year 5 at 8% simple interest.
Plan 2 $7346.64 at the end of year 5 at 8% compound interest.
Plan 3 $400 per year for 4 years and $5400 at the end of year 5 at 8% simple interest.
Plan 4 Decreasing payments of interest and partial principal in years 1 ($1400) through 5 ($1080) at 8% compound interest.
Plan 5 $1252.28 per year for 5 years at 8% compound interest.

Beginning in Chapter 2, we will make many calculations like plan 5, where interest is compounded and a constant amount is paid each period. This amount covers accrued interest and a partial principal repayment.

1.6 TERMINOLOGY AND SYMBOLS

The equations and procedures of engineering economy utilize the following terms and symbols. Sample units are indicated.

P = value or amount of money at a time designated as the present or time 0. Also, P is referred to as present worth (PW), present value (PV), net present value (NPV), discounted cash flow (DCF), and capitalized cost (CC); dollars

F = value or amount of money at some future time. Also, F is called future worth (FW) and future value (FV); dollars

A = series of consecutive, equal, end-of-period amounts of money. A is also called the annual worth (AW), equivalent uniform annual worth (EUAW), and equivalent annual cost (EAC); dollars per year, dollars per month

n = number of interest periods; years, months, days

i = interest rate or rate of return per time period; percent per year, percent per month, percent per day

t = time, stated in periods; years, months, days

The symbols P and F represent one-time occurrences: A occurs with the same value each interest period for a specified number of periods. It should be clear that a present value P represents a single sum of money at some time prior to a future value F or prior to the first occurrence of an equivalent series amount A.

It is important to note that the symbol A always represents a uniform amount (i.e., the same amount each period) that extends through *consecutive* interest periods. Both conditions must exist before the series can be represented by A.

The interest rate i is assumed to be a compound rate, unless specifically stated as simple interest. The rate i is expressed in percent per interest period, for example, 12% per year. Unless stated otherwise, assume that the rate applies throughout the entire n years or interest periods. The decimal equivalent for i is always used in engineering economy computations.

All engineering economy problems involve the element of time n and interest rate i. In general, every problem will involve at least four of the symbols P, F, A, n, and i, with at least three of them estimated or known.

EXAMPLE 1.7

A new college graduate has a job with Boeing Aerospace. She plans to borrow \$10,000 now to help in buying a car. She has arranged to repay the entire principal plus 8% per year interest after 5 years. Identify the engineering economy symbols involved and their values for the total owed after 5 years.

Solution

In this case, P and F are involved, since all amounts are single payments, as well as n and i. Time is expressed in years.

P = \$10,000 $\quad$ i = 8% per year $\quad$ n = 5 years $\quad$ F = ?

The future amount F is unknown.

EXAMPLE 1.8

Assume you borrow \$2000 now at 7% per year for 10 years and must repay the loan in equal yearly payments. Determine the symbols involved and their values.

Solution

Time is in years.

P = \$2000
A = ? per year for 10 years
i = 7% per year
n = 10 years

In Examples 1.7 and 1.8, the P value is a receipt *to* the borrower, and F or A is a disbursement *from* the borrower. It is equally correct to use these symbols in the reverse roles.

EXAMPLE 1.9 On July 1, 2008, your new employer Ford Motor Company deposits \$5000 into your money market account, as part of your employment bonus. The account pays interest at 5% per year. You expect to withdraw an equal annual amount each year for the following 10 years. Identify the symbols and their values.

Solution

Time is in years.

$$P = \$5000$$
$$A = \text{? per year}$$
$$i = 5\% \text{ per year}$$
$$n = 10 \text{ years}$$

EXAMPLE 1.10 You plan to make a lump-sum deposit of \$5000 now into an investment account that pays 6% per year, and you plan to withdraw an equal end-of-year amount of \$1000 for 5 years, starting next year. At the end of the sixth year, you plan to close your account by withdrawing the remaining money. Define the engineering economy symbols involved.

Solution

Time is expressed in years.

$$P = \$5000$$
$$A = \$1000 \text{ per year for 5 years}$$
$$F = \text{? at end of year 6}$$
$$i = 6\% \text{ per year}$$
$$n = 5 \text{ years for the } A \text{ series and 6 for the } F \text{ value}$$

1.7 CASH FLOWS: THEIR ESTIMATION AND DIAGRAMMING

Cash flows are inflows and outflows of money. These cash flows may be estimates or observed values. Every person or company has cash receipts—revenue and income (inflows); and cash disbursements—expenses and costs (outflows). These receipts and disbursements are the cash flows, with a plus sign representing cash inflows and a minus sign representing cash outflows. Cash flows occur during specified periods of time, such as 1 month or 1 year.

Of all the elements of an engineering economy study, cash flow estimation is likely the most difficult and inexact. Cash flow estimates are just that—estimates about an uncertain future. Once estimated, the techniques of this book guide the decision-making process. But the time-proven accuracy of an alternative's estimated cash inflows and outflows clearly dictates the quality of the economic analysis and conclusion.

Cash inflows, or receipts, may be comprised of the following, depending upon the nature of the proposed activity and the type of business involved.

Samples of Cash Inflow Estimates

Revenues (from sales and contracts)

Operating cost reductions (resulting from an alternative)

Salvage value

Construction and facility cost savings

Receipt of loan principal

Income tax savings

Receipts from stock and bond sales

Cash outflows, or disbursements, may be comprised of the following, again depending upon the nature of the activity and type of business.

Samples of Cash Outflow Estimates

First cost of assets

Engineering design costs

Operating costs (annual and incremental)

Periodic maintenance and rebuild costs

Loan interest and principal payments

Major expected/unexpected upgrade costs

Income taxes

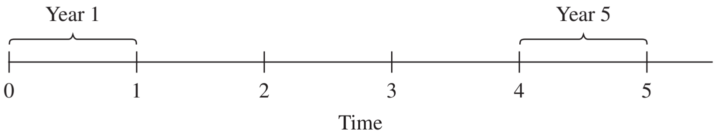
Background information for estimates may be available in departments such as accounting, finance, marketing, sales, engineering, design, manufacturing, production, field services, and computer services. The accuracy of estimates is largely dependent upon the experiences of the person making the estimate with similar situations. Usually *point estimates* are made; that is, a single-value estimate is developed for each economic element of an alternative. If a statistical approach to the engineering economy study is undertaken, a *range estimate* or *distribution estimate* may be developed. Though more involved computationally, a statistical study provides more complete results when key estimates are expected to vary widely. Though we use point estimates throughout most of this book, Chapter 8 discusses sensitivity analysis for estimates that vary over a specific range. Additionally, Chapter 14 introduces risk analysis using probability distributions, sampling, and spreadsheet-based simulation to understand the economic consequences of estimate variation.

Once the cash inflow and outflow estimates are developed, the net cash flow can be determined.

$$\begin{aligned}\textbf{Net cash flow} &= \textbf{receipts} - \textbf{disbursements} \\ &= \textbf{cash inflows} - \textbf{cash outflows}\end{aligned} \qquad \textbf{[1.5]}$$

Since cash flows normally take place at varying times within an interest period, a simplifying end-of-period assumption is made.

FIGURE 1.3
A typical cash flow time scale for 5 years.



> The *end-of-period convention* means that all cash flows are assumed to occur at the end of an interest period. When several receipts and disbursements occur within a given interest period, the *net* cash flow is assumed to occur at the *end* of the interest period.

It is important to understand that, although F or A amounts are located at the end of the interest period by convention, the end of the period is not necessarily December 31. In Example 1.9 the deposit took place on July 1, 2008, and the withdrawals will take place on July 1 of each succeeding year for 10 years. *Thus, end of the period means end of interest period, not end of calendar year.*

The *cash flow diagram* is a very important tool in an economic analysis, especially when the cash flow series is complex. It is a graphical representation of cash flows drawn on a time scale. The diagram includes what is known, what is estimated, and what is needed. That is, once the cash flow diagram is complete, another person should be able to work the problem by looking at the diagram.

Cash flow diagram time $t = 0$ is the present, and $t = 1$ is the end of time period 1. We assume that the periods are in years for now. The time scale of Figure 1.3 is set up for 5 years. Since the end-of-year convention places cash flows at the ends of years, the "1" marks the end of year 1.

While it is not necessary to use an exact scale on the cash flow diagram, you will probably avoid errors if you make a neat diagram to approximate scale for both time and relative cash flow magnitudes.

The direction of the arrows on the cash flow diagram is important. A vertical arrow pointing up indicates a positive cash flow. Conversely, an arrow pointing down indicates a negative cash flow. Figure 1.4 illustrates a receipt (cash inflow) at the end of year 1 and equal disbursements (cash outflows) at the end of years 2 and 3.

The perspective or vantage point must be determined prior to placing a sign on each cash flow and diagramming it. As an illustration, if you borrow \$2500 to buy a \$2000 used Harley-Davidson for cash, and you use the remaining \$500 for a new paint job, there may be several different perspectives taken. Possible perspectives, cash flow signs, and amounts are as follows.

Perspective	Cash Flow, \$
Credit union	−2500
You as borrower	+2500
You as purchaser,	−2000
and as paint customer	−500
Used cycle dealer	+2000
Paint shop owner	+500

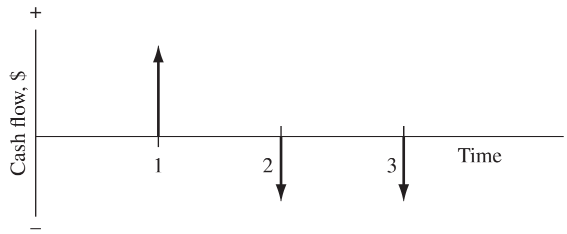


FIGURE 1.4 Example of positive and negative cash flows.

EXAMPLE 1.11

Reread Example 1.7, where P = \$10,000 is borrowed at 8% per year and F is sought after 5 years. Construct the cash flow diagram.

Solution

Figure 1.5 presents the cash flow diagram from the vantage point of the borrower. The present sum P is a cash inflow of the loan principal at year 0, and the future sum F is the cash outflow of the repayment at the end of year 5. The interest rate should be indicated on the diagram.

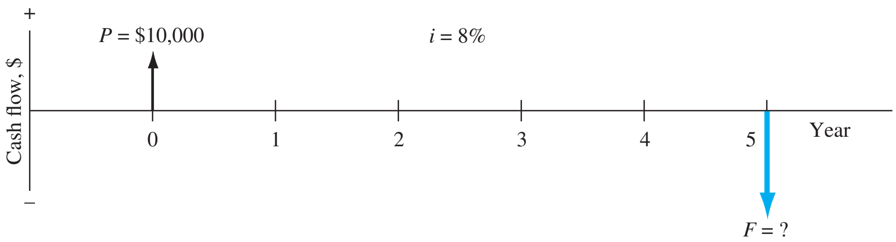


FIGURE 1.5 Cash flow diagram, Example 1.11.

EXAMPLE 1.12

Each year Exxon-Mobil expends large amounts of funds for mechanical safety features throughout its worldwide operations. Carla Ramos, a lead engineer for Mexico and Central American operations, plans expenditures of \$1 million now and each of the next 4 years just for the improvement of field-based pressure-release valves. Construct the cash flow diagram to find the equivalent value of these expenditures at the end of year 4, using a cost of capital estimate for safety-related funds of 12% per year.

Solution

Figure 1.6 indicates the uniform and negative cash flow series (expenditures) for five periods, and the unknown F value (positive cash flow equivalent) at exactly the same time as the fifth expenditure. Since the expenditures start immediately, the first \$1 million is shown at time 0, not time 1. Therefore, the last negative cash flow occurs at the end of the fourth year, when F also occurs. To make this diagram appear similar to that of Figure 1.5 with a full 5 years on the time scale, the addition of the year -1 prior to year 0 completes the diagram for a full 5 years. This addition demonstrates that year 0 is the end-of-period point for the year -1.

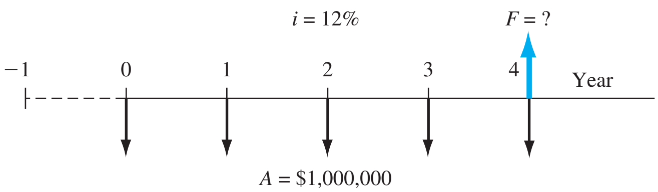


FIGURE 1.6 Cash flow diagram, Example 1.12.

EXAMPLE 1.13 A father wants to deposit an unknown lump-sum amount into an investment opportunity 2 years from now that is large enough to withdraw \$4000 per year for state university tuition for 5 years starting 3 years from now. If the rate of return is estimated to be 15.5% per year, construct the cash flow diagram.

Solution

Figure 1.7 presents the cash flows from the father's perspective. The present value P is a cash outflow 2 years hence and is to be determined ($P = ?$). Note that this present value does not occur at time $t = 0$, but it does occur one period prior to the first A value of \$4000, which is the cash inflow to the father.

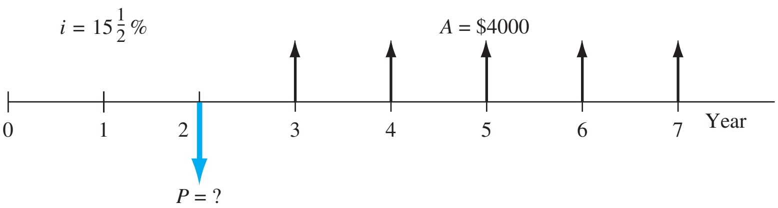


FIGURE 1.7 Cash flow diagram, Example 1.13.

1.8 INTRODUCTION TO SPREADSHEET AND CALCULATOR FUNCTIONS

There are four different ways to perform an equivalence calculation: equation, factor, spreadsheet, and financial calculator. The first two methods are discussed and illustrated in Chapter 2. Spreadsheet and calculator functions are briefly outlined in this section and utilized throughout the text in conjunction with factors and equations.

The functions on a computer spreadsheet can greatly reduce the amount of hand and calculator work for equivalency computations involving *compound interest* and the terms P, F, A, i, and n. Often a predefined function can be entered into one cell and we can obtain the final answer immediately. Any spreadsheet system can be used; Excel is used throughout this book because it is readily available and easy to use.

Appendix A is a primer on using spreadsheets and Excel. The functions used in engineering economy are described there in detail, with explanations of all the parameters (also called arguments) placed between parentheses after the function identifier. The online help system provides similar information. Appendix A also includes a section on spreadsheet layout that is useful when the economic analysis is presented to someone else—a coworker, a boss, or a professor.

A total of seven spreadsheet functions can perform most of the fundamental engineering economy calculations. However, these functions are no substitute for knowing how the time value of money and compound interest work. The functions are great supplemental tools, but they do not replace the understanding of engineering economy relations, assumptions, and techniques.

Using the symbols P, F, A, i, and n exactly as defined in Section 1.6, the spreadsheet functions most used in engineering economic analysis are formulated as follows.

To find the present value P of an A series: = PV(i%,n,A,F)

To find the future value F of an A series: = FV(i%,n,A,P)

To find the equal, periodic value A: = PMT(i%,n,P,F)

To find the number of periods n: = NPER(i%,A,P,F)

To find the compound interest rate i: = RATE(n,A,P,F)

To find the compound interest rate i: = IRR(first_cell:last_cell)

To find the present value P of any series: = NPV(i%, second_cell:last_cell) + first_cell

If some of the parameters don't apply to a particular problem, they can be omitted and zero is assumed. If the parameter omitted is an interior one, the comma must be entered. The last two functions require that a series of numbers be entered into adjacent spreadsheet cells, but the first five can be used with no supporting data. In all cases, the function must be preceded by an equals sign (=) in the cell where the answer is to be displayed.

Most *calculators* that have financial functions include time value of money (TVM) functions. These are very useful for in-class and exam work for cash flows that are not too complex. On many calculators there are keys labeled PV, FV, PMT, i and n, or similar terms. When four of the five values are entered, the remaining parameter is calculated by pressing the appropriate key. The procedures to input the four known values and to obtain the fifth value vary slightly between calculators manufactured by different companies. For our notation purposes, each calculator function is identified in a manner similar to the first five spreadsheet functions, without an = sign. The interest rate is entered as a percent on most calculators. The notation is as follows:

Find present value P of an A series:	PV(i,n,A,F)
Find future value F of an A series:	FV(i,n,A,P)
Find A series of P and/or F values:	PMT(i,n,P,F)
Find number of periods n:	n(i,A,P,F)
Find compound interest rate i:	i(n,A,P,F)

Some calculators use different letters than spreadsheet functions and those used in this text. For example, the letter P may represent a uniform series that we label A. Others use B to represent a present worth amount, which is P in this text. Check the user's manual to be sure you understand how to correctly apply a TVM function.

Several spreadsheet and financial calculator functions have optional parameters that can be entered as the last argument in the parenthesis. One example is "type," which identifies the cash flows as occurring at the beginning or end of each period. The default is end-of-period (type = 0); however, many finance applications require beginning-of-period cash flows, thus requiring an entry of type = 1.

There are no built-in functions for spreadsheets or calculators that accommodate *gradients* where the cash flows increase or decrease by a constant amount or constant percentage each time period. As we will learn in Chapter 2, equivalence computations involving gradients are best handled using a spreadsheet, first, with tabulated factors or equivalence equations as alternatives.

Spreadsheet and calculator functions will be introduced and illustrated at the point in this text where they are most useful. However, to get an idea of how they work, look back at Examples 1.7 and 1.8. In Example 1.7, the future amount F is unknown, as indicated by F = ? in the solution. In Chapter 2, we will learn how the time value of money is used to find F, given P, i, and n. To find F in this example using a calculator or spreadsheet, simply enter the FV function. The

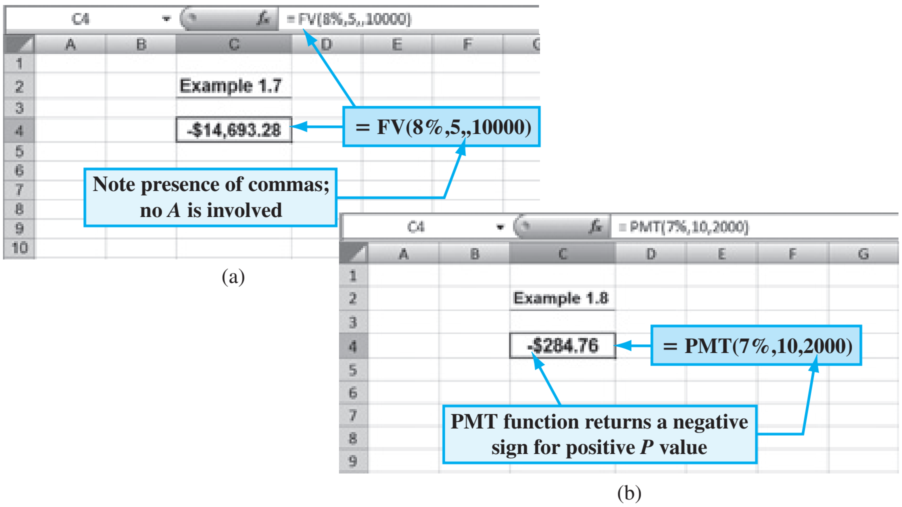


FIGURE 1.8
Use of spreadsheet functions for (*a*) Example 1.7 and (*b*) Example 1.8.

one-cell spreadsheet format is =FV(i%,n,,P) or =FV(8%,5,,10000). The extra comma is entered because there is no A involved. Figure 1.8a is a screen image of the spreadsheet with the FV function entered into cell C4. The answer of \$−14,693.28 is displayed. The answer is a negative amount from the borrower's perspective to repay the loan after 5 years. The FV function is shown in the formula bar above the worksheet, and a cell tag shows the format of the FV function.

In Example 1.8, the uniform annual amount A is sought, and P, i, and n are known. Find A using the function =PMT(7%,10,2000). Figure 1.8b shows the result.

1.9 ETHICS AND ECONOMIC DECISIONS

Initially, you may not think that engineering economic decisions are closely allied with ethics. However, economics and ethically good or poor actions can be closely connected for some individuals who work for corporations, who own their own businesses, and who serve the public in appointed or elected government positions. The fundamental cause for ethically bad decisions is commonly *money*, in the form of increased profit, lower costs, favors, or kickbacks.

Let's begin an examination of the connections between economics and ethics through an understanding of the underlying tenets that form the character and conduct of a person when judging right from wrong. These tenets are called *morals;* there are morals for society in general and for one individual. The term *ethics* is used when examining decisions and actions based on morals that can be evaluated using a measure, such as a *code of ethics*. This code forms the standards to guide a person's decisions and actions in a particular profession, for example, engineering, medicine, law, education, etc.

Universal or common morals: Fundamental moral beliefs that are held by virtually all people. Most people believe that injurious actions taken against another person are morally wrong. These include lying, stealing, physical harm, and murder.

It is possible for actions and intentions to come into conflict with a common moral. Consider the World Trade Center buildings in New York City. After their collapse on September 11, 2001, it was apparent that the design was not sufficient to withstand the heat generated in the fire storm caused by the impact of an aircraft. The structural engineers who worked on the building's design surely did not have the intent to harm occupants; however, their design did not foresee this outcome as a measurable possibility. Did they violate the common moral belief of not doing physical harm to or murdering others? Likely, they did not.

Individual or personal morals: The moral beliefs that a person has and maintains over time. These usually parallel the common morals in that stealing, lying, murdering, etc. are immoral acts.

It is quite possible that an individual strongly supports the common morals and has excellent personal morals, but these can conflict when tough decisions must be made. Consider the university student who genuinely believes that lying in the form of cheating on an exam is wrong. Assume he or she is in the last semester before graduation and does not know how to work several problems on a take-home final exam, yet a minimum grade on the exam is necessary to graduate. The decision to cheat or not on the final exam by copying from a friend is an exercise in adhering to or violating a personal moral. Likewise, if to cheat is the decision, the friend who provides the answers also has to make the decision to adhere to or violate his or her own personal moral about cheating.

Professional ethics: People working in specific disciplines are usually guided in their decision making and work activities by a formal standard or code. The code states the commonly accepted standards of honesty and integrity that each individual is expected to demonstrate. There are codes of ethics for medical doctors, attorneys, elected officials, and, of course, engineers.

Though each engineering profession has its own code of ethics, the *Code of Ethics for Engineers* published by the National Society of Professional Engineers (www.nspe.org/ethics) is commonly applied. This code, reprinted in Figure 1.9, includes numerous sections that have direct or indirect economic and financial impact upon the designs, actions, and decisions that engineers make in their professional activities. Some examples are:

- Section I.5: Avoid deceptive acts.
- Section III.3.a: Don't make statements that contain misrepresentation of fact or that omit material facts.
- Section III.5.a: Do not accept financial consideration from suppliers for specifying their product.

In the everyday practice of engineering, there are numerous money-related situations that can involve ethical dimensions. Here are a few samples:

- Compromising safety in the design of a product or service so that the price comes in low enough to win a contract when the bids are evaluated.
- Delaying regularly scheduled equipment maintenance to save money, thus placing the safety of people and product in jeopardy.
- Substituting cheaper, poorer-quality materials (chemicals, parts, etc.) to reduce cost, resulting in increased profit, and violating company health standards for employees and customers.
- Mislabeling to the public in that a much cheaper, similar-functioning product is substituted while the price charged is that of the product identified. (Example 1.14 is an illustration of this type of unethical practice.)

Many ethical questions arise when corporations operate in international settings where the corporate rules, worker incentives, cultural practices, and costs in the home country differ from those in the host country. Often these ethical dilemmas are fundamentally based in economics which provide cheaper labor, reduced raw material costs, less government oversight, and a host of other cost-reducing factors. When an engineering economy study is performed, the engineer performing the study must consider all ethically related matters to ensure that cost estimates reflect what is likely to happen once the project or system is operating.

National Society of Professional Engineers®

Code of Ethics for Engineers

Preamble

Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.

I. Fundamental Canons

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. Rules of Practice

1. Engineers shall hold paramount the safety, health, and welfare of the public.
   a. If engineers' judgment is overruled under circumstances that endanger life or property, they shall notify their employer or client and such other authority as may be appropriate.
   b. Engineers shall approve only those engineering documents that are in conformity with applicable standards.
   c. Engineers shall not reveal facts, data, or information without the prior consent of the client or employer except as authorized or required by law or this Code.
   d. Engineers shall not permit the use of their name or associate in business ventures with any person or firm that they believe is engaged in fraudulent or dishonest enterprise.
   e. Engineers shall not aid or abet the unlawful practice of engineering by a person or firm.
   f. Engineers having knowledge of any alleged violation of this Code shall report thereon to appropriate professional bodies and, when relevant, also to public authorities, and cooperate with the proper authorities in furnishing such information or assistance as may be required.
2. Engineers shall perform services only in the areas of their competence.
   a. Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved.
   b. Engineers shall not affix their signatures to any plans or documents dealing with subject matter in which they lack competence, nor to any plan or document not prepared under their direction and control.
   c. Engineers may accept assignments and assume responsibility for coordination of an entire project and sign and seal the engineering documents for the entire project, provided that each technical segment is signed and sealed only by the qualified engineers who prepared the segment.
3. Engineers shall issue public statements only in an objective and truthful manner.
   a. Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony, which should bear the date indicating when it was current.
   b. Engineers may express publicly technical opinions that are founded upon knowledge of the facts and competence in the subject matter.
   c. Engineers shall issue no statements, criticisms, or arguments on technical matters that are inspired or paid for by interested parties, unless they have prefaced their comments by explicitly identifying the interested parties on whose behalf they are speaking, and by revealing the existence of any interest the engineers may have in the matters.
4. Engineers shall act for each employer or client as faithful agents or trustees.
   a. Engineers shall disclose all known or potential conflicts of interest that could influence or appear to influence their judgment or the quality of their services.
   b. Engineers shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.
   c. Engineers shall not solicit or accept financial or other valuable consideration, directly or indirectly, from outside agents in connection with the work for which they are responsible.
   d. Engineers in public service as members, advisors, or employees of a governmental or quasi-governmental body or department shall not participate in decisions with respect to services solicited or provided by them or their organizations in private or public engineering practice.
   e. Engineers shall not solicit or accept a contract from a governmental body on which a principal or officer of their organization serves as a member.
5. Engineers shall avoid deceptive acts.
   a. Engineers shall not falsify their qualifications or permit misrepresentation of their or their associates' qualifications. They shall not misrepresent or exaggerate their responsibility in or for the subject matter of prior assignments. Brochures or other presentations incident to the solicitation of employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint venturers, or past accomplishments.
   b. Engineers shall not offer, give, solicit, or receive, either directly or indirectly, any contribution to influence the award of a contract by public authority, or which may be reasonably construed by the public as having the effect or intent of influencing the awarding of a contract. They shall not offer any gift or other valuable consideration in order to secure work. They shall not pay a commission, percentage, or brokerage fee in order to secure work, except to a bona fide employee or bona fide established commercial or marketing agencies retained by them.

III. Professional Obligations

1. Engineers shall be guided in all their relations by the highest standards of honesty and integrity.
   a. Engineers shall acknowledge their errors and shall not distort or alter the facts.
   b. Engineers shall advise their clients or employers when they believe a project will not be successful.
   c. Engineers shall not accept outside employment to the detriment of their regular work or interest. Before accepting any outside engineering employment, they will notify their employers.
   d. Engineers shall not attempt to attract an engineer from another employer by false or misleading pretenses.
   e. Engineers shall not promote their own interest at the expense of the dignity and integrity of the profession.
2. Engineers shall at all times strive to serve the public interest.
   a. Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community.
   b. Engineers shall not complete, sign, or seal plans and/or specifications that are not in conformity with applicable engineering standards. If the client or employer insists on such unprofessional conduct, they shall notify the proper authorities and withdraw from further service on the project.
   c. Engineers are encouraged to extend public knowledge and appreciation of engineering and its achievements.
   d. Engineers are encouraged to adhere to the principles of sustainable development[1] in order to protect the environment for future generations.

FIGURE 1.9 *Code of Ethics for Engineers* from the National Society of Professional Engineers

3. Engineers shall avoid all conduct or practice that deceives the public.
   a. Engineers shall avoid the use of statements containing a material misrepresentation of fact or omitting a material fact.
   b. Consistent with the foregoing, engineers may advertise for recruitment of personnel.
   c. Consistent with the foregoing, engineers may prepare articles for the lay or technical press, but such articles shall not imply credit to the author for work performed by others.
4. Engineers shall not disclose, without consent, confidential information concerning the business affairs or technical processes of any present or former client or employer, or public body on which they serve.
   a. Engineers shall not, without the consent of all interested parties, promote or arrange for new employment or practice in connection with a specific project for which the engineer has gained particular and specialized knowledge.
   b. Engineers shall not, without the consent of all interested parties, participate in or represent an adversary interest in connection with a specific project or proceeding in which the engineer has gained particular specialized knowledge on behalf of a former client or employer.
5. Engineers shall not be influenced in their professional duties by conflicting interests.
   a. Engineers shall not accept financial or other considerations, including free engineering designs, from material or equipment suppliers for specifying their product.
   b. Engineers shall not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with clients or employers of the engineer in connection with work for which the engineer is responsible.
6. Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by other improper or questionable methods.
   a. Engineers shall not request, propose, or accept a commission on a contingent basis under circumstances in which their judgment may be compromised.
   b. Engineers in salaried positions shall accept part-time engineering work only to the extent consistent with policies of the employer and in accordance with ethical considerations.
   c. Engineers shall not, without consent, use equipment, supplies, laboratory, or office facilities of an employer to carry on outside private practice.
7. Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.
   a. Engineers in private practice shall not review the work of another engineer for the same client, except with the knowledge of such engineer, or unless the connection of such engineer with the work has been terminated.
   b. Engineers in governmental, industrial, or educational employ are entitled to review and evaluate the work of other engineers when so required by their employment duties.
   c. Engineers in sales or industrial employ are entitled to make engineering comparisons of represented products with products of other suppliers.
8. Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising out of their practice for other than gross negligence, where the engineer's interests cannot otherwise be protected.
   a. Engineers shall conform with state registration laws in the practice of engineering.
   b. Engineers shall not use association with a nonengineer, a corporation, or partnership as a "cloak" for unethical acts.
9. Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others.
   a. Engineers shall, whenever possible, name the person or persons who may be individually responsible for designs, inventions, writings, or other accomplishments.
   b. Engineers using designs supplied by a client recognize that the designs remain the property of the client and may not be duplicated by the engineer for others without express permission.
   c. Engineers, before undertaking work for others in connection with which the engineer may make improvements, plans, designs, inventions, or other records that may justify copyrights or patents, should enter into a positive agreement regarding ownership.
   d. Engineers' designs, data, records, and notes referring exclusively to an employer's work are the employer's property. The employer should indemnify the engineer for use of the information for any purpose other than the original purpose.
   e. Engineers shall continue their professional development throughout their careers and should keep current in their specialty fields by engaging in professional practice, participating in continuing education courses, reading in the technical literature, and attending professional meetings and seminars.

Footnote 1 "Sustainable development" is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development.

As Revised July 2007

"By order of the United States District Court for the District of Columbia, former Section 11(c) of the NSPE Code of Ethics prohibiting competitive bidding, and all policy statements, opinions, rulings or other guidelines interpreting its scope, have been rescinded as unlawfully interfering with the legal right of engineers, protected under the antitrust laws, to provide price information to prospective clients; accordingly, nothing contained in the NSPE Code of Ethics, policy statements, opinions, rulings or other guidelines prohibits the submission of price quotations or competitive bids for engineering services at any time or in any amount."

Statement by NSPE Executive Committee

In order to correct misunderstandings which have been indicated in some instances since the issuance of the Supreme Court decision and the entry of the Final Judgment, it is noted that in its decision of April 25, 1978, the Supreme Court of the United States declared: "The Sherman Act does not require competitive bidding."

It is further noted that as made clear in the Supreme Court decision:

1. Engineers and firms may individually refuse to bid for engineering services.
2. Clients are not required to seek bids for engineering services.
3. Federal, state, and local laws governing procedures to procure engineering services are not affected, and remain in full force and effect.
4. State societies and local chapters are free to actively and aggressively seek legislation for professional selection and negotiation procedures by public agencies.
5. State registration board rules of professional conduct, including rules prohibiting competitive bidding for engineering services, are not affected and remain in full force and effect. State registration boards with authority to adopt rules of professional conduct may adopt rules governing procedures to obtain engineering services.
6. As noted by the Supreme Court, "nothing in the judgment prevents NSPE and its members from attempting to influence governmental action . . ."

Note: In regard to the question of application of the Code to corporations vis-a-vis real persons, business form or type should not negate nor influence conformance of individuals to the Code. The Code deals with professional services, which services must be performed by real persons. Real persons in turn establish and implement policies within business structures. The Code is clearly written to apply to the Engineer, and it is incumbent on members of NSPE to endeavor to live up to its provisions. This applies to all pertinent sections of the Code.

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FIGURE 1.9 *Code of Ethics for Engineers* from the National Society of Professional Engineers (continued)

EXAMPLE 1.14

In October 2011, *The Boston Globe* newspaper presented a series of articles and a video indicating that a large percentage of the fish served at restaurants in the Boston area were mislabeled. ("Seafood mislabeled at many local restaurants," LaPierre, Scott; Abelson, Jenn; and Daley, Beth; October 23, 2011; video at www.bostonglobe.com/business/specials/fish). The investigation clearly showed that the promise of larger profits, fueled by the scarcity of more expensive fish varieties, motivated restaurant owners and fish suppliers to substitute cheap fish varieties for similar looking and tasting, but more expensive fish listed on their menus. For example, catfish marketed by international suppliers were found to be purchased for $1.50 per pound, labeled as Atlantic cod, and sold for $12 per pound. DNA tests showed that some 48% of the samples from restaurants were mislabeled, all using significantly cheaper fish for more pricey varieties listed on the menu.

In one case, a restaurant owner knowingly advertised and charged the price of the expensive red snapper fish, but substituted ocean perch, a much cheaper fish. He stated that the red snapper was hard to find on the market, and that ocean perch cooks and tastes very similar to red snapper. His claim was that he wanted to offer his customers what they wanted, that is, red snapper. When interviewed, he stated that he did not even think of the substitution of perch for snapper as a price saver for him. In his mind, he was simply providing a way for customers to purchase what they wanted in fish variety. However, the price for perch averaged $4.25 per pound, while snapper cost about $8.95 a pound, when available. Yet, his menu did not state anything about the substitution or that snapper may be unavailable. Finally, when exposed, he said he would change his menu to be more truthful.

Use the NSPE Code of Ethics for Engineers as a model code to identify some of the ethically-questionable practices of the restaurant owner in mislabeling fish and selling them for the price of a more expensive variety. Describe some actions that the owner could have taken to demonstrate honestly and integrity in operating his business when the red snapper variety was unavailable.

Solution

As the NSPE Code of Ethics for Engineers is applied to this situation, consider the restaurant owner to be the engineer referenced in the code and the clients to be customers of the restaurant. Sample sections of the code that identify unethical practices are listed below; refer to the code sections for details of each violation (Figure 1.9).

Fundamental Canons: violation of *Sections I.5* and *I.6*

Rules of Practice: violation of *Section II.3.a*

Professional Obligations: violation of *Section III.3.a*

To ensure honesty and integrity in his business practices, the restaurant owner could have done several things. It could have been noted on the menu that red snapper is not always available and that substitution of a cheaper fish at the price of the snapper is never made by the restaurant. Since red snapper is one of the "'big sellers," the owner could place a separate note in the menu when snapper is not available and mention that ocean perch is available, has the same taste and texture, and sells at a significantly lower price than snapper.

The biggest lesson for the owner is to realize that the "rationalization" of doing customers a service by deceptive acts is totally wrong and unethical. The owner's future practices need to be based on honesty in advertising and pricing for all of his menu items.

SUMMARY

Engineering economy is the application of economic factors to evaluate alternatives by considering the time value of money. The engineering economy study involves computing a specific economic measure of worth for estimated cash flows over a specific period of time.

The concept of *equivalence* helps in understanding how different sums of money at different times are equal in economic terms. The differences between simple interest (based on principal only) and compound interest (based on principal and interest upon interest) have been described in formulas, tables, and graphs.

The MARR is a reasonable rate of return established as a hurdle rate to determine if an alternative is economically viable. The MARR is always higher than the return from a safe investment and the corporation's cost of capital.

Also, this chapter introduced the estimation, conventions, and diagramming of cash flows.

PROBLEMS

Definitions and Basic Concepts

1.1 Discuss the importance of alternative identification in the engineering economic process.

1.2 Which of the following would be considered noneconomic factors in deciding which type of power plant to build: (a) equipment cost; (b) morale; (c) goodwill; (d) salvage value; (e) public acceptance; and (f) aesthetics?

1.3 In economic analysis, revenues and costs are examples of what?

1.4 The analysis techniques that are used in engineering economic analysis are only as good as what?

1.5 What is meant by the *do-nothing alternative*?

1.6 What is meant by the term *evaluation criterion*?

1.7 What evaluation criterion is used in economic analysis?

1.8 What is meant by the term *intangible factor*?

1.9 Give three examples of intangible factors.

1.10 What is meant by the term *time value of money*?

1.11 Interest is a manifestation of what general concept in engineering economy?

1.12 Of the fundamental dimensions length, mass, time, and electric charge, which one is the most important in economic analysis? Why?

Interest Rate and Equivalence

1.13 The term that describes compensation for "renting" money is what?

1.14 When an interest rate statement does not include a time period, e.g., 3%, the time period is assumed to be what?

1.15 The original amount of money in a loan transaction is known as what?

1.16 What is meant by the term *minimum attractive rate of return (MARR)*?

1.17 When the yield on a U.S. Government Bond is 3% per year, investors expect the inflation rate to be approximately what?

1.18 In order to build a new warehouse facility, the regional distributor for Valco Multi-position Valves borrowed \$1.6 million at 10% per year interest. If the company repaid the loan in a lump sum amount after two years, what was (a) the amount of the payment, and (b) the amount of interest?

1.19 A medium-size consulting engineering firm is trying to decide whether it should remodel its office now or wait and do it one year from now. If the firm does it now, the cost will be $38,000. The interest rate is 10% per year.

a. What would the cost have to be one year from now to render the decision indifferent?

b. If the cost one year from now is $41,600, should the firm remodel now or later?

1.20 At an interest rate of 8% per year, $50,000 one year hence is equivalent to how much now?

1.21 Bennett Industries invested $10,000,000 in a co-venture one year ago. One year later, Bennett realized a profit of $1,450,000. What annual rate of return does this represent?

1.22 Trucking giant Yellow Corp agreed to purchase rival Roadway for $966 million in order to reduce so-called back-office costs, that is, payroll and insurance, by $45 million per year. If the savings are realized as planned, what is the rate of return on the investment?

1.23 If Ford Motor Company's profits increased from 22 cents per share to 29 cents per share in the April-June quarter compared to the previous quarter, what was the rate of increase in profits for that quarter?

1.24 A broadband service company borrowed $2 million for new equipment and repaid the principal of the loan plus $275,000 interest after 1 year. What was the interest rate on the loan?

1.25 A design-build engineering firm completed a pipeline project wherein the company realized a profit of $2.3 million in one year. If the amount of money the company invested was $6 million, what was the rate of return on the investment?

1.26 A sum of $2 million now is equivalent to $2.36 million one year from now at what interest rate?

1.27 Last year, Lee Industries decided to restructure some of its debt by paying off one of its short-term loans. To do so, the company borrowed the money one year ago at an interest rate of 10% per year. If the total cost of repaying the loan was $53 million, what was the amount of the original loan?

1.28 A start-up company with multiple nanotechnology products established a goal of making a rate of return of at least 25% per year on its investments for the first five years. If the company acquired $400 million in venture capital, how much did it have to earn in the first year?

1.29 How many years does it take for an investment of $280,000 to accumulate to at least $425,000 at 15% per year interest?

1.30 The MARR used for a project's acceptance or rejection is set relative to what cost?

1.31 An engineer told you that a project is economically acceptable when it's rate of return equals or exceeds the corporation's cost of capital. Is this correct? Explain your answer.

Simple and Compound Interest

1.32 Valley Rendering, Inc. is considering the purchase of a new flotation system for recovering more grease. The company can finance a $150,000 system at 5% per year compound interest or 5.5% per year simple interest.

a. If the total amount owed is due in a single payment at the end of 3 years, which interest rate should the company select?

b. How much is the difference in interest between the two schemes?

1.33 Valtro Electronic Systems, Inc. set aside a lump sum investment four years ago in order to finance a plant expansion now. The money returned 10% per year simple interest. How much did the company set aside if the investment is now worth $850,000?

1.34 At 10% per year simple interest, how long will it take for a deposit of $1000 now to accumulate to $100,000?

1.35 Fill in the missing values A through D in the table for a loan of $10,000, if the interest rate is compounded at 10% per year.

End of Year	Interest for Year	Total Owed at End of Year	End-of-Year Payment	Total Owed after Payment
0	—	—	—	10,000
1	1000	11,000	2000	9,000
2	900	9,900	2000	**A**
3	**B**	**C**	2000	**D**

1.36 An engineer who was in the business of customizing software for small construction companies repaid a loan that she got 3 years ago at 7% per year simple interest. If the amount she repaid was \$35,000, what was the principal amount of the loan?

1.37 How much can you borrow today if you promise to repay \$20,000 two years from today at a compound interest rate of 20% per year?

1.38 A design-build-operate engineering company borrowed \$6 million for 3 years so that it can purchase new equipment. The interest is compounded and the total amount owed will be paid in a single lump sum amount at the end of the 3-year period. The interest at the end of the first year will be \$900,000.

a. What is the interest rate on the loan?

b. How much interest will be charged at the end of the second year?

1.39 A company that manufactures general-purpose transducers invested \$2 million four years ago in high-yield junk bonds. If the bonds are now worth \$2.8 million, what rate of return per year did the company make on the basis of (a) simple interest, and (b) compound interest?

1.40 How many years would it take for money to triple in value at 20% per year simple interest?

1.41 If Aquatronics Inc. wants its investments to double in value in 4 years, what rate of return would it have to make on the basis of (a) simple interest, and (b) compound interest?

1.42 Companies frequently borrow money under an arrangement that requires them to make periodic payments of "interest only" and then pay the principal all at once. If Cisco International borrowed \$500,000 (identified as loan A) at 10% per year simple interest and another \$500,000 (identified as loan B) at 10% per year compound interest and paid *only the interest* at the end of *each year* for three years on both loans, (a) on which loan did the company pay more interest, and (b) what was the difference in interest paid between the two loans?

Terminology and Symbols

1.43 *All* engineering economy problems will involve which two of the following symbols: P, F, A, i, n?

1.44 Define the economy symbols to determine how many years it would take for \$13,000 to double in size at a compound interest rate of 6.8% per year.

1.45 At 9% per year simple interest, \$1000 is equivalent to \$1270 in three years. Define the symbols for the compound interest rate per year that would make this equivalence correct, i.e., \$1000 now and \$1270 in 3 years.

1.46 Define the symbols involved when a construction company wants to know how much money it can spend 3 years from now to purchase a new truck in lieu of spending \$50,000 now. The compound interest rate is 15% per year.

1.47 Identify the symbols involved if a pharmaceutical company wants to have a liability fund worth \$200 million five years from now. Assume the company will invest an equal amount of money *each year* beginning one year from now and that the investments will earn 12% per year.

1.48 Vision Technologies, Inc. is a small company that uses ultra-wideband technology to develop devices that can detect objects (including people) inside of buildings, behind walls, or below ground. The company expects to spend \$100,000 per year for labor and \$125,000 per year for supplies before a product can be marketed. If the company wants to know the total equivalent future amount of the company's expenses at the end of 3 years at 15% per year interest, identify the engineering economy symbols involved and the values for the ones that are given.

1.49 Corning Ceramics expects to spend \$400,000 to upgrade equipment two years from now. If the company wants to know the equivalent value now of the planned expenditure, identify the symbols and their values, assuming Corning's minimum attractive rate of return is 20% per year.

1.50 Sensotech, Inc., a maker of microelectromechanical systems, believes it can reduce product recalls by 10% if it purchases new software for detecting faulty parts. The cost of the new software is \$225,000. Identify the symbols involved and the values for the symbols that are given in determining how much the company would have to save each year to recover its investment in 4 years at a minimum attractive rate of return of 15% per year.

1.51 Atlantic Metals and Plastics uses austenitic nickel-chromium alloys to manufacture resistance heating wire. The company is considering a new annealing-drawing process to reduce costs. The new process will cost \$1.8 million dollars now. Identify the symbols that are involved and the values of those that are given, if the company wants to know how much it must save each year to recover the investment in 6 years at an interest rate of 12% per year.

1.52 Phillips Refining plans to expand capacity by purchasing equipment that will provide additional smelting capacity. The cost of the initial investment is expected to be $16 million. The company expects revenue to increase by $3.8 million per year after the expansion. If the company's MARR is 18% per year, how long will it take for the company to recover its investment? Identify the engineering economy symbols involved and their values.

Cash Flows

1.53 What does the term "end-of-period convention" mean? What does it not mean?

1.54 In the phrase "end-of-period convention," the word "period" refers to what?

1.55 The difference between cash inflows and cash outflows is known as what?

1.56 Identify the following as cash inflows or outflows to Anderson and Dyess Design-Build Engineers: office supplies, GPS surveying equipment, auctioning of used earth-moving equipment, staff salaries, fees for services rendered, interest from bank deposits.

1.57 Identify the following as cash inflows or outflows to Honda: income taxes, loan interest, salvage value, rebates to dealers, sales revenues, accounting services, and cost reductions by subcontractors.

1.58 Construct a cash flow diagram to find the present worth of a future outflow of $40,000 in year 5 at an interest rate of 15% per year.

1.59 Construct a cash flow diagram for the following cash flows: $10,000 outflow at time zero, $3000 per year inflow in years 1 through 5 at an interest rate of 10% per year, and an unknown future amount in year 5.

1.60 Kennywood Amusement Park spends $75,000 each year in consulting services for ride inspection and maintenance recommendations. New actuator element technology enables engineers to simulate complex computer-controlled movements in any direction. Construct a cash flow diagram for determining how much the park could afford to spend now on the new technology if the cost of annual consulting services will be reduced to $30,000 per year? Assume the park uses an interest rate of 15% per year and it wants to recover its investment in 5 years.

Spreadsheet and Financial Calculator Functions

1.61 Write the engineering economy symbol that corresponds to each of the following spreadsheet functions.

a. FV
b. PMT
c. NPER
d. IRR
e. PV

1.62 What are the values of the engineering economy symbols *P*, *F*, *A*, *i*, and *n* in the following spreadsheet or TVM calculator functions? Use a "?" for the symbol that is to be determined.

a. FV(8%,10,2000,−10000)
b. PMT(12%,30,16000)
c. PV(9%,15,1000,700)
d. *n*(8.5,5000,−50000,20000)

1.63 State the purpose for each of the following built-in spreadsheet functions:

a. FV(i%,*n*,*A*,*P*)
b. IRR(first_cell:last_cell)
c. PMT(i%,*n*,*P*,*F*)
d. PV(i%,*n*,*A*,*F*)

1.64 In a built-in spreadsheet function, if a certain parameter does not apply, under what circumstances can it be left blank and when must a comma be entered in its place?

Ethics and Economics

1.65 Explain the relation between a common moral and a personal moral.

1.66 What is one primary use of a *code of ethics* for a specific discipline of professional practice?

1.67 Yesterday, Carol, an engineer with Hancock Enterprises, was at lunch with several work friends. Joe, a person Carol has known for a year or so from similar lunches, proudly mentioned that he got a free flight and tickets to a major league playoff game two weeks from now in a distant city. Joe happened to also mention the company; it is Dryer. Carol is aware that Dryer is one of the prime bidders on a major contract to be evaluated by Hancock next month. Upon inquiry, Carol learned that both she and Joe are on the bid evaluation committee. Carol suspects that someone in Dryer has offered Joe the tickets as a consideration for Joe's favorable evaluation of their bid.

a. Carol has determined that she could do one of several things about the situation: recommend to Joe directly that he refuse the tickets; show Joe the NSPE Code of Ethics for Engineers and let him make his own decision; go to Joe's supervisor and tell her of the situation; go to her own supervisor and inform him of her suspicion; write an e-mail to Joe with a copy to her supervisor recommending that Joe consider the ethical dilemma involved for him; do nothing. Considering only these actions, select the one you think is the best and explain why you chose it.

b. Identify other options for Carol's response at this time and determine if one of them is better than her options outlined above.

1.68 Watch the video mentioned in Example 1.14. Give an example of a situation that you have experienced at a restaurant, retailer, or some other business that sells to the public. In your view, what should the business have done to be more ethical in their dealings with the public?

ADDITIONAL PROBLEMS AND FE EXAM REVIEW QUESTIONS

1.69 At a compound interest rate of 10% per year, \$10,000 one year ago is equivalent to this amount now:
a. \$8,264
b. \$9,091
c. \$11,000
d. \$12,100

1.70 All of the following are intangible factors except:
a. Taxes
b. Goodwill
c. Morale
d. Convenience

1.71 Amounts of \$1000 one year ago and \$1345.60 one year hence are equivalent at the following compound interest rate per year:
a. 12.5% per year
b. 14.8% per year
c. 17.2% per year
d. None of the above

1.72 The simple interest rate per year required to accumulate the same amount of money in 2 years at 20% per year compound interest is:
a. 20.5%
b. 21%
c. 22%
d. 23%

1.73 An investment of \$8,000 nine years ago has accumulated to \$16,000 now. The compound rate of return earned on the investment is closest to:
a. 6%
b. 8%
c. 10%
d. 12%

1.74 In most engineering economy studies, the best alternative is the one which:
a. Will last the longest time
b. Is the easiest to implement
c. Costs the least
d. Is the most politically correct

1.75 The cost of tuition at a public university was \$200 per credit hour 5 years ago. The cost today (exactly 5 years later) is \$268. The annual rate of increase is closest to:
a. 4%
b. 6%
c. 8%
d. 10%

1.76 The time it would take for money to double at a simple interest rate of 5% per year is closest to:
a. 10 years
b. 12 years
c. 15 years
d. 20 years

1.77 For the spreadsheet built-in function PV(i%,*n*,*A*,*F*), the only parameter that can be completely omitted is:
a. i%
b. *n*
c. *A*
d. *F*