School for Professional Studies
Undergraduate Program

# CS208
# COMPUTER SCIENCE FUNDAMENTALS

Supplemental Course Materials

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# CHAPTER ONE

# NUMBERING SYSTEMS AND DATA REPRESENTATION

# Section I: **Binary Numbers and Codes**

Computer languages allow the programmer to write programs to be carried out by the computer. **Machine language** is the most fundamental of the languages. A sample set of machine language instructions may look like this:

1010111010110111
1110001110100011
0001010100111010
0111000101101110
0101010101110001

Programs are stored in the computer's memory as small electric charges. You can think of each storage location as having a charge (on) or not having a charge (off) just as a light switch turns a light bulb on or off. These on and off states are frequently written as 1 or 0. Since there are only two possible values for each location, each 1 and 0 is known as a **binary digit** or **bit**. For convenience and speed, the computer's central processing unit (**CPU**) processes bits in groups; many computers use groups of 8 bits although 16 and 32 bit groups are not uncommon. Each 8-bit group is known as a **byte**. Since machine language is **the** language of the computer, some knowledge of the binary numbering system and the use of binary codes for data representation is essential for an understanding of how the computer stores data and processes programming instructions.

As indicated above, each location or circuit can have two states, on or off. These states can be used to represent data as follows: **no** may be represented by **off**
**yes** may be represented by **on**.

As the number of circuits is expanded the number of states representing data is also expanded. For example, two circuits provides four states in the following manner:

| | | | |
|---|---|---|---|
| off-off | off-on | on-off | on-on |

These four states can then be used to represent common items of data such as the four seasons:

| | | | |
|---|---|---|---|
| Winter | off-off | Summer | on-off |
| Spring | off-on | Fall | on-on |

In terms of storing the data in the computer's memory, two bits could be used as follows:

| | | | |
|---|---|---|---|
| Winter | 00 | Summer | 10 |
| Spring | 01 | Fall | 11 |

In general, whenever a circuit is added, the number of available states is doubled.

From algebra we have $2^0 = 1$, $2^1 = 2$, $2^2 = 4$, $2^3 = 8$, etc. The raised number, or exponent, represents the number of twos to be multiplied. It can then be seen that with one bit, $2^1$ states can be represented, with two bits, $2^2$ states can be represented, etc. In general, with **n** bits, $2^{\mathbf{n}}$ states can be represented. Thus, if we wish to represent the months in a year, we need a minimum of $2^4$ for 16 states, since $2^3$ provides only 8 states. Of course, 4 of the 16 states will not be used. The value for each state is chosen by the implementor. It makes sense to assign January the value 1, February the value 2, etc. So the 12 months could then be represented using 4 bits as follows:

| | | | | | |
|---|---|---|---|---|---|
| January | 0001 | May | 0101 | September | 1001 |
| February | 0010 | June | 0110 | October | 1010 |
| March | 0011 | July | 0111 | November | 1011 |
| April | 0100 | August | 1000 | December | 1100 |

To represent the days of the week, we would only need 7 states. Noting that $2^3$ would provide 8 states, we can use 7 of the 8 states represented using 3 bits, as follows:

| | | | | | |
|---|---|---|---|---|---|
| Sunday | 000 | Wednesday | 011 | Saturday | 110 |
| Monday | 001 | Thursday | 100 | | |
| Tuesday | 010 | Friday | 101 | | |

**Binary numbering system**. The decimal system which we use every day uses the ten digits 0 through 9. Since the only digits available to represent the states in a computer are 0 and 1, we will use these as **base-2** numbers for the binary numbering system. Just as the decimal system uses the position of a digit within a number to determine the value of the individual digit, so too, with a binary number. For example, the decimal number 3,234 can be broken out as follows:

| Thousands | Hundreds | Tens | Units |
|---|---|---|---|
| 3 | 2 | 3 | 4 |

Using exponential representation we have:

$$3{,}234 = 3 \times 10^3 + 2 \times 10^2 + 3 \times 10^1 + 4 \times 10^0$$

In the binary system, the base 2 is substituted for the base 10. The binary number 1010, for example, can be analyzed and converted to a decimal number as follows:

$$1010_{\mathbf{2}} = 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0 = 10_{\mathbf{10}}$$

Note the use of the subscripts 2 and 10, to eliminate any confusion in a term or expression.

Another way of looking at a binary number in terms of its decimal value is as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| positional powers of 2: | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
| decimal positional value: | 32 | 16 | 8 | 4 | 2 | 1 |
| binary number: | 1 | 1 | 0 | 1 | 0 | $1_2$ |
| sum of decimal values of "on" binary positions is: | 32 + | 16 + | 0 + | 4 + | 0 + | 1 = $53_{10}$ |

**Figure 1.1** Values for Powers of 2.

| $2^{10}$ | $2^9$ | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1024 | 512 | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

**Binary to Decimal Conversion.** The position of each digit represents the number 2 raised to an exponent based on that position (starting at $2^0$ for the rightmost digit). To convert to base 10, add all the values where a one digit occurs. Ex:

| | | | | | |
|---|---|---|---|---|---|
| **$101011_2$** = | 1 x $2^5$ + 0 x $2^4$ | + 1 x $2^3$ | + 0 x $2^2$ | + 1 x $2^1$ | + 1 x $2^0$ |
| = | 32 | + 8 | | + 2 | +1 |
| = | **$43_{10}$** | | | | |

**Decimal to Binary Conversion.** There are two methods that you can use to convert a decimal number to a binary number. Both are explained below.

*The Division Method.* Divide by 2 until you reach zero, and then collect the remainders in reverse.

**Ex 1:**

| | Rem: |
|---|---|
| 2 ) 56 | |
| 2 ) 28 | 0 |
| 2 ) 14 | 0 |
| 2 ) 7 | 0 |
| 2 ) 3 | 1 |
| 2 ) 1 | 1 |
| 0 | 1 |

Answer:
$56_{10} = 111000_2$

**Ex 2:**

| | Rem: |
|---|---|
| 2 ) 43 | |
| 2 ) 21 | 1 |
| 2 ) 10 | 1 |
| 2 ) 5 | 0 |
| 2 ) 2 | 1 |
| 2 ) 1 | 0 |
| 0 | 1 |

$43_{10} = 101011_2$

**Ex 3:**

| | Rem: |
|---|---|
| 2 ) 35 | |
| 2 ) 17 | 1 |
| 2 ) 8 | 1 |
| 2 ) 4 | 0 |
| 2 ) 2 | 0 |
| 2 ) 1 | 0 |
| 0 | 1 |

$35_{10} = 100011_2$

*The Largest Fit Method.* Subtract out largest power of 2 possible (without going below zero) each time until you reach 0. Place a one in each position where you were able to subtract the value, and a 0 in each position that you could not subtract out the value without going below zero.

**Ex 1:**

56
**- 32**
24
**- 16**
8
**- 8**
0

| $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|
| **32** | **16** | **8** | 4 | 2 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 |

Answer: $56_{10} = 111000_2$

**Ex 2:**

35
**- 32**
3
**- 2**
1
**- 1**
0

| $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|
| **32** | 16 | 8 | 4 | **2** | **1** |
| 1 | 0 | 0 | 0 | 1 | 1 |

Answer: $35_{10} = 100011_2$

**Ex 3:**

21
**- 16**
5
**- 4**
1
**- 1**
0

| $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|
| 32 | **16** | 8 | **4** | 2 | **1** |
| 0 | 1 | 0 | 1 | 0 | 1 |

Answer: $21_{10} = 10101_2$ (leading zeroes may be dropped)

**Character representation**. To communicate with a computer using the everyday familiar symbols requires a character code - a scheme for converting the letters, numbers, punctuation marks and other symbols from the keyboard to the bits and bytes understood by the computer. The conversion must also take place in the opposite direction - from the computer to the terminal screen or a printer. Each character on the keyboard must have an equivalent code associated with it, that is made up of zeroes and ones. The code must be agreed upon by all users of a specific computer. The two most widely used codes have been ASCII and EBCDIC (used by IBM on its mainframe computers).

Today the code most widely used for this purpose is the **American Standard Code for Information Interchange** (**ASCII**). The basic ASCII code is a fixed-length code which uses seven bits to represent each character, thereby allowing 128 characters to be represented ($2^7$). An extended ASCII character set using 8 bits allows 256 ($2^8$) characters to be represented. The extended set is used for such data representation as graphics, foreign language symbols, and mathematical symbols. The first 32 ASCII codes are non-printing control characters which can be used to control video displays, printers and facilitate communications.

| **Rightmost** | | | **Leftmost Three Bits** | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Four Bits** | **000** | **001** | **010** | **011** | **100** | **101** | **110** | **111** |
| **0000** | NUL | DLE | Space | 0 | @ | P | ` | p |
| **0001** | SOH | DC1 | ! | 1 | A | Q | a | q |
| **0010** | STX | DC2 | " | 2 | B | R | b | r |
| **0011** | ETX | DC3 | # | 3 | C | S | c | s |
| **0100** | EOT | DC4 | $ | 4 | D | T | d | t |
| **0101** | ENQ | NAK | % | 5 | E | U | e | u |
| **0110** | ACK | SYN | & | 6 | F | V | f | v |
| **0111** | BEL | ETB | ' | 7 | G | W | g | w |
| **1000** | BS | CAN | ( | 8 | H | X | h | x |
| **1001** | HT | EM | ) | 9 | I | Y | i | y |
| **1010** | LF | SUB | * | : | J | Z | j | z |
| **1011** | VT | ESC | + | ; | K | [ | k | { |
| **1100** | FF | FS | , | < | L | \ | l | \| |
| **1101** | CR | GS | - | = | M | ] | m | } |
| **1110** | SO | RS | . | > | N | ^ | n | ~ |
| **1111** | SI | US | / | ? | O | _ | o | DEL |

**Figure 1.2** The Basic ASCII Character Set.

NOTE: Codes less than $32_{10}$ or greater than $126_{10}$ on this chart are non-printable, however, they generally appear as various symbols on output.

So, for example, to get the binary ASCII representation of the upper and lower case letters ‘f’ and ‘F’, look up the leftmost three bits and rightmost four bits from the ASCII chart and put them together.

‘F’ = 100 0110 and ‘f’ = 110 0110 (binary ASCII values)

So the binary ASCII value for the letter ‘F’ is 1000110, and for the letter ‘f’ is 1100110.

These binary numbers can be converted to their decimal, octal, or hexadecimal value, as needed. For example, since $1000110_2$ is equivalent to $70_{10}$, it follows that: 'F' = 70 (decimal ASCII value).

Ex 2: Find the binary ASCII and decimal ASCII values for the '%' character.

From the chart:
'%' = 0100101 (binary ASCII value)

Convert the binary value to decimal:
$0100101_2 = 32 + 4 + 1 = 37_{10}$

Therefore:
'%' = 37 (decimal ASCII value)

Ex 3: Find the binary ASCII and octal ASCII values for the '#' character.

From the chart:
'#' = 0100011 (binary ASCII value)

Group the bits by threes, starting at the rightmost of the seven bits, to convert to octal (add leading zeros if necessary):

'#' = 100 011 = 43 (octal)

Therefore:
'#' = 43 (octal ASCII value)

Ex 4: Find the hexadecimal ASCII and decimal ASCII values for the 'f' character.

From the chart:
'f' = 110 0110 (binary ASCII value)

Group the bits by fours, starting at the rightmost of the seven bits, to convert to hexadecimal (add leading zeros if necessary):

'f' = 0110 0110 = 66 (hexadecimal ASCII value)

Convert either the binary or hexadecimal value to decimal to get the decimal ASCII value:

'f' = 66 (hex) = (6 x 16) + (6 x 1) = 102 (decimal ASCII value)

**Section I Exercises** (Binary Numbers and Code).

1. How many "states" can be represented by 6 binary circuits (positions)?

2. Convert the following binary numbers to decimal numbers:

   a. 11110011 b. 1101101 c. 10000111 d. 101011

3. Convert the following decimal numbers to binary numbers:

   a. 27 b. 133 c. 248 d. 91

4. What ASCII characters are represented by the following binary digits?

   a. 0100000 b. 0111111 c. 1011010 d. 1110101

5. Convert the following phrase, character by character, to its binary, ASCII representation.

   CS208 is fun!

6. What ASCII characters are represented by the following octal ASCII digits?

   a. 115 b. 53 c. 175

7. What is the hexadecimal ASCII value for the following characters?

   a. '&' b. 'w' c. 'A'

8. What is the decimal ASCII value for the following characters?

   a. '&' b. 't' c. 'H'

**Section I Exercise Answers**.

1. How many "states" can be represented by 6 binary circuits (positions)?

ANS: $2^6 = 64$

2. Convert the following binary numbers to decimal numbers:

| | a. 11110011 | b. 1101101 | c. 10000111 | d. 101011 |
|---|---|---|---|---|
| ANS: | 243 | 109 | 135 | 43 |

3. Convert the following decimal numbers to binary numbers:

| | a. 27 | b. 133 | c. 248 | d. 91 |
|---|---|---|---|---|
| ANS: | 11011 | 10000101 | 11111000 | 1011011 |

4. What ASCII characters are represented by the following binary digits?

| | a. 0100000 | b. 0111111 | c. 1011010 | d. 1110101 |
|---|---|---|---|---|
| ANS: | 'Space' | '?' | 'Z' | 'u' |

5. Convert the following phrase, character by character, to its binary, ASCII representation.
CS208 is fun!

| | | |
|---|---|---|
| ANS: | 1000011 1010011 0110010 0110000 0111000 | (CS208) |
| | 0100000 | (space) |
| | 1101001 1110011 | (is) |
| | 0100000 | (space) |
| | 1100110 1110101 1101110 0100001 | (fun!) |

6. What ASCII characters are represented by the following octal ASCII digits?

| | a. 115 | b. 53 | c. 175 |
|---|---|---|---|
| | 1001101 | 0101011 | 1111101 |
| ANS: | 'M' | '+' | '}' |

7. What is the hexadecimal ASCII value for the following characters?

| | a. '&' | b. 'w' | c. 'A' |
|---|---|---|---|
| | 0100110 | 1110111 | 1000001 |
| ANS: | 26 | 77 | 41 |

8. What is the decimal ASCII value for the following characters?

| | a. '&' | b. 't' | c. 'H' |
|---|---|---|---|
| | 0100110 | 1110100 | 1001000 |
| ANS: | 38 | 116 | 72 |

## Section II: **Binary Operations**

**Arithmetic Operations**.

**ADDITION.**

**Rules.**

| | |
|---|---|
| 0 + 0 = 0 | |
| 0 + 1 = 1 | |
| 1 + 0 = 1 | |
| 1 + 1 = 0 | with 1 to carry |
| 1 + 1 + 1 = 1 | with 1 to carry |

Let's explore the logic behind the addition rules, so they will make sense. 0+0, 0+1, and 1+0 produce the same results as they would if you added them in the decimal number system, because the result is 1 or 0, both of which can be represented with one digit in binary. But what happens when the result is more than 1, requiring more binary digits? Let's look at the other two rules:

| | |
|---|---|
| 1 + 1 = 0,<br>with 1 to carry. | When you add 1+1 in decimal, you get decimal 2.<br>The equivalent of decimal 2 is binary 10, which means 0 with 1 to carry. |
| 1 + 1 + 1 = 1,<br>with 1 to carry. | When you add 1+1+1 in decimal, you get decimal 3.<br>The equivalent of decimal 3 is binary 11, which means 1 with 1 to carry. |

Ex 1:
```
  1010  (10)
 +0111   (7)
 10001  (17)
```

Ex 2:
```
  1001   (9)
+ 1011  (11)
 10100  (20)
```

**SUBTRACTION**.

**Rules.**

| | |
|---|---|
| 0 - 0 = 0 | |
| 0 - 1 = 1 | with a borrow of 1 |
| 1 - 0 = 1 | |
| 1 - 1 = 0 | |
| $10_2$ - 1 = 1 | |

0-0, 1-1, and 1-0 again produce the same results as in decimal, because the result is 1 or 0, both of which can be represented in binary. Now let's analyze the other two rules:

| | |
|---|---|
| 0 - 1 = 1,<br>with 1 borrowed. | In decimal, the 1 that we borrow has a value of 10.<br>But in binary, the 1 that we borrow only has a value of 2. So subtracting the original 1 from the borrowed 2 results in 1. |
| $10_2$ - 1 = 1, | The binary number $10_2$ is equivalent to decimal value 2. So once again, when we subtract 1 from 2, the result is 1. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ex 1: | 1001 | (9) | Ex 2: | 0110 | (6) → | 1111 | (15) |
| | -0101 | (5) | | -1111 | (15) | -0110 | (6) |
| | 0100 | (4) | | | | -1001 | (-9) |

*To subtract a larger number from a smaller number*: As with decimal arithmetic, the smaller number is subtracted from the larger, and a minus sign is placed in front of the result.

**Logical Operations**.

In addition to representing numbers, binary values may also represent other conditions. For example, a 1 may represent a value of true, while a 0 represents a value of false. Often entire bytes, or even several bytes, are used in this manner. A particular bit, or set of bits, within the byte is set to 1 or 0 depending on conditions encountered during the execution of a program. When so used, these bits are often called "**flags**". Frequently, the programmer must manipulate these individual bits - an activity sometimes known as "**bit twiddling**". The logical and shift operations provide the means for manipulating the bits.

**OR, XOR, NOT and AND**.

**OR**. Results in 1 if either or both of the operands are 1.

**Rules.**
0 OR 0 = 0
0 OR 1 = 1
1 OR 0 = 1
1 OR 1 = 1

Examples. To set or insure that a particular bit value is 1, OR the binary value with a string containing a 1 in the position you want set to 1, and zeros in the remaining positions to retain the original bit values.

| | | | | | |
|---|---|---|---|---|---|
| Ex 1: | 1001 | | Ex 2: | 0111 | |
| | OR 0010 | | | OR 0010 | |
| | 1011 | | | 0111 | |

In the previous examples, the OR operand works on the second value from the right, setting it to one, while leaving the other values as they were. The target value is set to 1 regardless of its initial value.

**XOR**. The **exclusive OR**. Similar to OR except that it gives 0 when both its operands are 1.

**Rules.**
0 XOR 0 = 0
0 XOR 1 = 1
1 XOR 0 = 1
1 XOR 1 = 0

Examples. The XOR operation can be used to "**flip**" particular bits from 0 to 1 or from 1 to 0.

| Ex 1: | 1001 | Ex 2: | 0111 |
|---|---|---|---|
| XOR | 0010 | XOR | 0010 |
| | 1011 | | 0101 |

The first example above gives the same result as the first example for the OR operation. The second example, unlike the previous second example, flips the 1 in the target position (second from right) to 0. If XOR has an operand of 1111, it will flip all bits of a four bit value:

| Ex 3: | 1010 |
|---|---|
| XOR | 1111 |
| | 0101 |

**NOT**. NOT is a separate operator for flipping all bits.

| **Rules**. | NOT 0 = 1 | Example. | NOT 1010 |
|---|---|---|---|
| | NOT 1 = 0 | | 0101 |

**AND**. AND yields 1 only if both its operands are 1.

**Rules**.
0 AND 0 = 0
0 AND 1 = 0
1 AND 0 = 0
1 AND 1 = 1

Examples. AND can be used to set particular bits to 0. ANDing a four-bit value with 1001 sets the two middle bits to zero and leaves the outer two bits unchanged.

| Ex 1: | 1101 | | Ex 2: | 0111 |
|---|---|---|---|---|
| AND | 1001 | | AND | 1001 |
| | 1001 | | | 0001 |

**Shift and Rotate Operations**.

Whereas logical operations allow the changing of bit values in place, shift and rotate operations allow bits to be moved left or right without changing their values.

**SHL**. SHL (shift left) shifts each bit one place to the left. The original leftmost bit is lost and a 0 is shifted into the rightmost position.

| Ex 1. SHL | 1101 | | Ex 2. SHL | 1100 |
|---|---|---|---|---|
| | 1010 | | | 1000 |

**ROL**. ROL (rotate left) shifts each bit one place to the left. The original leftmost bit is shifted into the rightmost position. No bits are lost.

| | | | | | |
|---|---|---|---|---|---|
| Ex 1. | ROL | 1101 | Ex 2. | ROL | 1100 |
| | | 1011 | | | 1001 |

**SHR**. SHR (shift right) shifts each bit one place to the right. The original rightmost bit is lost and a 0 is shifted into the leftmost position.

| | | | | | |
|---|---|---|---|---|---|
| Ex 1. | SHR | 1011 | Ex 2. | SHR | 0011 |
| | | 0101 | | | 0001 |

**ROR**. ROR (rotate right) shifts each bit one place to the right. The original rightmost bit is shifted into the leftmost position. No bits are lost.

| | | | | | |
|---|---|---|---|---|---|
| Ex 1. | ROR | 1011 | Ex 2. | ROR | 0011 |
| | | 1101 | | | 1001 |

**COMBINATIONS**. A combination of logical and shift operations is often used to carry out bit manipulations. For example, if we have two sets of four-bit values, 1011 and 0110, and want to isolate the rightmost two bits of each and combine them into a single four-bit value, 1110, we could proceed as follows:

| | | | |
|---|---|---|---|
| 1. | SHL | 1011 | |
| | | 0110 | Our initial goal is to get the two rightmost bits of 1011 into the leftmost two positions, the position these two bits will occupy in the final value. This requires two SHL operations. |
| | SHL | 0110 | |
| | | **1100** | |
| 2. | | 0110 | Now to isolate the rightmost bits of the second value 0110, we AND the 0110 with the value 0011(which will set the left two bits to zero and retain the value of the right two bits). |
| | AND | 0011 | |
| | | **0010** | |
| 3. | | 1100 | |
| | OR | 0010 | Finally, the two intermediate results, 1100 and 0010 can be OR'd to get the final desired result, 1110. |
| | | 1110 | |

**Section II Exercises** (Binary Operations).

1. **Add** the following binary numbers:

a. 1001 +0010 b. 1101 +0110 c. 10010 +10110 d. 011100 +010111

2. **Subtract** the following binary numbers as indicated:

a. 1010 -0001 b. 11101 -00111 c. 110011 -100111 d. 0110011 -1111111

3. Show the results of the following binary logical operations:

a. 1111 AND 0000 b. 1001 AND 0111 c. 101010 OR 111100

d. 1001 XOR 1000 e. NOT 0101 AND 1101

4. Show the results of the following **shift** operations:

a. SHL 0010 b. SHL 1111 c. SHR 0001 d. SHR 1111

5. Show the results of the following **rotate** operations:

a. ROL 0010 b. ROL 1110 c. ROR 0001 d. ROR 0111

**Section II Exercises Answers.**

1. Add the following binary numbers:

a. 1001 (9)
0010 (2)
1011 (11)

b. 1101 (13)
0110 ( 6)
10011 (19)

c. 10010 (18)
10110 (22)
101000 (40)

d. 011100 (28)
010111 (23)
110011 (51)

2. Subtract the following binary numbers as indicated:

a. 1010 (10)
-0001 ( 1)
1001 ( 9)

b. 11101 (29)
-00111 ( 7)
10110 (22)

c. 110011 (51)
-100111 (39)
001100 (12)

d. 0110011 ( 51) → 1111111
-1111111 (127) -0110011
-1001100

Note for 2d. Since the subtrahend is larger than the minuend, the minuend is subtracted from the larger subtrahend, and a minus sign appended to the result.

3. Show the results of the following binary logical operations:

| | a. | b. | c. | d. |
|---|---|---|---|---|
| | 1111 | 1001 | 101010 | 1001 |
| | AND 0000 | AND 0111 | OR 111100 | XOR 1000 |
| ANS: | 0000 | 0001 | 111110 | 0001 |

e. NOT 0101 → 1010
AND 1101 AND 1101
ANS: 1000

4. Show the results of the following **shift** operations:

| | a. | b. | c. | d. |
|---|---|---|---|---|
| | SHL 0010 | SHL 1111 | SHR 0001 | SHR 1111 |
| ANS: | 0100 | 1110 | 0000 | 0111 |

5. Show the results of the following **rotate** operations:

| | a. | b. | c. | d. |
|---|---|---|---|---|
| | ROL 0010 | ROL 1110 | ROR 0001 | ROR 0111 |
| ANS: | 0100 | 1101 | 1000 | 1011 |

## Section III: **Octal Notation**

No matter how convenient the binary system may be for digital computers, it is exceedingly cumbersome for human beings. Consequently, most computer programmers use base 8 (octal) or base 16 (hexadecimal) representations instead. The computer system components --- assemblers, compilers, loaders, etc -- convert these numbers to their binary equivalents. Octal and hexadecimal numbers are not only convenient, but are also easily derived. Conversion simply requires the programmer to separate the binary number into 3-bit or 4-bit groups. Let us examine the octal numbering system in this section, and hexadecimal in the next.

Converting binary to octal is relatively easy because three binary digits equate to one of the eight octal digits. Consider, for example, the sample set of machine level instructions presented at the beginning of Section I:

1010111010110111
1110001110100011
0001010100111010
0111000101101110
0101010101110001

This same set of code may be grouped by 3, then presented in octal as:

| | | |
|---|---|---|
| 1 010 111 010 110 111 | | 1 2 7 2 6 7 |
| 1 110 001 110 100 011 | | 1 6 1 6 4 3 |
| 0 001 010 100 111 010 | → | 0 1 2 4 7 2 |
| 0 111 000 101 101 110 | | 0 7 0 5 5 6 |
| 0 101 010 101 110 001 | | 0 5 2 5 6 1 |

The octal system represents numbers using the eight symbols 0 through 7 (octal does **not** use digits 8 or 9), and is, therefore, a base-8 number system. Because the octal numbering system provides more symbols than the binary numbering system, fewer digits are required to represent the same value. When necessary to avoid confusion, the subscript 8 can be used to indicate a number written in this system:

$2237_{8}$

In the octal system, the base 8 is substituted for the base 10. The octal number $2237_{8}$, for example, can be analyzed and converted to a decimal number as follows:

$$1237_{8} = 1 \times 8^{3} + 2 \times 8^{2} + 3 \times 8^{1} + 7 \times 8^{0} = 671_{10}$$

Note the use of the subscripts 8 and 10. These can be used any time there is room for confusion in a term or expression.

Another way of looking at an octal number in terms of its decimal value is as follows:

| | | | | | |
|---|---|---|---|---|---|
| positional powers of 8: | | $8^4$ | $8^3$ | $8^2$ | $8^1$ $8^0$ |
| decimal positional value: | | 4096 | 512 | 64 | 8 1 |
| octal number: | | **1** | **3** | **5** | **6** **$2_8$** |
| sum of decimal values of the octal number | = | 1 x 4096 + | 3 x 512 + | 5 x 64 + | 6 x 8 + 2 x 1 |
| | = | 4096 + | 1536 + | 320 + | 48 + 2 |
| | = | **$6002_{10}$** | | | |

So, as you can see, $13562_8 = 6002_{10}$. Any octal number can be converted to its decimal equivalent using this method.

**Figure 3.1** Values for Powers of 8.

| $8^5$ | $8^4$ | $8^3$ | $8^2$ | $8^1$ | $8^0$ |
|---|---|---|---|---|---|
| 32768 | 4096 | 512 | 64 | 8 | 1 |

**Octal to Decimal Conversion.** The position of each digit represents the number 8 raised to an exponent based on that position. To convert to base 10, beginning with the rightmost digit multiply each **n**th digit by $16^{(n-1)}$, and add all of the results together.

Ex:

| | | | | | |
|---|---|---|---|---|---|
| **$25143_8$** = | $2 \times 8^4$ | $+ 5 \times 8^3$ | $+ 1 \times 8^2$ | $+ 4 \times 8^1$ | $+ 3 \times 8^0$ |
| = | 2 x 4096 | + 5 x 512 | + 1 x 64 | + 4 x 8 | + 3 x 1 |
| = | 8192 | + 2560 | + 64 | + 32 | + 3 |
| = | **$10851_{10}$** | | | | |

**Decimal to Octal Conversion**. Divide by 8 until you reach zero, and then collect the remainders in reverse.

**Ex 1:**

| | |
|---|---|
| 8 ) 176 | Rem: |
| 8 ) 22 | 0 |
| 8 ) 2 | 6 |
| 0 | 2 |

Answer:
$176_{10} = 260_8$

**Ex 2:**

| | |
|---|---|
| 8 ) 2588 | Rem: |
| 8 ) 323 | 4 |
| 8 ) 40 | 3 |
| 8 ) 5 | 0 |
| 0 | 5 |

Answer:
$2588_{10} = 5034_8$

**Ex 3:**

| | |
|---|---|
| 8 ) 5052 | Rem: |
| 8 ) 631 | 4 |
| 8 ) 78 | 7 |
| 8 ) 9 | 6 |
| 8 ) 1 | 1 |
| 0 | 1 |

Answer:
$5052_{10} = 11674_8$

**Binary to Octal Conversion**. Three binary digits can easily be converted to one octal digit. Therefore, conversion from binary to octal is very simple.

So, for example, given the binary number 11100111000101001, convert to octal as follows. First separate the binary number into 3-bit groupings, beginning from the rightmost bit.

11 100 111 000 101 001

Then convert each group to an octal digit (see table below), adding leading zeros if necessary.

011 100 111 000 101 001
3 4 7 0 5 1

So, $11100111000101001_2 = 347051_8$

| Three-bit Group | Decimal Digit | Octal Digit |
|---|---|---|
| 000 | 0 | **0** |
| 001 | 1 | **1** |
| 010 | 2 | **2** |
| 011 | 3 | **3** |
| 100 | 4 | **4** |
| 101 | 5 | **5** |
| 110 | 6 | **6** |
| 111 | 7 | **7** |

**Figure 3.2** Correspondence of 3-bit Binary Groups, Decimal Digits, and Octal Digits.

**Octal Arithmetic Operations**.

**ADDITION.**

Octal addition is similar to decimal addition in that you begin with the right-hand side of the equation, and add each column of digits, writing a one digit result beneath the column. The addition may result in a carry. In decimal the largest digit is 9, so we carry **tens**. In octal, the largest digit is 7, so we must carry **eights**, and write down the value that remains after the eight(s) are carried.

Ex 1.
$$\begin{array}{r} (1)(1) \\ 2\ 7\ 6_8 \\ +\ 3\ 5\ 4_8 \\ \hline 6\ 5\ 2_8 \end{array}$$

To add $276_8 + 354_8$, beginning at the right side of the equation: Add 6+4 to get 10. We carry one 8, leaving the digit 2. Next adding 7+5+1(carried) gives us 13. We carry one 8, leaving the digit 5. Finally, we add 2+3+1(carried) to get the digit 6. So the answer is $652_8$.

**Figure 3.3** Octal Addition Table.

| + | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|---|
| **0** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 10 |
| **2** | 2 | 3 | 4 | 5 | 6 | 7 | 10 | 11 |
| **3** | 3 | 4 | 5 | 6 | 7 | 10 | 11 | 12 |
| **4** | 4 | 5 | 6 | 7 | 10 | 11 | 12 | 13 |
| **5** | 5 | 6 | 7 | 10 | 11 | 12 | 13 | 14 |
| **6** | 6 | 7 | 10 | 11 | 12 | 13 | 14 | 15 |
| **7** | 7 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |

*Note:* When the result is a 2-digit number, it means carry one 8.
For example: 15 indicates a 5 digit with one 8 carried.

So when adding octal numbers, remember that you must carry one 8 whenever the sum of the digits adds up to more than 7 (the biggest digit in octal). When the sum of the digits is equal or less than 7, simply write the result.

Ex 2.
$$\begin{array}{r} (1)\ (1) \\ 6\ 1\ 7_8 \\ +\ 3\ 3\ 5_8 \\ \hline 1\ 1\ 5\ 4_8 \end{array}$$

To add $617_8 + 335_8$ , beginning at the right side of the equation: Add 7+5 to get 12. We carry one 8, leaving the digit 4. Next adding 3+1+1(carried) gives us the digit 5. Finally, we add 6+3 to get 9. We carry one 8, leaving the digit 1. The one carry is written as the digit 1. So the answer is $1154_8$.

**SUBTRACTION.**

Octal subtraction is similar to decimal subtraction in that you begin with the right-hand side of the equation, and subtract each column of digits, writing a one digit result beneath the column. The subtraction may require a borrow from the column to the left. In decimal we borrow one **tens**. In octal, we borrow **eights**.

Ex 1.
$$\begin{array}{r} 6\ 7\ 2_8 \\ -\ 3\ 5\ 4_8 \\ \hline 3\ 1\ 6_8 \end{array}$$

We cannot subtract 4 from 2, so we must borrow one. The one we borrow has a value of 8. Add the borrowed 8 to the original 2 to get 10, and then subtract the 4 (10-4), to get the digit 6. Since we borrowed one, we now subtract 5 from 6 to get the digit 1. Finally we subtract 3 from 6 to get the leftmost 3 digit.

**Figure 3.4** Octal Subtraction Table.

| - | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|---|
| **0** | 0 | $7^{b}$ | $6^{b}$ | $5^{b}$ | $4^{b}$ | $3^{b}$ | $2^{b}$ | $1^{b}$ |
| **1** | 1 | 0 | $7^{b}$ | $6^{b}$ | $5^{b}$ | $4^{b}$ | $3^{b}$ | $2^{b}$ |
| **2** | 2 | 1 | 0 | $7^{b}$ | $6^{b}$ | $5^{b}$ | $4^{b}$ | $3^{b}$ |
| **3** | 3 | 2 | 1 | 0 | $7^{b}$ | $6^{b}$ | $5^{b}$ | $4^{b}$ |
| **4** | 4 | 3 | 2 | 1 | 0 | $7^{b}$ | $6^{b}$ | $5^{b}$ |
| **5** | 5 | 4 | 3 | 2 | 1 | 0 | $7^{b}$ | $6^{b}$ |
| **6** | 6 | 5 | 4 | 3 | 2 | 1 | 0 | $7^{b}$ |
| **7** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

*Note:* $^{b}$notation means the result given is after borrowing one 8.

So when subtracting octal numbers, remember that when you borrow one, its value is 8.

Ex 2.
$$\begin{array}{r} 6\,0\,3_{8} \\ -\ 1\,3\,5_{8} \\ \hline 4\,4\,6_{8} \end{array}$$

We cannot subtract 5 from 3, so we must borrow one. We must go over two places to find one to borrow. After borrowing from the 6, the middle position now has a value of 8. We borrow one of these 8s. Add the borrowed 8 to the original 3 to get 11, and then subtract the 5 (11-5), to get the digit 6. Now work on the middle digits. Subtract the 3 from 7 (the one borrowed worth 8 minus the 1 lent) to get the digit 4. Finally, subtract 1 from the remaining 5 (after lending one) to get the digit 4.

**Section III Exercises** (Octal Notation).

1. Convert the following octal numbers to decimal numbers:

   a. 45 b. 77 c. 276 d. 143

2. Convert the following decimal numbers to octal numbers:

   a. 234 b. 1234 c. 87 d. 103

3. Convert the following binary numbers to octal numbers:

   a. 10100011 b. 00111110 c. 11001101 d. 10111111

4. Add the following octal numbers.

   a. 1624 + 3434 b. 5632 +2331 c. 3771 +2617

5. Subtract the following octal numbers.

   a. 5324 - 3434 b. 5102 - 2335 c. 3171 - 2617

**Section III Exercise Answers.**

1. Convert the following octal numbers to decimal numbers:

| | a. 45 | b. 77 | c. 276 | d. 143 |
|---|---|---|---|---|
| ANS: | 37 | 63 | 190 | 99 |

2. Convert the following decimal numbers to octal numbers:

| | a. 234 | b. 1234 | c. 87 | d. 103 |
|---|---|---|---|---|
| ANS: | 352 | 2322 | 127 | 147 |

3. Convert the following binary numbers to octal numbers:

| | a. 10100011 | b. 00111110 | c. 11001101 | d. 10111111 |
|---|---|---|---|---|
| ANS: | 243 | 76 | 315 | 277 |

4. Add the following octal numbers.

| | a. | b. | c. |
|---|---|---|---|
| | 1624 | 5632 | 3771 |
| | + 3434 | +2331 | +2617 |
| ANS: | 5260 | 10163 | 6610 |

5. Subtract the following octal numbers.

| | a. | b. | c. |
|---|---|---|---|
| | 5324 | 5102 | 3171 |
| | - 3434 | - 2335 | - 2617 |
| ANS: | 1670 | 2545 | 352 |

## Section IV: **Hexadecimal Notation**

Often the programmer must examine the contents of certain memory locations. Normally, the contents are displayed in hexadecimal (or hex) numbers rather than binary, because binary takes up too much space and is more difficult to interpret. Many diagnostic messages are also output in hexadecimal notation.

Converting binary to hexadecimal is relatively easy because four binary digits equate to one of the sixteen hexadecimal digits. Therefore, each 8-bit byte within a computer can be converted to two hexadecimal characters. And further, any bit stream can be converted. Consider, for example, the sample set of machine level instructions presented at the beginning of Section I:

```
1010111010110111
1110001110100011
0001010100111010
0111000101101110
0101010101110001
```

This same set of code may be grouped by 4, then presented in hexadecimal as:

```
1010  1110  1011  0111          A   E   B   7
1110  0011  1010  0011          E   3   A   3
0001  0101  0011  1010    ➔     1   5   3   A
0111  0001  0110  1110          7   1   6   E
0101  0101  0111  0001          5   5   7   1
```

The hexadecimal system represents numbers using the sixteen symbols 0 through 9 and A through F, and is, therefore, a base-16 number system. We use the letters, since our numbering system only provides 10 symbols and letters are familiar to everyone. Because the hexadecimal numbering system provides more symbols than either the binary or octal numbering systems, even fewer digits are required to represent the same value. When necessary to avoid confusion, the subscript 16 can be used to indicate a number written in this system: $A1B7_{16}$

In the hexadecimal system, the base 16 is substituted for the base 10. The hexadecimal number $A1B7_{16}$, for example, can be analyzed and converted to a decimal number as follows:

$$A1B7_{16} = 10 \times 16^3 + 1 \times 16^2 + 11 \times 16^1 + 7 \times 16^0 = 41399_{10}$$

Note the use of the subscripts 16 and 10. These can be used any time there is room for confusion in a term or expression.

**Figure 4.1** Values of Powers of 16.

| $16^4$ | $16^3$ | $16^2$ | $16^1$ | $16^0$ |
|---|---|---|---|---|
| 65536 | 4096 | 256 | 16 | 1 |

Another way of looking at a hexadecimal number in terms of its decimal value is as follows:

| positional powers of 16: | $16^3$ | $16^2$ | $16^1$ | $16^0$ |
|---|---|---|---|---|
| decimal positional value: | 4096 | 256 | 16 | 1 |
| hexadecimal number: | **4** | **A** | **3** | **F** |

| sum of decimal values of the hexadecimal number= | 4 x 4096 + | 10 x 256 + | 3 x 16 + | 15 x 1 |
|---|---|---|---|---|
| = | 16384 + | 2560 + | 48 + | 15 |
| = | **$19007_{10}$** | | | |

So, as you can see, $4A3F_{16} = 19007_{10}$. Any hexadecimal number can be converted to its decimal equivalent using this method.

**Decimal to Hexadecimal Conversion**. Divide by 16 until you reach zero, and collect the remainders in reverse.

**Ex 1:**

| | Rem: |
|---|---|
| 16 ) 56 | |
| 16 ) 3 | 8 |
| 0 | 3 |

Answer:
$56_{10} = 38_{16}$

**Ex 2:**

| | Rem: |
|---|---|
| 16 ) 2604 | |
| 16 ) 162 | 12 → C |
| 16 ) 10 | 2 |
| 16 ) 0 | 10 → A |

Answer:
$2604_{10} = A2C_{16}$

**Ex 3:**

| | Rem: |
|---|---|
| 16 ) 5052 | |
| 16 ) 315 | 12 → C |
| 16 ) 19 | 11 → B |
| 16 ) 1 | 3 |
| 0 | 1 |

Answer:
$5052_{10} = 13BC_{16}$

**Binary to Hexadecimal Conversion**. Four binary digits can easily be converted to one hexadecimal digit. Therefore, conversion from binary to hexadecimal is very simple.

So, for example, given the binary number 11100111000101001, convert to hexadecimal as follows. First separate the binary number into 4-bit groupings, beginning from the rightmost bit.

1 1100 1110 0010 1001

Then convert each group to an hexadecimal digit (see table below), adding leading zeros if necessary.

0001 1100 1110 0010 1001
1 C E 2 9

So, $11100111000101001_2 = 1CE29_{16}$

| Four-bit Group | Decimal Digit | Hexadecimal Digit |
|---|---|---|
| 0000 | 0 | **0** |
| 0001 | 1 | **1** |
| 0010 | 2 | **2** |
| 0011 | 3 | **3** |
| 0100 | 4 | **4** |
| 0101 | 5 | **5** |
| 0110 | 6 | **6** |
| 0111 | 7 | **7** |
| 1000 | 8 | **8** |
| 1001 | 9 | **9** |
| 1010 | 10 | **A** |
| 1011 | 11 | **B** |
| 1100 | 12 | **C** |
| 1101 | 13 | **D** |
| 1110 | 14 | **E** |
| 1111 | 15 | **F** |

**Figure 4.2** Correspondence of 4-bit Binary Groups, Decimal Digits, and Hexadecimal Digits.

**Hexadecimal Arithmetic Operations**.

**ADDITION.**

Hexadecimal addition is similar to decimal addition in that you begin with the right-hand side of the equation, and add each column of digits, writing a one digit result beneath the column. The addition may result in a carry. In decimal the largest digit is 9, so we carry **tens**. In hexadecimal, the largest digit is F (value=15), so we must carry **sixteens**, and write down the value that remains after the sixteen(s) are carried.

Ex 1.
$$\begin{array}{r} {\scriptstyle (1)(1)} \\ A\ 7\ 6_{16} \\ +\ 3\ 9\ E_{16} \\ \hline E\ 1\ 4_{16} \end{array}$$

To add $A76_{16} + 39E_{16}$ , beginning at the right side of the equation: Add 6+E to get the value 20. We carry one 16, leaving the digit 4. Next adding 7+9+1(carried) gives us value 17. We carry one 16, leaving the digit 1. Finally, we add A+3+1(carried) to get the value 14, which is symbolized by the digit E. So the answer is $E14_{16}$

Ex 2.
$$\begin{array}{r} {\scriptstyle (1)\ \ (1)} \\ 8\ 1\ C_{16} \\ +\ B\ 9\ 5_{16} \\ \hline 1\ 3\ B\ \ 1_{16} \end{array}$$

To add $81C_{16} + B95_{16}$ , beginning at the right side of the equation: Add C+5 to get value 17. We carry one 16, leaving the digit 1. Next adding 9+1+1(carried) gives us the value 11, which is symbolized by the digit B. Finally, we add 8+B to get the value 19. We carry one 16, leaving the digit 3. The one carry is written as the digit 1. So the answer is $13B1_{16}$.

**Figure 4.3** Hexadecimal Addition Table.

| + | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
| **1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | 10 |
| **2** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | 10 | 11 |
| **3** | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | 10 | 11 | 12 |
| **4** | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | 10 | 11 | 12 | 13 |
| **5** | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 |
| **6** | 6 | 7 | 8 | 9 | A | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 |
| **7** | 7 | 8 | 9 | A | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **8** | 8 | 9 | A | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| **9** | 9 | A | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| **A** | A | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| **B** | B | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A |
| **C** | C | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A | 1B |
| **D** | D | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A | 1B | 1C |
| **E** | E | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A | 1B | 1C | 1D |
| **F** | F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A | 1B | 1C | 1D | 1E |

*Note:* When the result is a 2-digit number, it means carry one 16.
For example: 1A indicates an A digit with one 16 carried.

So when adding hexadecimal numbers, remember that you must carry one 16 whenever the sum of the digits adds up to more than E (value=15), the biggest digit in hex. When the sum of the digits is equal or less than 15, simply write the result, remembering to use letters for values 10 to 15.

**SUBTRACTION.**

Hexadecimal subtraction is similar to decimal subtraction in that you begin with the right-hand side of the equation, and subtract each column of digits, writing a one digit result beneath the column. The subtraction may require a borrow from the column to the left. In decimal we borrow one **tens**. In octal, we borrow **sixteens**.

Ex 1.
$$\begin{array}{r} E\ 7\ 2_{16} \\ -\ 3\ 5\ A_{16} \\ \hline B\ 1\ 8_{16} \end{array}$$

To subtract $E72_{16}$-$35A_{16}$: We cannot subtract A (value 10) from 2, so we must borrow one. The one we borrow has a value of 16. Add the borrowed 16 to the original 2 to get value 18. Then subtract the A (18-A), to get the digit 8. Since we borrowed one, we now subtract 5 from 6 to get the digit 1. Finally we subtract 3 from E(value 14) to get the value 11, symbolized by the leftmost B digit.

Ex 2.
$$\begin{array}{r} F\ 0\ 5_{16} \\ -\ 9\ 3\ B_{16} \\ \hline 5\ C\ A_{16} \end{array}$$

To subtract $F05_{16}$-$93B_{16}$: We cannot subtract B (value 11) from 5, so we must borrow one. We must go over two places to find one to borrow. After borrowing from the F, the middle position now has a value of 16. We borrow one of these 16s. Add the borrowed 16 to the original 5 to get the value 21, and then subtract the B (21-11), to get the value 10 symbolized by the digit A. Now work on the middle digits. Subtract the 3 from 15 (the one borrowed worth 16 minus the 1 lent) to get the value 12, symbolized by the digit C. Finally, subtract 9 from the remaining 14 (after lending one) to get the digit 5.

So remember, when subtracting hexadecimal numbers, when you borrow one, its value is 16.

**Section IV Exercises** (Hexadecimal Notation).

1. Convert the following hexadecimal numbers to decimal numbers:

   a. 45 b. AC c. F9B d. 4C8

2. Convert the following decimal numbers to hexadecimal numbers:

   a. 234 b. 1234 c. 87 d. 103

3. Convert the following binary numbers to hexadecimal numbers:

   a. 10100011 b. 00111110 c. 11001101 d. 10111111

4. Add the following hexadecimal numbers.

   a. 8 2 3 b. 5 6 E c. 9 B 7
   +1 A B + A 2 8 + 9 2 D

5. Subtract the following hexadecimal numbers.

   a. D 9 5 b. B 0 4 c. A E 9 3
   - B 3 2 - 8 3 F - 5 C 4

**Section IV Exercise Answers.**

1. Convert the following hexadecimal numbers to decimal numbers:

| | a. 45 | b. AC | c. F9B | d. 4C8 |
|---|---|---|---|---|
| ANS: | 69 | 172 | 3995 | 1224 |

2. Convert the following decimal numbers to hexadecimal numbers:

| | a. 234 | b. 1234 | c. 87 | d. 103 |
|---|---|---|---|---|
| ANS: | E A | 4 D 2 | 5 7 | 6 7 |

3. Convert the following binary numbers to hexadecimal numbers:

| | a. 10100011 | b. 00111110 | c. 11001101 | d. 10111111 |
|---|---|---|---|---|
| ANS: | A 3 | 3 E | C D | B F |

4. Add the following hexadecimal numbers.

| | a. | b. | c. |
|---|---|---|---|
| | 8 2 3 | 5 6 E | 9 B 7 |
| | +1 A B | + A 2 8 | + 9 2 D |
| ANS: | 9 C E | F 9 6 | 1 2 E 4 |

5. Subtract the following hexadecimal numbers.

| | a. | b. | c. |
|---|---|---|---|
| | D 9 5 | B 0 4 | A E 9 3 |
| | - B 3 2 | - 8 3 F | - 5 C 4 |
| ANS: | 2 6 3 | 2 C 5 | A 8 C F |

## Section V: **Signed Numbers**

Up till now we've been concentrating on unsigned numbers. There are a number of schemes for representing positive and negative numbers in binary format. Three of the more common in use are the **sign-magnitude** representation, **one's complement** representation and the **twos-complement** representation.

**THE SIGN-MAGNITUDE REPRESENTATION**.

In this representation, the leftmost bit of a binary code represents the sign of the value: 0 for positive, 1 for negative; the remaining bits represent the numeric value. The following figure illustrates the sign-magnitude representation for a four-bit set.

| Value | Representation | Value | Representation |
|---|---|---|---|
| +0 | 0000 | -0 | 1000 |
| +1 | 0001 | -1 | 1001 |
| +2 | 0010 | -2 | 1010 |
| +3 | 0011 | -3 | 1011 |
| +4 | 0100 | -4 | 1100 |
| +5 | 0101 | -5 | 1101 |
| +6 | 0110 | -6 | 1110 |
| +7 | 0111 | -7 | 1111 |

**Figure 5.1** Sign-Magnitude Representation.

**Computing Negative Values using Sign/Magnitude representation**. Begin with the binary sign/magnitude representation of the positive value, and simply flip the leftmost zero bit. Using 8-bit numbers:

Ex 1. $6_{10} = 00000110_2$ (w/flipped bit) → 10000110

*So:* $-6_{10} = 10000110_2$ *(in 8-bit sign/magnitude form)*

Ex 2. $36_{10} = 00100100_2$ (w/flipped bit) → 10100100

*So:* $-36_{10} = 10100100_2$ *(in 8-bit sign/magnitude form)*

Ex 3. $70_{10} = 01000110_2$ (w/flipped bit) → 11000110

*So:* $-70_{10} = 11000110_2$ *(in 8-bit sign/magnitude form)*

**ONE'S COMPLEMENT REPRESENTATION**.

In this representation, the leftmost bit of a binary code represents the sign of the value: 0 for positive, 1 for negative; For positive numbers, the remaining bits represent the numeric value. For negative numbers, each bit of the numeric value is reversed. The following figure illustrates the one's complement representation for a four-bit set.

| Value | Representation | Value | Representation |
|---|---|---|---|
| +0 | 0000 | -0 | 1111 |
| +1 | 0001 | -1 | 1110 |
| +2 | 0010 | -2 | 1101 |
| +3 | 0011 | -3 | 1100 |
| +4 | 0100 | -4 | 1011 |
| +5 | 0101 | -5 | 1010 |
| +6 | 0110 | -6 | 1001 |
| +7 | 0111 | -7 | 1000 |

**Figure 5.2** One's Complement Representation

**Computing Negative Values using One's Complement representation**. Begin with the binary sign/magnitude representation of the positive value, and flip every bit. Using 8-bit numbers:

Ex 1. $6_{10} = 00000110_2$ (w/all bits flipped) → 11111001

*So:* $-6_{10} = 11111001_2$ *(in 8-bit one's complement form)*

Ex 2. $36_{10} = 00100100_2$ (w/all bits flipped) → 11011011

*So:* $-36_{10} = 11011011_2$ *(in 8-bit one's complement form)*

The sign-magnitude and one's complement representations are easily understood, but present some disadvantages for use with computers. Before adding two sign-magnitude numbers, the computer must examine their signs. If the signs are the same, the numbers are to be added; if they have opposite signs, the smaller magnitude must be subtracted from the larger value. If the two numbers have the same sign, that will be the sign of the result; if the signs are opposite, the sign of the larger number will be the sign of the result. These operations slow the computer down.

These methods also differentiate between +0 and -0, a distinction not made in arithmetic. The computer must convert the -0 to +0 whenever a negative 0 is encountered as the result of an arithmetic operation. This is just one more disadvantage to slow things down.

Due to these drawbacks, sign-magnitude and one's complement forms are rarely used for binary integers, although, as we'll see later, sign-magnitude is often used for floating point numbers. For binary integers, most computers use the twos-complement system, which avoids the problems found in the other representations.

**THE TWOS-COMPLEMENT REPRESENTATION**.

The twos-complement representation is the (one's complement + 1). The following figure illustrates the twos-complement representation for a four-bit set:

| Value | Representation | Value | Representation |
|---|---|---|---|
| +0 | 0000 | -1 | 1111 |
| +1 | 0001 | -2 | 1110 |
| +2 | 0010 | -3 | 1101 |
| +3 | 0011 | -4 | 1100 |
| +4 | 0100 | -5 | 1011 |
| +5 | 0101 | -6 | 1010 |
| +6 | 0110 | -7 | 1001 |
| +7 | 0111 | -8 | 1000 |

**Figure 5.3** Twos-Complement Representation

As in the previous two representations, the leftmost bit serves as a sign bit: 0 for positive numbers, 1 for negative numbers. Notice that the two left columns of Figures 5.1, 5.2, and 5.3 are the same. Positive numbers are represented the same way in all implementations. For the right two columns of Figure 5.3 the -0 has been eliminated and the four-bit representation has been inverted relative to those of Figure 5.1.

**Three Methods of computing Negative Values using Two's Complement representation.**

step 1) For all 3 methods, begin with the sign/magnitude binary representation of the positive value.

Ex. $6_{10} = 00000110_2$

step 2) **method a**. Given an **n** digit binary number in positive sign/magnitude form, subtract it from the binary representation of $2^n$.

Ex.
```
  100000000    ( 2^9 )
- 00000110     (positive 6)
  11111010
```

**method b**. Find first one bit, from low-order (right) end, and complement the pattern to the left.

Ex. 00000**1**0 (left complemented) → **11111**010

**method c**. Complement the entire positive form, and then add one.

Ex.
```
00000110 ->   (complemented)   →   11111001
              (add one)        →   +       1
                                   11111010
```

*So:* $-6_{10} = 11111010_2$ *(in 2's complement form, using any of above methods)*

Example 2:

step 1) For all 3 methods, begin with the sign/magnitude binary representation of the positive value.

$76_{10} = 01001100_2$

step 2) **method a**. Given an **n** digit binary number in positive sign/magnitude form, subtract it from the binary representation of $2^n$.

Ex. 100000000 ( $2^9$ )
- 01001100 (positive 76)
10110100

**method b**. Find first one bit, from low-order (right) end, and complement the pattern to the left.

Ex. 01001**1**00 (left complemented) → **10110**100

**method c**. Complement the entire positive form, and then add one.

Ex. 01001100 -> (complemented) → 10110011
(add one) → + 1
10110100

*So:* $-76_{10} = 10110100_2$ *(in 2's complement form, using any of above methods)*

The most important characteristic of the twos-complement system is that the binary codes can be added and subtracted as if they were unsigned binary numbers, without regard to the signs of the numbers they actually represent. Any carry from or borrow by the leftmost column is ignored. For example, to add +4 and -3, we simply add the corresponding binary codes, 0100 and 1101:

```
 0100  (+4)
+1101  (-3)
 0001  (+1)
```

A carry from the leftmost column has been ignored. The result, 0001, is the code for +1, the sum of +4 and -3. Likewise, to subtract +7 from +3, we subtract the code for +7, 0111, from that for +3, 0011:

```
 0011  (+3)
-0111  (+7)
 1100  (-4)
```

A borrow by the leftmost column has been ignored. The result, 1100, is the code for -4, the result of subtracting +7 from +3.

Not only is addition and subtraction simplified in the twos-complement system, -0 has been eliminated, replaced by -8, for which there is no corresponding positive number. In general, with **n** bits the twos-complement system represents values ranging from $-2^{n-1}$ through $2^{n-1} - 1$; $-2^{n-1}$ is the negative number having no positive counterpart. Although this extra negative number can occasionally be troublesome, it is not nearly so troublesome as -0 in the sign-magnitude and one's complement representations.

The twos-complement system offers no particular advantages for multiplication and division. Many computers convert twos-complement numbers to the sign-magnitude representation before multiplying or dividing them, then convert the result back to twos-complement representation. Addition and subtraction, however, are by far the most frequent operations performed on binary integers, so any system that speeds up these operations is worthwhile even it makes multiplication and division more complicated.

**Section V Exercises** (Signed Numbers).

1. Convert the following decimal numbers to their 8-bit sign-magnitude representation:

   a. 0 b. +3 c. -30 d. 25

2. Convert the following 8-bit sign-magnitude numbers to their decimal equivalents:

   a. 10000011 b. 00000101 c. 00010001 d. 10100110

3. Convert the following decimal numbers to their 8-bit twos-complement representation:

   a. 0 b. -6 c. +27 d. -38

4. Convert the following 8-bit twos-complement numbers to their decimal equivalents:

   a. 11111110 b. 00000110 c. 11010110 d. 00101011

5. What is the 6-bit 2's complement value of:

   a. -2 b. -10 c. -17 d. -21

6. Add or subtract the following twos-complementary numbers as indicated:

| a. 0010 | b. 1111 | c. 110110 | d. 101010 |
|---|---|---|---|
| +0100 | +1101 | -000011 | +010110 |

**Section V Exercise Answers.**

1. Convert the following decimal numbers to their 8-bit sign-magnitude representation:

| | a. -0 | b. +3 | c. -20 | d. 25 |
|---|---|---|---|---|
| ANS: | 10000000 | 00000011 | 10010100 | 00011001 |

2. Convert the following 8-bit sign-magnitude numbers to their decimal equivalents:

| | a. 10000011 | b. 00000101 | c. 00010001 | d. 10100110 |
|---|---|---|---|---|
| ANS: | -3 | +5 | +17 | -38 |

3. Convert the following decimal numbers to their 8-bit twos-complement representation:

| | a. 0 | b. -6 | c. +27 | d. -38 |
|---|---|---|---|---|
| ANS: | 00000000 | 11111010 | 00011011 | 11011010 |

4. Convert the following 8-bit twos-complement numbers to their decimal equivalents:

| | a. 11111110 | b. 00000110 | c. 11010110 | d. 00101011 |
|---|---|---|---|---|
| ANS: | -2 | +6 | -42 | +43 |

5. What is the 6-bit 2's complement value of:

| | a. -2 | b. -10 | c. -17 | d. -21 |
|---|---|---|---|---|
| | +2 = 000010 | +10 = 001010 | +17 = 010001 | +21 = 010101 |
| 1's comp: | 111101 | 110101 | 101110 | 101010 |
| | +1 | +1 | +1 | +1 |
| ANS: | -2 = 111110 | -10 = 110110 | -17 = 101111 | -21 = 101011 |

6. Add or subtract the following twos-complement numbers as indicated:

| a. 0010 (+2) | b. 1111 (-1) | c. 110110 (-10) | d. 101010 (-22) |
|---|---|---|---|
| +0100 (+4) | + 1101 (-3) | -000011 ( 3) | +010110 (+22) |
| 0110 (+6) | 1100 (-4) | 110011 (-13) | 000000 ( 0) |

NOTE: DIGITS CARRIED PAST THE LEFTMOST PLACE IN THE RESULTS ARE IGNORED.

## Section VI: **Floating-Point Numbers**

In the decimal system, a decimal point separates the whole numbers from the fractional part. Other systems also use a point to separate these parts. Henceforth, this point will be known as a **radix point**, since its use is not limited to the decimal numbering system.

In the decimal system, the digits to the right of the radix point, read from left to right, represent tenths, hundredths, thousandths, and so forth. For example, 27.45 can be analyzed as:

| Tens | Units | Tenths | Hundredths |
|---|---|---|---|
| 2 | 7 | 4 | 5 |

Thus, 27.45 represents two tens, seven units, four tenths, and five hundredths. Arithmetically, this can be expressed as:

$$27.45 = 2 \times 10 + 7 \times 1 + 4 \times 1/10 + 5 \times 1/100$$

We can represent the powers of ten in exponential notation by using the convention that a number with a negative exponent is one over the number with the corresponding positive exponent - in symbols, $a^{-n} = = 1/a^n$. Thus we can write 1/10 as $10^{-1}$ and 1/100 as $10^{-2}$:

$$27.45 = 2 \times 10^1 + 7 \times 10^0 + 4 \times 10^{-1} + 5 \times 10^{-2}$$

In binary notation, the digits to the right of the radix point, taken from left to right, represent halves, quarters, eighths, and so on. For example, we can analyze $10.11_2$ as:

| Twos | Units | Halves | Quarters |
|---|---|---|---|
| 1 | 0 | 1 | 1 |

Thus, $10.11_2$ represents one two, zero units, one half, and one quarter. Arithmetically, we can express this as:

$$\begin{aligned} 10.11_2 &= 1 \times 2 + 0 \times 1 + 1 \times ½ + 1 \times 1/4 \\ &= 2 + 0 + .5 + .25 \\ &= 2.75 \end{aligned}$$

Using exponential notation for the powers of two gives:

$$10.11_2 = 1 \times 2^1 + 0 \times 2^0 + 1 \times 2^{-1} + 1 \times 2^{-2}$$

In the decimal system, numbers are often written in **scientific** or **floating point** notation. The significant digits of a number are always written with the radix point between the first and second digits; this part of the number is called the **mantissa**. The mantissa is multiplied by a power of 10 to move the radix point to the desired position.

For example, 1,250,000 is written $1.25 \times 10^6$. The mantissa is 1.25. Since multiplying a number by 10 moves the radix point one place to the right, multiplying by $10^6$ - that is, multiplying by 10 six times, moves the radix point six places to the right, giving 1,250,000.

In the same manner, 0.0000352 can be written in floating-point notation as $3.52 \times 10^{-5}$. The mantissa is 3.52. Since multiplying a number by 1/10 moves the radix point one place to the left, multiplying by $10^{-5}$, that is, multiplying by 1/10 five times, moves the radix point five places to the left, giving 0.0000352.

The advantage of floating-point notation is that nonsignificant zeros, zeros that serve only to show the position of the radix point, do not have to be written. This is particularly important in computing, for we usually have only a fixed number of digits with which to represent a number inside a computer. If some of these digits are wasted on nonsignificant zeros, fewer digits are available to represent the significant part of the number, and the accuracy with which the number can be represented is reduced.

Binary numbers can also be written in floating point in much the same manner as decimal numbers, except that powers of two, rather than powers of ten are used to shift the radix point. For example, 11010000 can be written as $1.101_2 \times 2^7$ and 0.0000111 as $1.11_2 \times 2^{-5}$. For ease of reading, the exponents (7 and -5) are written in decimal notation, although they must be coded in binary before being stored in the computer.

**IEEE Floating Point Representation**.

Floating point numbers can be represented by binary codes by dividing them into three parts: the **sign**, the **exponent**, and the **mantissa.** The sign-magnitude representation is often used to represent floating point numbers since there is so much work involved with this type of number that the additional work occasioned by the use of sign-magnitude is almost negligible.

The first, or leftmost, field of our floating point representation will be the sign bit: 0 for a positive number, 1 for a negative number.

The second field of the floating point number will be the exponent. Since we must be able to represent both positive and negative exponents, we will use a convention which uses a value known as a **bias** to determine the representation of the exponent. For example, if we choose a bias of 127, we add 127 to the value of the exponent before storing it. An exponent of 5 is therefore stored as 127 + 5 or 132; an exponent of -5 is stored as 127 + (-5) OR 122. If the actual exponent ranges from -127 through 128, the **biased exponent**, the value actually stored, will range from 0 through 255. This is the range of values that can be represented by 8-bit, unsigned binary numbers. Thus we will store biased exponents as unsigned binary numbers in an 8-bit field.

The mantissa is said to be **normalized** when the digit to the left of the radix point is 1. Every mantissa, **except the one corresponding to the number zero**, can be normalized by choosing the exponent so that the radix point falls to the right of the leftmost 1 bit. Ignoring zero for the moment, we will assume that every mantissa is normalized. Since the digit to the left of the radix point is 1, we don't actually have to store it; only bits to the right of the radix point need be stored. The mantissa is often stored in a 23 bit field, which will be the size used in our examples (the total number of bits used for the three parts of our floating-point representation is, therefore, 32, or four 8-bit bytes).

**NOTE:** As a **special case**, if all 32 bits in our floating-point representation are zeros, then the number represents 0 (zero cannot be normalized and so the special case is necessary). Had we not defined zero as a special case, the exponent, 00000000, would translate to $2^{-127}$.

**Converting decimal floating point values to stored IEEE standard values**.

Step 1. Compute the binary equivalent of the whole part and the fractional part.

**Example 1**: Given decimal value 40.15625, convert 40 and .15625.

| | | | |
|---|---|---|---|
| 40 | | .15625 | |
| - 32 | Result: | - .12500 | Result: |
| 8 | 101000 | .03125 | .00101 |
| - 8 | | - .03125 | |
| 0 | | .0 | |

So: $40.15625_{10} = 101000.00101_2$

Step 2. Normalize the number by moving the decimal point to the right of the leftmost one.
$101000.00101 = 1.0100000101 \times 2^5$

Step 3. Convert the exponent to a biased exponent
$127 + 5 = 132 \quad ==> \quad 132_{10} = 10000100_2$

Step 4. Store the results from above

| Sign | Exponent (from step 3) | Significand (numbers to right of decimal from step 2) |
|---|---|---|
| 0 | 10000100 | 01000001 01000000 0000000 |

Let's try a second number:

Step 1. Compute the binary equivalent of the whole part and the fractional part.

Example 2: Given decimal value -24.75, convert 24 and .75.

| | | | |
|---|---|---|---|
| 24 | | .75 | |
| - 16 | Result: | - .50 | Result: |
| 8 | 11000 | .25 | .11 |
| - 8 | | - .25 | |
| 0 | | .0 | |

So: $-24.75_{10} = -11000.11_2$

Step 2. Normalize the number by moving the decimal point to the right of the leftmost one.
$-11000.11 = -1.100011 \times 2^4$

Step 3. Convert the exponent to a biased exponent
$127 + 4 = 131 \quad ==> \quad 131_{10} = 10000011_2$

Step 4. Store the results from above

| Sign | Exponent (from step 3) | Significand (numbers to right of decimal from step 2) |
|---|---|---|
| 1 | 10000011 | 10001100 00000000 0000000 |

Sometimes the numbers are already in binary exponential notation, and just need to be converted to the storage format. Now let's store the following number:

$1.101_2 \times 2^7$

The sign bit is 0, the biased exponent is 7 + 127 = 134 = $10000110_2$. The bits to the right of the radix point in the mantissa are 101 followed by enough 0s to fill out the 23-bit mantissa field:

| Sign | Biased Exponent | Mantissa |
|---|---|---|
| 0 | 10000110 | 10100000000000000000000 |

As another example, $-1.11_2 \times 2^{-5}$ is represented as:

| Sign | Biased Exponent | Mantissa |
|---|---|---|
| 1 | 01111010 | 11000000000000000000000 |

**Converting stored IEEE standard values back to decimal floating point values**.

To convert back to decimal, simply reverse the process.

| Example: Given | Sign | Biased Exponent | Mantissa |
|---|---|---|---|
| | 0 | 10000010 | 10100110000000000000000 |

Step 1: Determine what the exponent value is by converting the biased exponent to an unbiased value:

1000 0010 = 130
130 - 127 = 3 so the exponent is 3.

Step 2: Write the number in exponential notation, remembering to insert a 1 before the decimal point, and placing the mantissa after the decimal point:

$1.1010011 \times 2^3$

Step 3: Re-write the number in floating point format, without the exponent by moving the decimal point the number of places indicated by the exponent.

1101.0011

Step 4: Convert the binary values to decimal.

| | | |
|---|---|---|
| 1101 = | 8 + 4 + 1 = | 13 |
| .0011 = | .125 + .0625 = | .1875 |

So the decimal equivalent is: 13.875

**Section VI Exercises** (Floating-Point Numbers).

1. Convert the following binary numbers to normalized exponential notation:

a. 11011 b. 101.111 c. 0.0011 d. 1.0011

2. Using a bias of 127 decimal, place the following exponents (expressed in decimal) in an 8 bit field which represents the exponent in binary format.

a. 3 b. -8 c. 10 d. -2

3. Convert the following binary exponents, represented with a bias of 127, to their decimal equivalents.

a. 10000100 b. 01110011 c. 10001101 d. 01111001

4. Convert the following decimal floating point numbers to their 32 bit binary representation in the sign/exponent/mantissa format; use a bias of 127 for the exponent:

a. 37.75 b. -25.125 c. 108.5

5. Convert the following 32 bit binary numbers to their decimal floating point equivalents. Assume a bias of 127 for the exponent. Decimal answers may be rounded to two decimal points (0..0 indicates the remainder of the mantissa is filled with zeros):

| | Sign | Exponent | Mantissa |
|---|---|---|---|
| a. | 1 | 01111101 | 01000000000000000000000 |
| b. | 0 | 10000011 | 11010000000000000000000 |
| c. | 0 | 10000110 | 11010111110000000000000 |

**Section VI Exercise Answers**.

1. Convert the following binary numbers to normalized exponential notation:

| | a. 11011 | b. 101.111 | c. 0.0011 | d. 1.0011 |
|---|---|---|---|---|
| ANS: | $1.1011 \times 2^4$ | $1.01111 \times 2^2$ | $1.1 \times 2^{-3}$ | $1.0011 \times 2^0$ |

2. Using a bias of 127 decimal, place the following exponents (expressed in decimal) in an 8 bit field which represents the exponent in binary format.

| | a. 3 | b. -8 | c. 10 | d. -2 |
|---|---|---|---|---|
| | INTERIM STEP: | Add the bias (127) to each exponent: | | |
| | 3 | -8 | 10 | -2 |
| | +127 | +127 | +127 | +127 |
| | 130 | 119 | 137 | 125 |
| ANS: | 10000010 | 01110111 | 10001001 | 01111101 |

3. Convert the following binary exponents, represented with a bias of 127, to their decimal equivalents.

| | a. 10000100 | b. 01110011 | c. 10001101 | d. 01111001 |
|---|---|---|---|---|
| | INTERIM STEP - Convert the exponent to decimal and subtract the bias (127). | | | |
| | 132 | 115 | 141 | 121 |
| | -127 | -127 | -127 | -127 |
| ANS: | +5 | -12 | +14 | -6 |

4. Convert the following decimal numbers to their 32 bit binary representation in the sign/exponent/mantissa format; use a bias of 127 for the exponent:

a. $37.75_{10}$ → $100101.11_2$ → $1.0010111_2 \times 2^5$

| → | Sign | Exponent | Mantissa |
|---|---|---|---|
| ANS: | 0 | 10000100 | 00101110..0 |

b. $-25.125_{10}$ → $-11001.001_2$ → $-1.1001001_2 \times 2^4$

| → | Sign | Exponent | Mantissa |
|---|---|---|---|
| ANS: | 1 | 10000011 | 10010010..0 |

c. $108.5_{10}$ → $1101100.1_2$ → $1.1011001_2 \times 2^6$

| → | Sign | Exponent | Mantissa |
|---|---|---|---|
| ANS: | 0 | 10000101 | 10110010..0 |

5. Convert the following 32 bit binary numbers to their decimal floating point equivalents. Assume a bias of 127 for the exponent. Decimal answers may be rounded to two decimal points (0..0 indicates the remainder of the mantissa is filled with zeros):

| | Sign | Exponent | Mantissa |
|---|---|---|---|
| a. | 1 | 01111101 | 010..0 |
| INTERIM: | - | 125-127=-2 | $-1.01 \times 2^{-2}$ |

ANS: $-0.0101_2$ → $-0.25 + 0.0625$ → $-0.3125_{10}$

| | Sign | Exponent | Mantissa |
|---|---|---|---|
| b. | 0 | 10000011 | 11010..0 |
| INTERIM: | + | 131 – 127 = 4 | $1.1101 \times 2^4$ |

ANS: $11101_2$ → $29.0_{10}$

| | Sign | Exponent | Mantissa |
|---|---|---|---|
| c. | 0 | 10000110 | 11010111110000000000000 |
| INTERIM: | + | 134 – 127 = 7 | $1.1101011111 \times 2^7$ |

11101011 = 128 + 64 + 32 + 8 + 2 + 1 = 235
.111 = 0.5 + 0.25 + 0.125 = 0.875

ANS: $11101011.111_2 = 235.875_{10}$

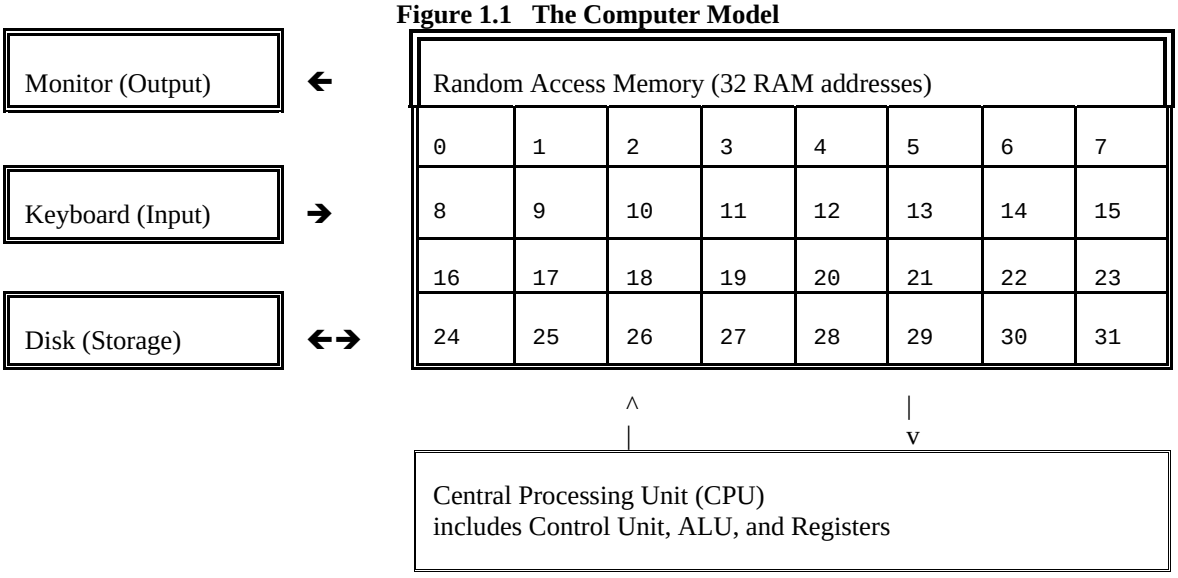
# CHAPTER TWO

# BASIC COMPUTER ARCHITECTURE AND SOFTWARE

## Section I: **A Simple Computer Model**

We will use a simple computer model to study basic computer architecture and assembly language. Our computer will consist of a keyboard for data input, a monitor for displaying output, random access memory (RAM) to hold executing programs and data, a hard drive or floppy disk for program storage, and a central processing unit.

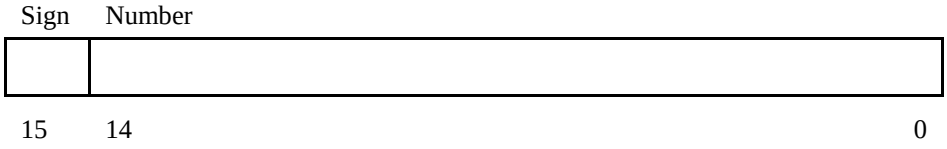
**Figure 1.1 The Computer Model**




**Random Access Memory (RAM)**

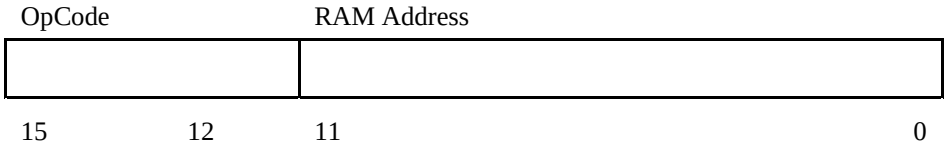
Our computer's memory will consist of blocks of bits called **words**. Word sizes vary from computer to computer. The word size for our simple computer will be 16 bits (two 8-bit bytes). Each word will hold either data or program instructions. For simplicity, our model will work only with *signed* number data (leftmost bit is the sign bit). To avoid consideration of -0, we will assume the use of the twos-complement representation (range -32768 through 32767).

**Figure 1.2 Representing *Data* with a 16-Bit Word**



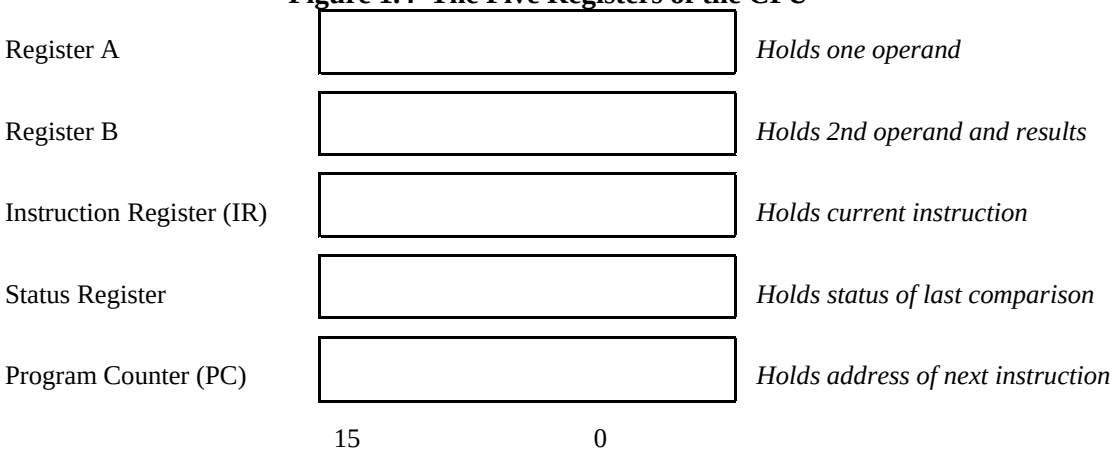

Each word in our computer's memory is an addressable unit. Our model's memory (RAM) will consist of 32 addressable memory locations where data and instructions can be stored and retrieved as needed during program execution. Data is stored in the computer as shown above in figure 1.2. Now we need a method of storing instructions. There are 16 operations possible in our model computer's assembly programming language. To represent 16 states, we need four bits. Therefore, the first 4 bits of any instruction will be reserved for the operation code (opcode). The remaining bits will be used to refer to any one of our 32 memory addresses, numbered 0 to 31.

**Figure 1.3 Representing *Instructions* with a 16-Bit Word**




**The central processing unit (CPU)**.
The CPU contains a small number of word-size memory locations called **registers**. Different registers perform different tasks such as manipulating data, keeping track of the results of decision making operations, and pointing to the next instruction to be **executed**.

**Figure 1.4 The Five Registers of the CPU**




The program can load data from RAM into registers A and B for mathematical manipulation or logical comparison. The other registers are used by the CPU to control program flow. The **Instruction Register (IR)** contains the actual instruction which is currently being executed by the CPU. The **Status Register** records the result of comparing the contents of register A with the contents of register B. The **Program Counter (PC)** contains the address of the next instruction to be executed by the program.

Registers A & B hold the operands for each arithmetic operation (ie. the values on which the operation will be performed). Arithmetic operations available are addition, subtraction, multiplication, and division. After the operation has been carried out, the result is always stored in Register B. Therefore, after an arithmetic operation has been performed, the second operand is no longer stored in Register B, because it has been *overwritten* by the result of the operation.

The computer also has a **Compare** instruction that can be used to compare the contents of register A with those of register B. The comparison can have three possible outcomes: (1) the contents of register A can be less than those of register B; (2) the contents of the register A can be equal to those of register B; (3) the contents of the register A can be greater than those of register B.

After a comparison has been done, the Status Register will hold a code that stores the results of the comparison. The results are coded as follows:

| | |
|---|---|
| -1 | if the contents of register A are less than those of register B (A < B); |
| 0 | if the contents of registers A and B are the same (A = B); |
| 1 | if the contents of register A are greater than those of register B (A > B). |

The Program Counter contains the address of the next instruction the computer is to execute. When a program is loaded into RAM, the Program Counter is set to 0, so that the program will begin by running the instruction at address 0.

Each instruction is run in two steps, known as the fetch-decode-execute cycle. During the **fetch** part of the cycle the CPU fetches the next instruction from the address contained in the Program Counter and places it in the Instruction Register.

As soon as an instruction is fetched, the CPU adds 1 to the contents of the Program Counter. Therefore, consecutive instructions will normally come from consecutive memory locations (for sequential programs). However, certain instructions called **jump** instructions can change the contents of the Program Counter to new value, thus causing the computer to jump to some other part of the program and continue execution from there. Jump instructions will be used for decisions and loops.

Once an instruction has been placed in the instruction register, a **decode unit** within the CPU deciphers the instruction so that **execution** may begin. After execution of the instruction has been completed the cycle starts all over again (unless the action of the instruction terminates the program).

## Section II: **A Model Assembly Language Instruction Set**

A computer performs various tasks by executing a sequence of instructions that the processor is able to understand. When a processor chip is designed, it is designed to understand and execute a set of machine code instructions (OpCodes) unique to that chip. One step up from machine code is assembly code. Each machine code instruction is given a mnemonic (name), so that it is easier for human beings to write code. There is a one-to-one correspondence between the assembly languages mnemonic instructions and the machine language numeric instructions. A list of assembly code instructions that will perform a task is called an assembly program.

Assembly language is a language that allows total control over *every individual machine instruction* generated by the assembler. High-level language compilers, on the other hand, make many decisions about how a given language statement will be translated into machine instructions. For example, the following single C++ instruction assigns a value of **55** to a numeric variable called **Num**:

**Num = 55;**

When the C++ compiler reads this line, it outputs a series of four or five machineinstructions that take the value **55** and store it in memory at a location named **Num**. Normally, you the programmer have *no idea* what these four or five instructions actually are, and you have no way of changing them, even if you know a sequence of machine instructions that is faster and more efficient than the sequence the compiler uses. Assembly language gives you the choice of which machine instructions will be used.

**Assembly Language Concepts**

• *Each individual instruction is very simple.* A single instruction rarely does more than move a single word from one storage area to another, compute a value, or compare the value contained in one storage area to a value contained in another. So you can concentrate on the simple task that is being accomplished by the instruction without worrying about the complexity of the entire program.

• *A program requires many instructions to do anything useful.* You can often write a useful program in a high-level language (like C++) in five or six lines. But a functional assembly language program cannot be implemented in fewer than about twenty lines, and anything demanding takes hundreds or thousands of lines.

• *The key to assembly language is understanding memory addresses.* In high-level languages like C++, the compiler takes care of *where* the data is located—you simply have to give the constant or variable data a name, and call it by that name when you want to use it. But in assembly language, you must always be aware of where things are in your computer's memory. All data will be accessed via memory *addresses*.

**Model Assembly Language**

We will use an assembly language code that consists of 16 instructions. The instruction set is listed below.

| Operation | What it means to the CPU |
|---|---|
| STP | Stop the program |
| LDA | Load register A with contents of a specified memory location |
| LDB | Load register B with contents of a specified memory location |
| STR | Store register B contents to a specified memory location |
| INP | Store data input by user to a specified memory location |
| PNT | Print the contents of a specified memory location to the screen |
| JLT | Jump if less than (Status register = -1) to a specified memory location |
| JGT | Jump if greater than (Status register = 1) to a specified memory location |
| JEQ | Jump if equal (Status register = 0) to a specified memory location |
| JMP | Unconditional jump to a specified memory location |
| CMP | Compare register A to register B and set Status Register value |
| ADD | Add (register A + register B) and store sum in register B |
| SUB | Subtract (register A - register B) and store difference in register B |
| MUL | Multiply (register A * register B) and store product in register B |
| DIV | Divide for quotient (register A / register B) and store quotient in register B |
| MOD | Divide for remainder (register A / register B) and store remainder in register B |

Notice that instructions LDA, LDB, STR, INP, PNT, JLT, JGT, JEQ, and JMP all require a "specified memory address". The complete instruction actually consists of two parts: an opcode and an operand. The opcode is one of the operations listed above and the operation is a memory address.

**The load and store instructions**. The load instructions load values (ie. copy the contents) from main memory locations into registers A and B. There is one load instruction for register A, **LDA**, and one for register B, **LDB**. The store instruction, **STR**, stores a value (ie. copies the contents) from the register B into main memory location.

**Examples**

The instruction: LDA 20

loads the contents of memory location 20 into the register A. The contents of memory location 20 are not affected by the copying; its value remains the same.

The instruction: LDB 21

loads the contents of memory location 21 into the register B. The contents of memory location 21 are not affected by the copying; its value remains the same.

The instruction: STR 22

stores the contents of register B into memory location 22. The contents of register B are not affected by the copying; its value remains the same.

**The input and output instructions**. The input instruction, **INP**, transfers data entered by the user at the computer's single input device (the keyboard) to a main memory location. The output instruction, **PNT**, displays the data contents of a main memory location on the computer's single output device (the monitor screen).

The instruction: INP 23

reads one number entered at the keyboard and stores it in memory location 23.

The instruction: PRT 23

displays the number in memory location 23. The contents of location 23 remain unchanged.

**The arithmetic instructions**. The arithmetic instructions are ADD, SUB, MUL, DIV, and MOD. There are two division instructions, DIV and MOD. DIV yields the integer quotient of a division, while MOD yields the remainder. For each instruction, one of the numbers on which the operation is to be carried out must be in register A; the other must be in register B. The result of the operation is always stored back into register B. Since the operands must be stored in the registers, these operations do not require a memory address.

For addition and multiplication, the contents of the registers A and B are added/multiplied (ie. register A + register B). For subtraction, the contents of register B are subtracted from the contents of register A (ie. register A - register B). For division, the contents of register B are divided into the contents of register A (ie. register A / register B).

| | |
|---|---|
| The instruction: ADD | adds contents registers A and B. The **sum** is stored in the register B. |
| The instruction: SUB | subtracts the contents of register B *from* the contents of register A. The **difference** is stored in register B. |
| The instruction: MUL | multiplies the contents of registers A and B. The **product** is stored in register B. |
| The instruction: DIV | divides the contents of register A by the contents of register B. The whole **quotient** is stored in register B. |
| The instruction: MOD | divides the contents of register A by the contents of register B. The **remainder** of the division is stored in register B. |

**The compare instruction**. The compare instruction and the jump instructions work together to implement selection and repetition. The compare instruction, CMP, compares the contents of the register A with the contents of register B.

The instruction: CMP

compares the contents of register A with the contents of register B. It records in the Status Register whether register A's contents are less than, equal to, or greater than Register B's contents, according to the following chart:

-1 if the contents of register A are less than those of register B (A < B);
0 if the contents of registers A and B are the same (A = B);
1 if the contents of register A are greater than those of register B (A > B).

**The jump instructions**. The **unconditional** jump instruction, JMP, changes the value of the program counter, by storing a new memory address into it. This causes the computer to take its next instruction from the newly specified address. The computer jumps to the point in the program specified in the jump instruction and continues execution from that point.

The instruction: JMP 15

causes the computer to jump to memory location 15 and continue program execution from there. In the absence of further jump instructions, the computer will execute the instructions in locations 16, 17, 18, and so on.

JLT, JEQ, and JGT are **conditional** jump instructions. The jump only takes place if the contents of the Status Register have a particular value. If the contents of the Status Register do not have the required value, the jump does not take place and the computer continues execution of the program with the instruction in memory following the one that holds the jump instruction.

JLT jumps only if the contents of the status register are -1 (indicating register A was less than register B); JEQ jumps only if the contents are 0 (A was equal to B); JGT jumps only if the contents are 1 (A was greater than B).

The instruction: JLT 11

causes the computer to jump to location 11 in the program only if the contents of the status register are -1 (register A's contents were less than register B's contents when last compared). If the comparison code register contains 0 or 1, the computer continues with the instruction in the memory location following the one containing the jump instruction (no jump).

The instruction: JGT 12

causes the computer to jump to location 12 in the program only if the contents of the status register are 1 (A was greater than B).

The instruction: JEQ 11

causes the computer to jump to location 11 in the program only if the contents of the status register are 0 (A was equal to B).

If the condition for one of these jumps is true, then the address after the jump instruction is loaded into the program counter, which causes the jump to a new instruction.

**The stop instruction**. The stop instruction, STP, causes the CPU to stop fetching and executing instructions and go into standby mode. The address part of the instruction is ignored.

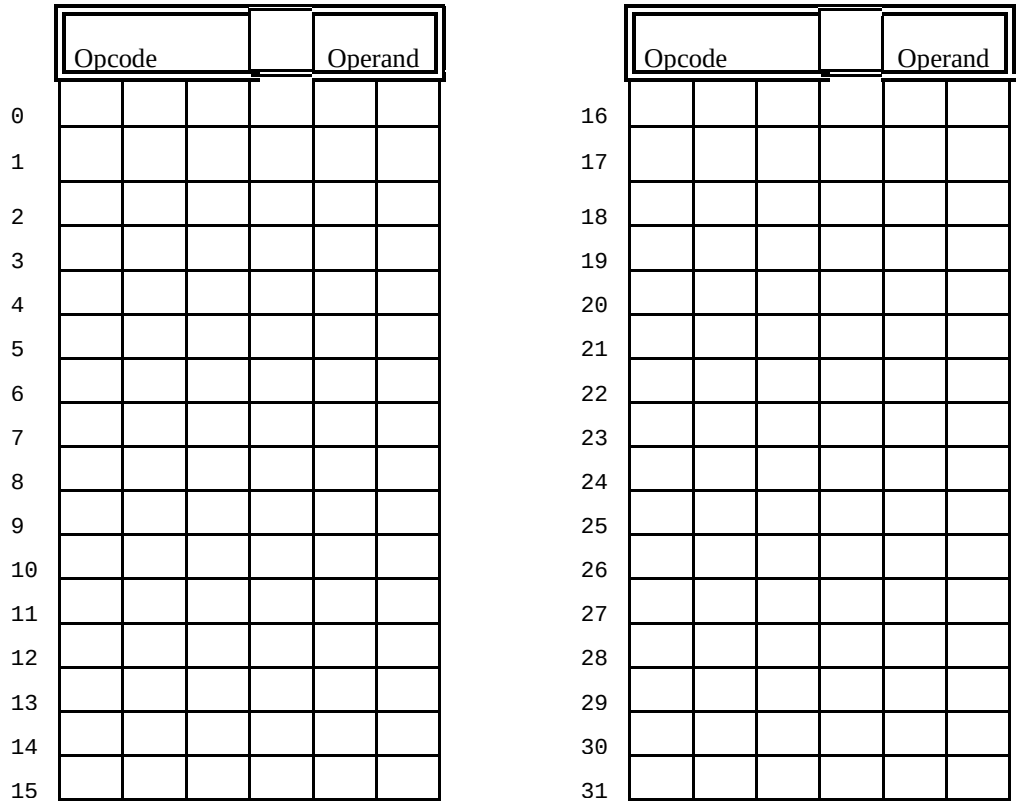
The instruction: STP brings the program execution to a stop.

## WRITING ASSEMBLY CODE PROGRAMS (on our Model Computer)

**Creating Programs**

You can use any text editor to create your programs, as long as it has the ability to save the data in ASCII format. Each line in the file will contain either program code (instructions) or program data. When a program is loaded, the first instruction will be placed at memory location 0, followed by the rest of the instructions in consecutive memory locations (ie. 1, 2, 3, 4...). Program data will be placed in memory locations directly following the program instructions.

Code Formatting Forms:




Formatting for program instructions:

Type the OpCode (ie. operation) in columns 1-3 (Note: must use UPPERCASE)
Column 4 must contain a space.
Type the operand (ie. memory address) for instructions that require one in columns 5-6.

To create program data values:

Data values will be placed on the lines immediately following the STP operation in your program. Beginning in column 1 of each line, type the value you wish to store in that memory location.

**The Model Assembler**

You will be using a model computer assembler. The program is located on the lab computers, and you are welcome to make a copy on a diskette for use on your home/work computers.

**Running Programs**

After starting the assembler, you can run assembly programs. Enter the name of the file containing the source code at the filename prompt. The program will be loaded into memory, and displayed on the screen. The program counter contains 0, the address of the first instruction, and all other registers are empty.

You can now run the program in either NORMAL or STEP mode.

NORMAL mode - Press 'r' to run (execute) the entire program.

The program will run, starting with the instruction at address 0, and will continue to run until termination, pausing only to get input from the user.

STEP mode - Press any key to execute ONE step at a time.

The program begins to run, starting with the instruction at address 0. Each line of your program code will take three steps to complete. Each time you press a key, one step will execute. The steps are as follows:

1) Fetch the instruction stored at the RAM address specified in the program counter and place it in the instruction register.

2) Increment the program counter by 1 (to point to the next instruction address).

3) Decode and execute the instruction.

The program display will show the user how the computer loads and performs the instructions within the program, as well as showing a simulated monitor to display the results of the program input/output.

## SAMPLE PROGRAMS

**Sample Program #1.**

Our first sample program will get a number as input from the user, and output its square to the user. First we need an English-like algorithm to describe the steps needed to solve our problem.

1. Input a number and store it in memory.
2. Compute the square by multiplying the number times itself.
3. Store the result in memory.
4. Output the results from memory.

Since our sample program will use two memory locations to store data, as follows:

| What's Stored | Memory Address |
|---|---|
| Input Number | 07 |
| Squared Result | 08 |

Step 1 of the algorithm inputs the number from the user and stores it in location 07.

```
INP  07
```

Step 2 computes the square of the number at location 07. First the number at location 07 is loaded into both registers. Then the register values are multiplied together. The result ends up in register B.

```
LDA  07
LDB  07
MUL
```

Step 3 stores the result (currently in register B) into memory location 08.

```
STR  08
```

Step 4 displays the contents of memory location 08 to the screen and then terminates the program.

```
PNT  08
STP
```

Putting all the instructions together, the program is shown below.

| Address | Memory Contents | Explanation |
|---|---|---|
| 00 | INP 07 | Get input number from user and store at location 07 |
| 01 | LDA 07 | Load input number into register A |
| 02 | LDB 07 | Load input number into register B |
| 03 | MUL | Multiply register A by register B, result in B |
| 04 | STR 08 | Store result from register B into location 08 |
| 05 | PNT 08 | Output result stored in location 08 |
| 06 | STP | Terminate execution |
| 07 | ? | Storage for Input Number |
| 08 | ? | Storage for Squared Result |

**Sample Program #2.**

Our second sample program will get a number from the user, and determine if the number is evenly divisible by 5. Output zero (false) if the number is NOT evenly divisible by 5 or one (true) if the number IS evenly divisible.

Again, we first we need an English-like algorithm to describe the steps needed to solve our problem.

1. Input a number and store it.
2. Determine if the input number is evenly divisible by 5.
    2.1 Divide the input number by 5 to get the remainder.
    2.2 Compare the remainder to 0.
        2.2.1 If remainder equals 0, the number IS evenly divisible.
        2.2.2 If the remainder does not equal 0, the number NOT evenly divisible.
3. Output the results
    3.1 If evenly divisible, output 1.
    3.2 If NOT evenly divisible, output 0.

This sample program will use four memory locations to store data.

| What's Stored | Address |
|---|---|
| Zero | 11 |
| One | 12 |
| Five | 13 |
| Input number | 14 |

Step 1 of the algorithm inputs the number from the user and stores it in location 14.

```
INP  14
```

Step 2 determines if the number is evenly divisible by 5. This is accomplished by loading the register A with the input number (from location 14), loading register B with value 5 (from location 13), and MODing the registers. Then the results of the MOD are compared with zero, by loading 0 into register A (from location 11) and comparing it to the remainder of the MOD in register B.

```
LDA  14
LDB  13
MOD
LDA  11
CMP
```

Step 3 takes the comparison results and outputs the answer. First, if the comparison showed the MOD result in register B was equal to 0 telling us the number is evenly divisible by 5, then the program jumps to output 1 (from location 12). Otherwise, the number is NOT evenly divisible, and the program outputs zero (from location 11).

```
JEQ 09
PNT 11
```

If 0 was output, the program must then jump to the stop statement, to prevent outputting of 1 also.

```
JMP 10
PNT 12
STP
```

Putting all the instructions together, the program is shown below.

| Address | Memory Contents | Explanation |
|---|---|---|
| 00 | INP 14 | Input number and store in location 14 |
| 01 | LDA 14 | Load value at location 14 into register A (input num) |
| 02 | LDB 13 | Load value at location 13 into register B (5) |
| 03 | MOD | MOD register A value (input num) by register B value (5) |
| 04 | LDA 11 | Load value at location 11 into register A (0) |
| 05 | CMP | Compare register A (0) to register B (mod result) |
| 06 | JEQ 09 | If condition code 0 (values equal), jump to instruction 09 |
| 07 | PNT 11 | Output value at location 11 number (input number) |
| 08 | JMP 10 | Jump to instruction 10 |
| 09 | PNT 12 | Output value at location 12 (0) |
| 10 | STP | Terminate execution |
| 11 | 0 | Storage for constant 0 |
| 12 | 1 | Storage for constant 1 |
| 13 | 5 | Storage for constant 5 |
| 14 | ? | Storage for input number |

**Sample Program #3.**

Our third sample program will add up a series of positive numbers entered by the user, until the user enters a negative number, then display the total.

Below is the English-like algorithm to solve the problem.

1. Copy the value 0 into the Running Total.
2. Input a value and store it in memory.
3. While the Input Value is not a negative number:
   - 3.1 Add the Input Value to the Running Total and store the sum back into the Running Total.
   - 3.2 Input another value and store it in memory.
4. Output the contents of the Running Total.

The program will use three memory locations to store data:

| What's Stored | Address |
|---|---|
| Zero | 13 |
| User input value | 14 |
| Running Total | 15 |

Step 1 of the algorithm clears the Running Total by copying 0 into the Running Total. This is done by **loading** 0 (from location ) into the register B and **storing** it into the Running Total (at location ).

```
LDB  13
STR  15
```

Step 2 gets the the first input value to be processed and stores it in location

```
INP  14
```

Steps 3.1 and 3.2 are to be repeated only so long as the Input Value is greater than or equal to zero. Before executing these steps, the computer must compare the contents of the Input Value with 0. If the contents of the Input Value are less than 0, the computer is to jump around steps 3.1 and 3.2 and go directly to step 4. If the Input Value is greater than or equal to 0 the computer is to continue with steps 3.1 and 3.2.

The program loads the Input Value (from location 14) into the register A, and 0 (from location 13) into register B, then compares the contents of the two registers.

```
LDA  14
LDB  13
CMP
```

If the Input Value in register A is less than 0 in register B, the computer should jump to step 4, the instructions for which begin at memory location 11.

```
JLT  11
```

If the Input Value in register A was greater than or equal to 0 in register B, the JLT instruction has no effect, and the computer goes on to the instructions for steps 3.1 and 3.2. Step 3.1 adds the Input Value (at location 14) to the Running Total (at location 15) and stores the result back into the Running Total. The Input Value has already been loaded into the register A; thus we must load the Total into register B and use an ADD instruction to add the contents of the two registers.

```
LDB  15
ADD
```

The STR instruction stores the resulting sum in register B back into the Running Total (at location 15).

```
STR  15
```

Steps 3.1 and 3.2 are to be repeated while the contents of the Input Value are greater than or equal to zero. This means that when step 3.2 has been executed, the computer must jump back to the beginning of step 3. Step 3 will check the new Input Value, jumping to step 4 if the Input Value is negative and continuing with steps 3.1 and 3.2 otherwise. When steps 3.1 and 3.2 have been executed, the computer will again jump back to the beginning of step 3, where the next Input Value will be checked, and so on. An unconditional jump instruction causes the computer to jump back to the beginning of step 3.

```
JMP  02
```

Step 4 outputs the Running Total (at location 15) and terminates the program.

```
PNT 15
STP
```

Putting all the instructions together, the program is shown below.

| Address | Contents | Explanation |
|---|---|---|
| 00 | LDB 13 | Load 0 into Register B (from location 13) |
| 01 | STR 15 | Store 0 into Total (initialize location 15) |
| 02 | INP 14 | Read user Input Value (into location 14) |
| 03 | LDA 14 | Load Input Value (from location 14) into register A |
| 04 | LDB 13 | Load 0 (from location 13) into register B |
| 05 | CMP | Compare contents of register A (input value) and register B (0) |
| 06 | JLT 11 | Jump out of loop if contents of A < contents of B |
| 07 | LDB 15 | Load the Total into register B |
| 08 | ADD | Add register A contents (input value) to register B contents (total) |
| 09 | STR 15 | Store resulting sum (in register B) to location 15 (total) |
| 10 | JMP 02 | Jump back to start of loop for next input |
| 11 | PNT 15 | Output total (from location 15) |
| 12 | STP | Terminate program execution |
| 13 | 0 | Storage for constant 0 |
| 14 | ? | Storage for Input Value |
| 15 | ? | Storage for Total |

**Section III Exercises** (Software).

Using the assembly language instruction set:

1. Write a program which multiplies two numbers obtained from the input device and sends the results to the output device.

2. Write a program which obtains two numbers from the input device, and sends the larger of the two numbers to the output device.

3. Write a program which obtains a single number from the input device, adds the numbers 1 through 5 to the number, and sends the results to the output device.

**NOTE: The answers to the exercises for Section II will be presented in class.**

# CHAPTER THREE

# THE

# SYSTEM DEVELOPMENT

# LIFE CYCLE (SDLC)

## What is a system?

A **system** is a group of related components designed to work together in order to accomplish specific objectives. Today's computer-based systems are very large and complex. To build them, teams of analysts, designers, programmers, testers and users must all work together. In order to manage this huge task, the **system development life cycle (SDLC)** methodology was created. It provides an outline of tasks and deliverables needed to develop systems. The SDLC methodology tracks a project from an idea through implementation and post-implementation analysis.

## Phases in the System Development Life Cycle

1. **Preliminary Investigation** – Confirm the need for the new system and establish its feasibility. Create a high-level view of the system, including its purpose and goals.

2. **System Analysis** – Analyze the needs of the end users, the organizational environment, and the current systems being used. Refine the project goals into functional requirements for the system

3. **System Design** – Create detailed system specifications from a technical viewpoint.

4. **System Development** – Program, develop, or purchase the system parts, and assemble and test the entire system.

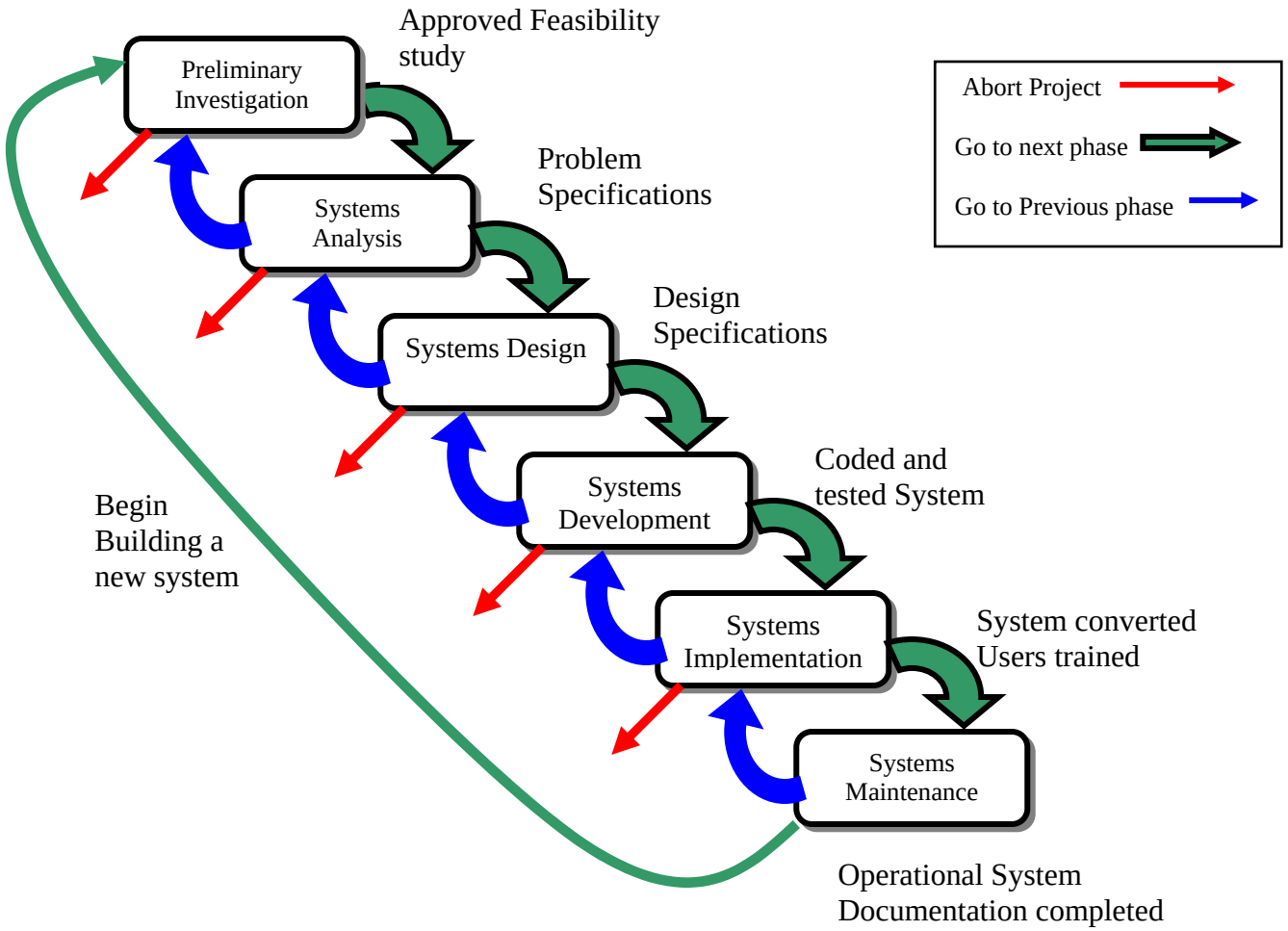
5. **System Implementation** – Train personnel and put the system into place.

6. **System Operation and Maintenance** – Physically run and maintain the system. Implement updates as needed.

The planning stages, systems analysis and design, are the most important stages. Good planning will help reduce errors and decrease the chance of missing deadlines or extending schedules. An undetected design error will take 10 times longer to fix during the development stage than it would have taken to fix had it been detected and corrected during the planning stages.

When following the SDCL, you may occasionally need to go back to prior steps when subsequent analysis points out problems. Typically, the life cycle has a spiral shape rather than a linear one, with repeated steps back to previous activities as requirements are refined and new information is collected.

Each phase of the SDLC has sub steps, which will be covered below.




## Phase 1: Preliminary Investigation

During the preliminary investigation phase, an organization will determine whether a problem exists and come up with alternative solutions to the problem.

The organization will conduct a **feasibility study** to determine the possibility of either improving the existing system or developing a new system. The feasibility study must address economic, operational, and technical feasibility. A system is **economically** feasible if the organization can afford to build and operate it. A system is **operationally** feasible if the organization can introduce and operate it within the organization's current environment. A system is **technically** feasible if it can be built with currently available technology.

A **cost/benefit analysis** will be conducted to determine whether or not the benefits of the new system would make the cost worthwhile. If a system is currently in place, the cost/benefit analysis will compare leaving the current system in place, improving the current system, and developing a new system. Otherwise, the new system will be compared to current manual methods.

Ideally, the preliminary investigation will include a review of the organization's strategic plan to ensure that the new system will help the organization achieve its strategic objectives. Management may need to approve concept ideas before any money is budgeted for the system development.

The final output of the preliminary investigation is a **Feasibility Report**. The Feasibility Report includes the system analyst's findings on the feasibility of changing to a new system. It will state the project purpose and goals, and outline each alternative with its costs, benefits and feasibility. The system analyst will document all research and opinions for later viewing, and make recommendations as to whether the project should move forward.

## Phase 2: System Analysis

During the system analysis phase, data will be collected and analyzed.

The first step is to conduct an in-depth analysis of the current system and assess the needs of the system users. The current system can be computerized or manual. Data will be gathered by reviewing written documents, interviewing current and proposed system users, and observing processes at work. The information gathered will help determine what the new system needs to do.

The Team

Information system professionals **must** involve end users in the system analysis process to ensure that the new system will function correctly and meets their needs and expectations. A project team should be assembled, composed of representatives from the various departments. The team should include users, system analysts, and programmers.

After analyzing the gathered data, the team will create data flow diagrams for the entire work process. The team will then give clarity to the project by defining the requirements for the new system. The requirements should be defined from the user's point of view. The requirements may include definitions of the data used by system, data-flow diagrams describing the path(s) data takes through system, and layouts of video screens, forms and reports.

Documentation produced by this phase will be methods used and compilations of gathered data, and any tools (diagrams, tables, etc) used to analyze the data. The final output of the system analysis phase will be a **Requirements Document**. The requirements document will summarize how the current system works, what its problems are, and list requirements for the new system with included recommendations. The Requirements Document should be referred to throughout the rest of the system development process to ensure the developing project aligns with user needs and requirements.

## Phase 3: System Design

The system design phase uses specifications in the Requirements Document from the systems analysis phase to design a model of the new system. IS professionals create the system design, but must review their work with the users to ensure the design meets users' needs. The IS team must determine the necessary specifications for the hardware, software, people, and data resources, and the procedures that will satisfy the functional requirements of the proposed system.

The process begins with a review of the review the major system components and the list alternative systems. The team first develops a Preliminary Design describing the general capabilities of the new system.

Computer-Aided Software Engineering (CASE) tools can help developers with the Detailed Design, which will describe how the proposed system will deliver general capabilities described in the preliminary design.

The final outputs of the system design phase is are a **Detailed Design**, including **System Specifications** for input and output, processing and system control, storage and backup, and networking (if necessary). The documentation will include data flow diagrams, system flowcharts, input/output designs, a data dictionary, etc, for the new system. The Detailed Design will serve as a blueprint for the system during system development.

## Phase 4: System Development

During system development, the system parts are developed and/or acquired to match the system design. Then the system parts are assembled, and the entire system is tested.

The organization must determine whether the system software will be bought or coded. A pre-written software package will usually be cheaper than developing in-house software. This option will only work if software exists that will meet the new system's needs. If there is no such existing software package, the organization can create the program itself, following the software development life cycle. Even if the organization purchases existing software, coding and debugging may be required for the interfaces that link the purchased software to existing systems that must communicate with the new system.

The system development phase does not change if the decision is made to purchase an off-the-shelf program rather than develop an in-house system. The coding and debugging process is replaced with a process used to evaluate the potential purchased products and to actually purchase the software.

Once the software has been chosen, the hardware to run it must be selected. At this point you can use existing hardware, upgrade the existing hardware, or purchase new hardware.

> A **Request for Proposal** (RFP) is used to solicit information from companies when you have general requirements, but no specific hardware in mind. Using the RFP requirements, the companies will propose systems that may work for your project.
>
> A **Request for Quotation** (RFQ) is used to solicit quotes from companies when you have a specific type of hardware in mind and want to get the best price.

After the hardware and software have been acquired (or developed), testing must be completed for each unit, each subsystem, and the entire system. Module or unit testing is used to test each individual part of the system, while integration testing tests system as a whole. The system must be tested to evaluate its actual functionality in relation to expected or intended functionality. The tests should simulate typical expected system usage.

During system development, documentation is written for the users and operators of the new system. The user's manual will summarize the benefits of the new system and provide detailed instructions for usage. The operator's manual will detail how to run and maintain the system.

## Phase 5: System Implementation

During system implementation, personnel are trained on the new system, and the system is put into operation.

For training, make classes, documentation and one-on-one sessions available to users. The users need to be made comfortable with the new system, to gain their support. Note that adequate training is essential for user acceptance of a new system.

Another issue to consider during this stage would be converting old data into the new data. If the previous system was manual, all the data must be entered into the new system. If the data existed on another computer system, it may need to be converted for compatibility with the new system.

System Implementation/Conversion

There are several popular methods that can be used to convert the old system to the new system. The organization must decide whether to implement the new system by the crash, parallel, phased, or pilot testing method.

1. **Direct Implementation**
   Also known as crash implementation or plunge implementation. Users stop using the old system one day and start using the new system the next day. This method is risky, but also the least costly.

2. **Parallel Implementation**
   Run the old and the new systems side by side until the new system is proven stable and reliable. When using this method, you will have the old system to fall back on if the new one has problems. Parallel implementation is safer, but has greater manpower costs, since two systems are in operation at once.

3. **Phased Implementation**
   Parts of the new system are phased in separately over time, using either parallel or direct implementation for each new part.

4. **Pilot Implementation**
   Only a few users (or users at one location) try out the entire system. Once they have proved that the system runs correctly, the system is installed for other users (or users at other locations).

Once the new system has been implemented, the organization needs to perform a post-implementation analysis of the new system. The analysis should evaluate whether the new system is meeting the original goals.

## Phase 6: System Operation and Maintenance

The system operation and maintenance phase is an on-going process that continues until the end of the system's life.

Maintenance includes:

- Keeping the machinery running
- Fixing bugs that were not discovered during development
- Updating and upgrading the system to keep pace with new requirements

Periodic system evaluations should also be performed to assess the capabilities, capacities, and whether or not the system is still adequate for the required tasks and objectives. The system should be flexible enough to accommodate minor changes. Major changes may require the organization to develop a new system, and begin the SDLC all over again.

## Computer-Aided Software Engineering (CASE) Tools

CASE tools are software products designed to help automate development of information systems. The goal of CASE tools is to decrease the human effort involved, while increasing the quality of software. The tools allow elements of the system to be drawn, described, stored, and where appropriate, to be automatically generated.

Using previous methods, only 35% of the time was spent on analysis and design and 65% of the time was used on coding and testing. CASE tools allowed analysts to apply as much as 85% of the time in the analysis and design stages of the development. This resulted in systems that more accurately met the users' requirements and allowed for more efficient and effective systems to be developed.

CASE tools can be divided into two main groups. Those that deal with the first three parts of the system development life cycle (preliminary investigation, analysis, and design) are referred to as Front-End CASE tools or Upper CASE tools. Those that deal mainly with the Implementation and Installation are referred to as Back-End CASE tools or Lower CASE tools.

By using a set of CASE tools, information generated from one tool can be passed to other tools, which, in turn, will use the information to complete its task, and then pass the new information back to the system to be used by other tools. CASE tools include:

**Diagramming Tools** - help develop system model diagrams and other visual-presentation materials.

**Prototyping Tools** - help create a limited working model of the new system. The goal is to demonstrate characteristics of system and allow users hands-on access, so they can test its usefulness. The biggest problem with prototyping is that the most critical parts of a system are often hard to prototype.

**Quality Management Tools** – analyze models and prototypes for consistency and completeness.

**Inquiry and Reporting Tools** – Extracts information from the data repository.

**Data Repository** – the data repository stores all data, data descriptions and formats, along with what the data means and how it is used. Using a data repository can enforce accuracy and consistency of data in the system.

**Data Sharing Tools** – provide import and export of repository information to/from software tools that cannot directly access the repository.

**Code Generators** - Convert detailed specifications to executable source code.

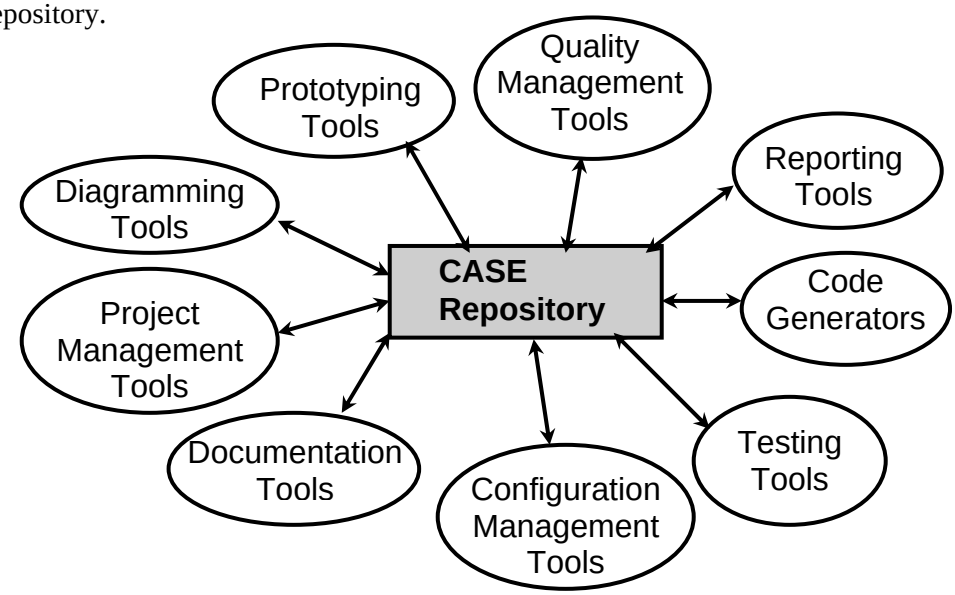
**Testing Tools** - generate data to test the new system

**Configurations management tools** – help keep track of software revisions and versions.

**Documentation tools** - help simplify ongoing documentation process

**Project management tools** - assist with project planning, scheduling and reporting, problem tracking, and resource management

The architecture of a CASE tool set is based upon a repository. The repository is a database containing descriptions of each uniquely identifiable element of the project. All changes and additions are reflected in the repository.




CASE tools integrate analysis, design and programming tools. Used throughout the SDLC, CASE tools provide the following advantages:

- Ensure consistency, completeness and conformance to standards
  - Standardizes data terminology and usage
- Improve quality and precision

- Increase efficiency and productivity
- Reduce the number of tedious tasks that need to be performed
- Encourage communication between developers and users
- Encourage collaboration among developers
- Make structured techniques practical
- Speed up the system development process
- Reduce the overall cost of developing systems
- Create better documentation through automatic generation and use of templates
- Reduce lifetime maintenance

The disadvantages of CASE tools are:

- There are no real standards for CASE tools
- There is a lack consistency and interoperability between vendors
- Most CASE tools are inflexible – they permit little latitude for individual preferences
    - Note: this may also be an **advantage**
- Few companies offer a fully complete and mature set of CASE tools
- There will be a short-term productivity loss for the time it takes the designers learn to use a particular set of CASE tools

Many companies offer CASE tools. Some of the more popular sets are Rational Rose, Oracle Designer, Visible Analyst, Excelerator, SilverRun, and PowerBuilder. Choosing the **right** set of CASE tools is extremely critical. The various tools that support specific development tasks **must** be interoperable so that you are working within an **integrated** CASE environment. With a mature set of CASE tools, used correctly, the productivity gain should more than outweigh the short-term productivity loss.

## Why do systems fail?

Systems fail for a variety of reasons. Among them are:

- Lack of communication between management, users, and the systems analysts
- Continuation of a project that should have been cancelled
- Failure of two or more portions of the new system to fit together properly
- Politics
- Lack of management support
- Technological incompetence
- Major changes in available technology in the middle of a project.
- Lack of user training

# CHAPTER FOUR

# PROGRAM DEVELOPMENT

# Section I: **Program Design Tools**

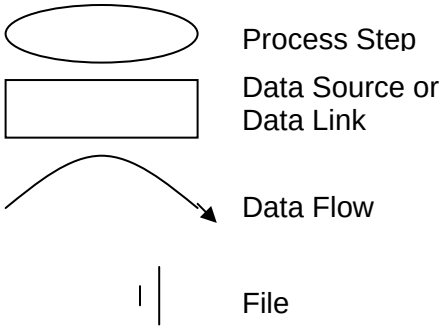
High-level programming languages are well suited to introduce the frequently used concepts of **top-down design** and **structured programming**. These concepts evolved in the early 1970s as a methodical approach to solving problems with the use of computers in mind. These techniques further lend themselves to formal documentation of the design and implementation of problem solutions. This section will provide an overview of some of these techniques.

## TOOLS USED IN SYSTEM DESIGN

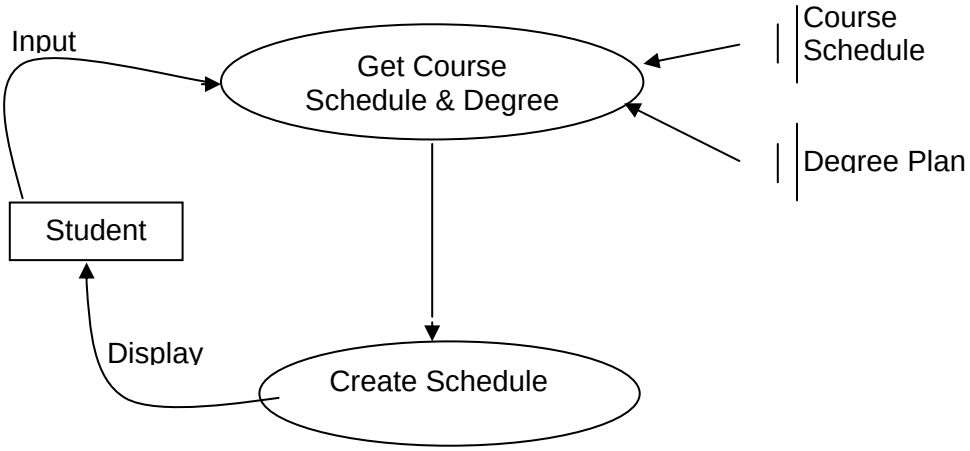
a) **Data Flow Diagrams** (DFD)

Graphic representation of a system that shows data flows to, from,and within the system, processing functions that change the data, and storage of the data.

Symbols used:




Example: An advisor is helping a student plan his/her schedule.



b) **Algorithms**

**General algorithm definition** - Step-by-step instructions on how to do a task; reducing a task to the process of following directions.

Example: Algorithm for making coffee

1. Go to cupboard
2. Open cupboard
3. Take out can of coffee and one filter
4. Close cupboard
5. Remove filter holder from coffeemaker
6. Place filter in holder
7. Open coffee can
8. Measure 7 tsps of coffee into filter
9. Close coffee can
10. Put filter holder back in coffeemaker
11. Take coffee pot to sink
12. Turn on cold water
13. Fill pot to top line
14. Turn off water
15. Take pot back to coffee maker
16. Pour water into coffee maker
17. Place pot on burner
18. Turn on coffee maker

**Computer algorithm definition** - a finite sequence of unambiguous, executable steps that ultimately terminate if followed. (Note: Machines are capable of performing **only** algorithmic tasks.)

The general algorithm for the specification of many computer problems is:

1. Read Input
2. Process Data
3. Display Output

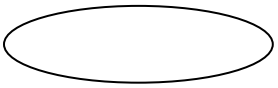
The program designer must then expand on each of these steps.

c) **Flowcharts**

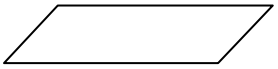
Graphical diagram showing in detail each step of the program and the exact sequence in which it occurs.

*Symbols used*:

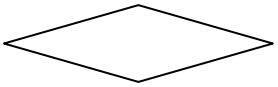
START/STOP



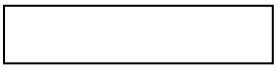
INPUT/OUTPUT



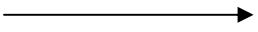
DECISIONS



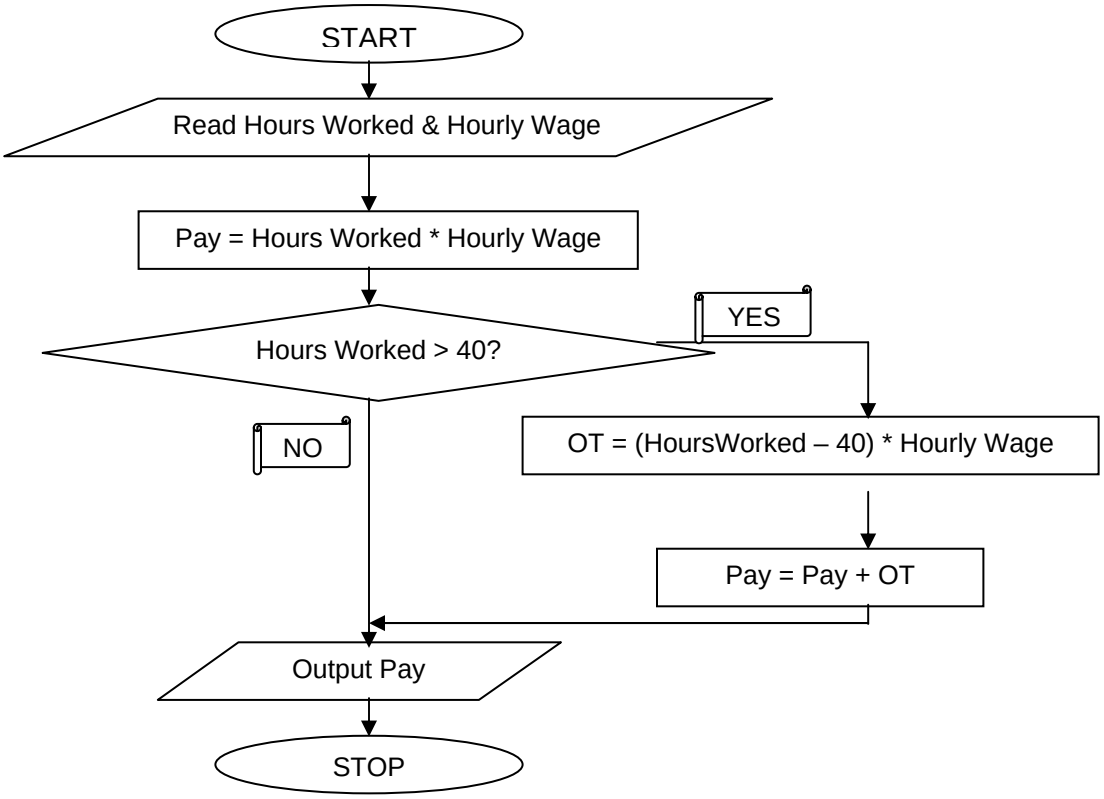
PROCESSING



FLOW OF CONTROL



*Example: Compute worker's pay, if overtime (over 40) hours are paid at double time.*

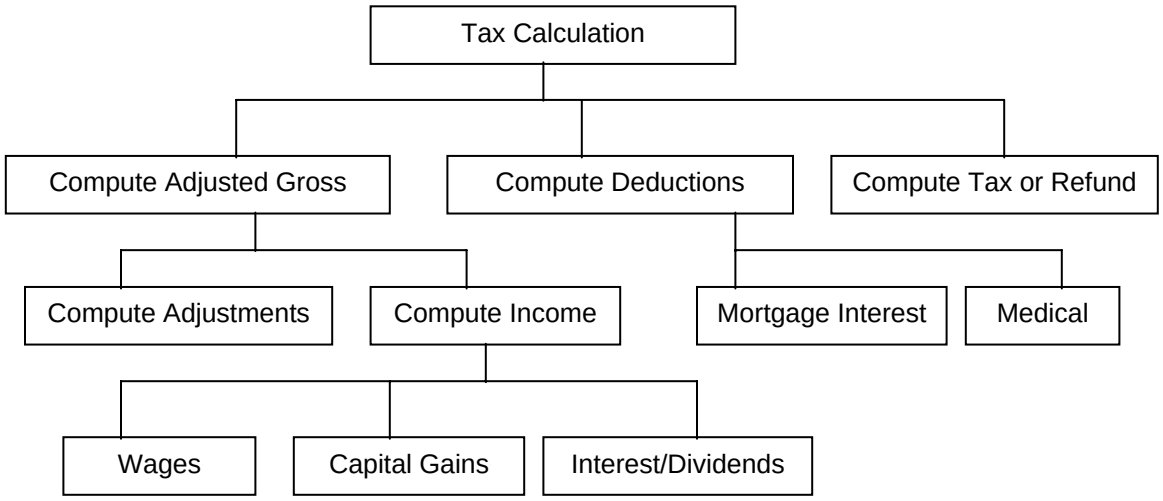


d) **Structure Charts**

Structure charts are used to specify the high-level design of a computer program. A structure chart for a programmer is similar to a blueprint for an architect. In the design stage, the chart is drawn and used as a way for the client and the software designers to communicate. During program coding (building), the chart is continually referred to as the master-plan. It is often modified as programmers learn new details about the program. After a program has been implemented, the structure chart is used to fix bugs and make changes (maintenance). The chart is especially important in this stage, because often the original "architect" is long gone, and a programmer new to the project must use the chart as a navigational tool into the often huge set of source code files.

The first step in creating a structure is to place the name of the program in the root of an upside-down tree which forms the structure chart. The next step is to conceptualize the main sub-tasks that must be performed by the program to solve the problem. These sub-tasks are placed in rectangular boxes below the root, and connecting lines are drawn from the root to each sub-task. Next, the programmer focuses on each sub-task individually, and conceptualizes how each can be broken down into even smaller tasks. Eventually, the program is broken down to a point where the bottom tasks of the tree represent very simple tasks that can be coded with just a few program statements.

**Example**: Computing a taxpayer's taxes (simplified).




These hierarchical diagrams show the overall process structure, the relationship between the modules of program code, and the shared data. Each box on a structure chart is a module, that will eventually become a compilable set of program code.

As a design tool, they aid the programmer in **dividing and conquering** a large software problem, by recursively breaking a problem down into parts that are small enough to be understood by a human brain. The process is called **top-down design** or **functional decomposition**.

**Data Shared by Modules within the Structure Chart**

It is important to know what data will be shared among different modules. On a structure chart, each shared piece of data is denoted as **input** data, **output** data, or **input/output** data.

**Input** data is data that the calling task sends to the subtask. It is shown on the chart with an arrow pointing down towards (into) the subtask.

**Output** data is data whose value is set by the called subtask. It is shown on the chart with an arrow pointing up from (out of) the subtask. One way to look at **output** data is that the calling task sends a blank piece of paper to the called subtask, which puts something on the paper and sends it back.

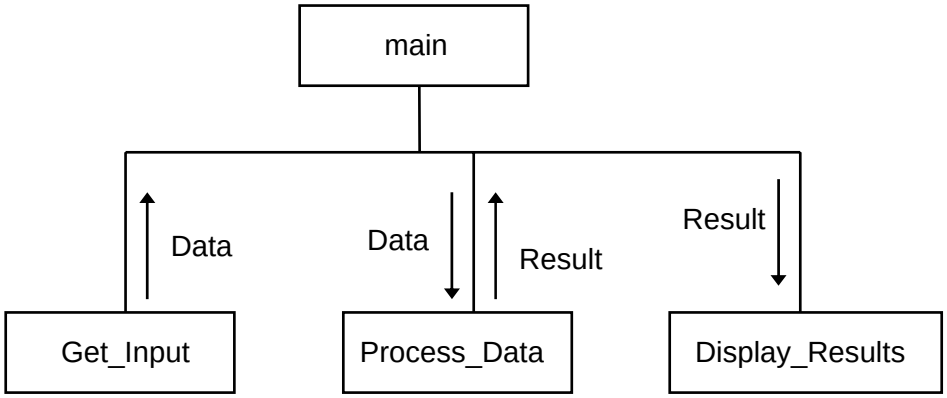
**Input/Output** data is a data value that is sent in to a subtask, accessed by the subtask, modified by the subtask, and passed back out. It is shown on the chart with an arrow pointing down towards (into) the subtask AND an arrow pointing up from (out of) the subtask. One way to look at **input/output** data is that the calling task sends the called subtask a piece of paper with a value on it, and the called subtask looks at the value on the paper, modifies it, and sends it back.

By specifying each piece of data as input, output, or input/output, the designer clearly states the effect of each task. Thus, just by analyzing the data and arrows on a structure chart, and without delving into code, a programmer can begin to understand a large program.

Taking the general algorithm from the previous section:

1. Read Input
2. Process Data
3. Display Output

The structure chart could be:




Each node in the chart represents a module. A module is a piece of code that performs a specific task. The root node represents the **main** module of the program. Each connecting line represents a subtask module. Any data that is passed into or out of the module is listed next to an arrow.

A structure chart is a high-level design notation, and leaves some coding details unspecified. Specifically, control structures for decisions (IF/THEN) and looping (WHILE/DO) are not depicted in a structure chart; All the above structure chart denotes is that the main program will contain calls to modules **Get_Input**, **Process_Data**, and **Display_Results** - it says nothing about other program statements that might be used.

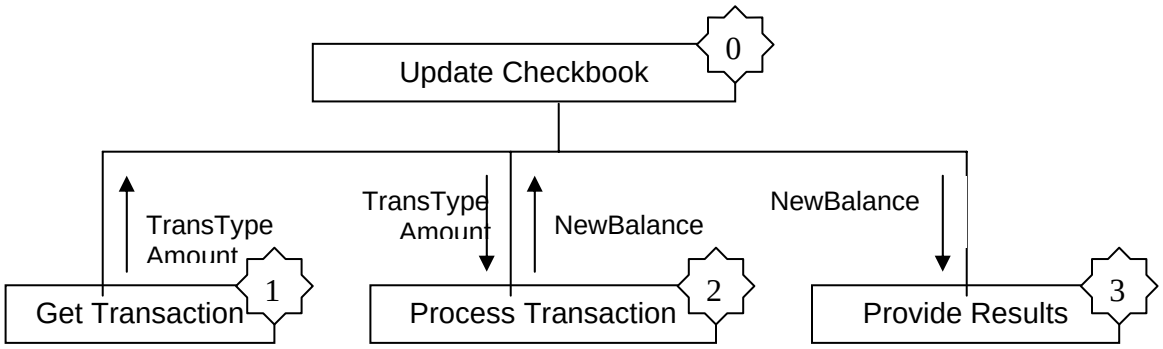
You use structure charts in your design by starting with the entire problem to solve -- this is the top box of your structure chart. Break this problem into major subproblems, and write down how you could solve the entire problem if you could solve the subproblems. Repeat this process for each subproblem until you've reached problems that you can solve directly. The resulting structure chart and notes is your structured design. Your design documentation should include both structure charts and the pseudocode you wrote during the above decomposition process.

Once the structure chart has been designed, it is used to drive the software implementation. Branches (tasks) of the tree are assigned as modules to be programmed by various members of the development team.

**Example**

Any problem can generally be broken down into two or more simpler problems, which, when addressed individually, can generally be solved easier than attempting to solve the problem as a whole. For example, the updating of a checkbook can be refined to obtaining transaction data (input), using the input data to process the update (deposits and withdrawals with new balance), and presenting the bank customer with a new balance which reflects the transaction which just occurred.

Using the discussion of stepwise refinement for the update problem, a simple structure chart could be as follows:




MODULE SPECIFICATIONS.

From the general outline of the structure chart it is possible to provide some details as to what each of the smaller problems represented in the block of the structure chart represent. The blocks pictured in the structure chart are frequently called modules. For example, the following specifications could be written for the modules depicted in the chart:

Module 0: **Update Checkbook**.
Update the current account balance from an input transaction. Provide the customer with the results of the process.

Module 1: **Get Transaction.**
Customer provides bank teller (or ATM) with the desired transaction. The transaction may be either a deposit or a withdrawal.

Module 2: **Process Transaction.**
The desired transaction (deposit or withdrawal) is processed against the current account balance producing a new balance.

Module 3: **Provide Results.**
Provide the customer with a document reflecting the result of the transaction.

## Section II: **Software Overview**

Computers are frequently classified as **general purpose** or **special purpose**. General purpose computers are intended to do many different types of tasks while special purpose computers perform single tasks, such as controlling cameras, microwaves, and automobile engines. In order to perform a variety of jobs, general purpose computers rely on different sets of computer instructions.

**Software** is a set of such instructions, called a **program**, which tells a computer what to do and when to do it. Applications programs such as word processors, spreadsheets, and database management systems are well known to many computer users. Other programs, written in a variety of **computer programming languages**, allow users to tailor programs to meet specific needs. Still other programs, called system software, perform tasks which interface with the computer in such a way as to allow the applications programs to **run** on the computer. This section will specify a low level instruction set for our hypothetical computer which will allow it to perform a number of simple operations similar in nature to those performed by real instruction sets in what is called assembly language. The next section will provide an introduction to Turbo Pascal, a programming language which is much easier to read and work with than an assembly language. Before specifying the language for our hypothetical computer, let's look briefly look at a hierarchy of **levels** of languages.

**Machine language**.
As we saw in an earlier section, the instructions a computer executes are stored in binary-coded form (zeroes and ones). These binary codes are called **machine code** or **machine language**. The central processor can only execute programs coded in machine language. A machine language programmer has to know the operation code for each operation the computer can carry out. Since most computers have hundreds of operation codes, programmers will make frequent use of reference manuals for these codes. These programmers must also be familiar with the internal organization (architecture) of the computer, such as the central processing unit and the layout of main memory, even though they are not directly related to the problem to be solved. Changing parts of a program may also involve changing references to memory locations and relocating the position of various instructions. Thousands of machine language instructions may be necessary to carry out a machine language program. In general, it is extremely tedious to write programs in machine language so mnemonic languages have been developed to make programming easier.

**Assembly language**.
Assembly language allows us to use convenient abbreviations (called **mnemonics**) for machine language operations and memory locations. Each assembly language is specific to a particular hardware architechture, and can only be used on a machine of that architecture. Since the CPU can only understand machine language, an assembly language program must be **translated** into machine code before it can be executed. The program that tells the computer how to perform the translation is called an **assembler**. This kind of program is known as a language **processor**. Language processors allow computer systems to execute programs written in languages other than machine language through the translation process.

With some exceptions, the assembly-language programmer must still write a line of code for each machine instruction, therefore, while writing the code may be easier than writing it in machine language, the programming process can still be tedious, especially for long programs. The programmer must also be familiar with the architecture of the CPU and main memory. **Macro instructions** or **macros** provide some relief by combining a series of machine language instructions into a single instruction. Macros are particularly helpful when well defined code segments are to be used repeatedly within an assembly language program. They can be labeled and called as needed (in somewhat the same manner as a DOS

batch file). Even with macros, however, assembly language is still tedious and requires knowledge of the internal workings of the computer.

**Higher-level languages**.
Higher level languages hide many of the details of computer operation and are often very "English-like" in their syntax. Since procedures for solving problems are expressed differently for various user communities (business, science, mathematics, education, etc.) a number of different programming languages have been developed to suit diverse needs over the years. FORTRAN has been in use by the science, engineering, and mathematics communities for over thirty years. COBOL has been used by the business community for almost the same length of time. BASIC, made popular by the microcomputer, and vice versa, is widely used in secondary education and personal computing and is even used in business applications. Pascal, developed primarily as a language for teaching modular programming techniques, has found uses in personal computing, business, and computer science research as well as college-level education. C is a newer, general purpose language. It is sometimes called a “mid-level” language, since it can be used to implement low-level functions that were previously written in assembly, without giving up any features of an HOL. There are close to 200 various computer languages and dialects currently in use (although the most frequently used number around 20).

**Language processors**.
As mentioned earlier, translator programs are used to convert non-machine language programs to machine code. A translator program for assembly language is usually called an **assembler**; translators for higher level languages are often called **compilers**. Translators, assemblers, and compilers are all examples of **language processors**. The result of the translation process is always a machine language program that can be executed by the computer just as if it had been coded by hand. The program to be translated is called the **source program** and the program produced by the translator is called the **object program**.

In practice, an additional step called **linking** must often be taken before a translated program can be executed. The object program produced by the translator may call (invoke) subprograms stored in auxiliary memory. The object program often contains references to these subprograms but does not contain the subprogram code. The linker is used to combine the object code with any subprogram code (already in machine code format) to produce an **executable** program which the computer can run.

**Interpreters** are another widely used type of language processor. Instead of going, in order, through the processes just described for the entire source program, the source program is executed by the interpreter one instruction at a time. It can take much longer to execute an interpreted program than a translated one. Most programs specify that some statements will be executed many times. Such repeated statements need to be analyzed only once by a translator, but an interpreter must analyze a repeated statement each time it is executed. An advantage of the interpreter is that it simplifies error correction and program modification by allowing the programmer to execute the program a few lines at a time, detect and correct errors, and run those same lines of code again without having to go through the entire translation process each time. (Many language compilers mitigate this advantage by providing excellent "debug" and correction facilities).

# Section III: **An Introduction to the C++ Language**

## INTRODUCTION

In general, high-level languages (HOLs) combine several assembly language instructions into a single HOL statement to simplify the programming process. Addition in assembler requires the programmer to write several instructions, which include moving data to and from memory to the accumulator, as well as performing the addition. Arithmetic can be performed in one instruction in a HOL, as, for example:

```
x = y + z;
```

There are two principal reasons for high-level languages. The first is to make program development easier – each instruction written in a HOL might represent dozens or hundreds of lower-level assembly instructions. The second is to make programs portable. A standard program written for one computer can be re-compiled and run on another.

C++ is one of these HOLs. C++ was developed by Bjarne Stroustrup of AT&T Bell Laboratories in the early 1980s, and is based on the C language. C++ supports the problem solving techniques of **top down design** and **structured programming**.

Characteristics of Structured Programming:

- Uses canonical control structures only (ie. have only a single entry/ exit)
- Is subdivided into modules (one logical thought, approximately one page long)
- Each page is organized into recognizable paragraphs, using indentation to show nesting and subordinate clauses.
- Embedded comments describe the function of each variable and purpose of each module.
- Straightforward, easily readable code is preferred over slightly more efficient, but obtuse, code.
- Final program is created via top-down design.
    - First develop the main code with empty modules.
    - Slowly refine to lowest level -- DEFER THE DETAILS.
    - Keeps programmer from being overwhelmed by job, and allows easy division of work (modules assigned to different programmers).

Benefits of Structured Programming:

1. More readable
2. Easier to maintain
3. More likely to be correct on first run
4. Easier to "prove" by systematic program verification

This chapter will examine C++, in sufficient detail to allow the student to write several short simple programs. All of today's programming languages have their own environments for assisting the programmer, whether the work is being accomplished for microcomputer, minicomputer, or mainframe

applications. Familiarity with one such environment brings a general understanding of what may be found in the development environment of other languages (or different versions of the same language). It is emphasized that the C++ language will be covered only to the extent necessary to explore its accompanying environment.

In order to learn the basics of C++, we will learn about a subset of C++. Using just some of the statements in C++, you can write many short C++ programs. We will concentrate on the following set of statements:

| Statement | Meaning |
|---|---|
| #include <iostream.h> | to include supporting code libraries for input and output |
| void main() | to define the main function |
| const | to define constants |
| int | to define integers |
| double | to define floating point numbers |
| cin | to read input |
| cout | to write output |
| assignment (=) | to perform calculations |
| if-else | to make decisions |
| while | to loop |

A SIMPLE PROGRAM.

```
#include <iostream.h>

void main()
{
      cout << "Danger!!";
}
```

The program simply displays the message "Danger!!" on the screen (without the quotes).

NOTES FOR THE SIMPLE PROGRAM.

All the **bolded** words have special meaning.

1. The first line contains a compiler directive.
   a. The **include** directive tells the program to use the **iostream.h** code library, which contains code that supports input and output.

   You will type this line at the top of every program you write for this class.

2. Either upper or lower cases letters or a mixture of both may be used with C++ statements. But you must remember that C++ is case-sensitive. Therefore, you must always type names exactly as you define them.

3. "**{**" and "**}**" are boundary scopes which indicate where blocks of code are to be found.

4. The "**cout**" statement is used to provide output to the screen. Literal output is enclosed in double quotes. Anything between the " " will be displayed exactly as is.

5. Note the use of the semi-colon (**;**) in the program. Semi-colons are used to terminate declarations and statements.

**Using the C/C++ Compiler**

Follow these steps:

1) Use the editor to create/edit C++ code in a text file
   NOTE: C++ filenames ended with extension .cpp
2) Compile and link the C++ file
3) Execute the executable file created
4) If find bugs or errors, go back to the first step and correct them and try again.

If you execute your executable file with the code written exactly as shown in the previous example, the DOS window may close before you have a chance to see your results. Therefore, you will have to add the following lines to EVERY C++ program that you write.

At the TOP of the file, add:

```
#include <stdlib.h>
```

At the BOTTOM of the file, just BEFORE the closing brace '**}**', add:

```
cout << endl << endl;
system("PAUSE");
```

So, for example, the SIMPLE PROGRAM on the previous page would become:

```
#include <stdlib.h>
#include <iostream.h>

void main()
{
     cout << "Danger!!";

     cout << endl << endl;
     system("PAUSE");
}
```

**Program Structure:**

```
<directives-section>

<function-header>
{
      <declaration-section>

      <executable-section>
}
```

The **directives section** tells the compiler which libraries to use.

> The **`include`** directive tells the compiler and the linker to link the program to a code library. The header file **`iostream`** contains routines that handle input from the keyboard and output to the screen (specifically the **`cin`** and **`cout`** statements).

The **function header** begins and names a function. The reserved word **main** is used to define the main function within a program. A C++ program will always begin execution with the function named **main**. Therefore, your program MUST contain a function named **main**. In this course, we will use ONLY the main function in our programs.

The **declaration section** defines program data. The programmer must determine in advance what data the program will use, and how it will be stored. Each piece of data that will be used in the program must be defined in the declaration section as either a constant or a variable. C++ requires that all constants and variables used in a program be given a data type. Declaring a variable to be of a specific type signals the compiler that it must reserve enough memory for the constant/variable to store that particular data value as the program executes.

C++ has two built-in data types for storing numbers: **int** and **double**.

> The **int** data type is used to store whole numbers. When typing these numbers, do not include leading zeros, commas or any other non-digit characters, except a sign (+/-).
>
> The **double** data type is used to store numbers written with a decimal point.

A third data type, **char**, is used to store one ASCII character, enclosed in single quotes.

A data item may be stored as a **constant** or a **variable**.

> A constant's value must be known before the program is run, and cannot be changed while the program is running. Defining a constant reserves a space in memory and stores a value in it.
>
> A variable's value does not have to be determined until the program is running, and may change as often as is necessary. Defining a variable reserves a space in memory, large enough to store the type of data specified, and gives the memory location a name.

You must determine whether a piece of data should be a constant or a variable, and what data type (int, double, char) it should be.

**Variable declaration format**

```
<type> <variable-name>;
```

Examples:
```
char Initial;
int Count;
double GPA;
```

**Constant declaration format**

```
const <type> <constant-name> = <value>;
```

Examples:
```
const double Pi = 3.14;
const double Taxrate = 0.28;
const int MaxItems = 50;
const char BestGrade = 'A';
```

Constant/variable names must begin with a letter, followed by any number of letters, digits, and underscores. You should choose names for your constants and variables that are descriptive, so it is easy to tell what will be stored in them.

The following is a list of reserved words that have a predefined meaning. They CANNOT be used as constant or variable names:

```
asm      continue   float     new         signed     try
auto     default    for       operator    sizeof     typedef
break    delete     friend    private     static     union
case     do         goto      protected   struct     unsigned
catch    double     if        public      switch     virtual
char     else       inline    register    template   void
class    enum       int       return      this       volatile
const    extern     long      short       throw      while
using    namespace  bool      static_cast const_cast dynamic_cast
true     false
```

**THE FUNCTION BODY**

The function body includes all lines of code between "**{**" and "**}**". Each C++ statement will end with a semicolon. You will learn about five different types of executable statements.

**Assignment Statement** (=)

Assigns a value to a previously defined variable. The variable name must appear on the left side of the statement and the value on the right side of the statement. The variable and the value must be of the same data type.

```
Count = 5;
```
→ store **5** in the variable **Count** memory location

The following math operators may be used to compute values within assignment statements:

| | |
|---|---|
| **+** | Add |
| **-** | Subtract |
| ***** | Multiply |
| **/** | Division |
| **%** | Modulus (Remainder) |

Examples:

```
Average = (Num1 + Num2) / 2;
Square = Num1 * Num1;
Value = Value + 1;
```

NOTE: It is a good idea to put one space before and after any operator, for readability.

**Input/Output Statements**

Input statements get input from the user's keyboard, and output statements display output to the user's monitor.

**`cout`** – writes output to the monitor

In general, the program statement

```
cout << Expression1 << Expression2 << ... << ExpressionN;
```

will produce the screen output

```
Expression1Expression2...ExpressionN
```

The series of statements

```
cout << Expression1;
cout << Expression2;
...
...
cout << ExpressionN;
```

will produce an identical output.

If you need a space between expressions, you must include them explicitly. Thus:

```
cout << Expression1 << " " << Expression2
```

produces

```
Expression1 Expression2
```

You can use either the expression **`endl`** to output a new line.The numbers in **bold** in the example screen output above have been typed in by the user

**`cout`** Examples:

```
cout << "Hello" << endl;
cout << "Please enter a number: ";
cout << "The answer is " << Sum;
```

**`cin`** - gets input from the keyboard (typed in by the user)

In general, the program statement

```
cin >> Variable-Name;
```

will store the data typed in by the user into the variable that is named.

Example:

```
cout << "Enter pay amount:";
cin >> Pay;
```

The **cout** statement prints a prompt on the display screen.
The **cin** statement stores the number typed in at keyboard into variable Pay.

A SLIGHTLY MORE COMPLEX PROGRAM.

```
#include <stdlib.h>                          // Include directive (for PAUSE)
#include <iostream.h>                        // Include directive (for Input/Output)

void main()                                  // main function header
{                                            // Start main function

  const double Pi = 3.14159;                 // Declares constant value for the name Pi
  double Radius, Area;                       // Declares two variables to store double values

  cout << "Enter circle radius: ";           // Prompts the user for keyboard input
  cin >> Radius;                             // Reads number typed at keyboard
                                             // into the memory location called Radius

  Area =  Pi * Radius * Radius;              // Calculates the area, using Radius and Pi

  cout << endl << endl;                      // Writes" one blank line to the screen
  cout << "Area =  ";                        // Displays text “Area =”
  cout << Area;                              // Displays value stored in variable Area

  cout << endl << endl;                      // Display a blank line
  system("PAUSE");                           // Pause before closing output window
}                                            // End of the function main
```

NOTES FOR PROGRAM.

1. Constants and variables are declared at the top of the function. Constant values cannot change. Variables are like named mail boxes where the contents constantly change as the program executes.

2. The `"="` assignment operator places the value on its right side into the variable on the left side. It is perfectly legal to have the same variable on both sides of the assignment operator. For example, if x had an initial value of 10, then the expression x = x + 5 is the same as x = 10 + 5.

3. `"cin"` is the means by which data is entered from the keyboard. The **cin** statement results in the cursor blinking on the screen until you enter the appropriate type of data. It is a good idea to always precede a **cin** statement with a **cout** statement, which prompts the user to enter a data. That way, the user is not confronted with a blinking cursor on a blank screen and no idea of what to enter.

4. `"//"` The double slashes are used to place comments in the program. Comments are ignored by the compiler and so are not executed.

# Section IV: **C++ Decisions**

RELATIONAL OPERATORS

Two values can be compared in C++ using relational operators. Relational operators test the relationship between two values and returns a TRUE or FALSE result.

| Operator | Example | Result |
|---|---|---|
| == | A == B | TRUE if A is equal to B |
| != | A != B | TRUE if A is not equal to B |
| < | A < B | TRUE if A is less than B |
| <= | A <= B | TRUE if A is less than or equal to B |
| > | A > B | TRUE if A is greater than B |
| >= | A >= B | TRUE if A is greater than or equal to B |

**The IF Statement**

Is used to make decisions about what statements in a program should be executed.

One Alternative
– allows a single statement to be executed or skipped, based on the test condition.

```
if ( <condition> )
        <statement_T>;          {do statement if condition is TRUE}
```

Two Alternatives
– allows a choice between two alternative statements to be executed.

```
if ( <condition> )
        <statement_T>;          {do if TRUE}
else
        <statement_F>;          {do if FALSE}
```

Examples:

```
if (Age > 18)
      cout << "Can Vote";

if (Divisor != 0)
      Answer = Num / Divisor;

if (Num >= 0)
      cout << "Positive number";
else
      cout << "Negative number";
```

A DECISION PROGRAM, USING AN IF STATEMENT.

```
#include <stdlib.h>                 // Include directives
#include <iostream.h>

void main()                         // main function header
{                                   // Start main function
  const int Highest = 100;          // Stores value 100 into constant Highest
  int Num;                          // Declares an integer type variable Num

  cout << "Enter a Number up to 100: ";      // Prompts user for a number
  cin >> Num;                                // Reads user's number into Num
  cout << endl << endl;                      //Display blank line

  if (Num <= Highest)                  // Tests if Num less than or equal to Highest
     cout << "Input is okay";          // Do this statement if test is TRUE
  else
     cout << "Error - bad input!";     // Do this statement if test is FALSE

  cout << endl << endl;
  system("PAUSE");                     // Pause before closing output window
}                                      // End of function
```

NOTES ON PROGRAM.

1. The number entered by the user is stored in variable Num.

2. Num is compared to the constant value 100, stored in the constant Highest.

3. The decision about which statement to run is based on the evaluation of the variable Num.

   When Num is less than or equal to Highest, the **if** statement evaluates to TRUE, and the statement `cout << "Input is okay";` is executed.

   When Num is greater than Highest, the **if** statement evaluates to FALSE, and the statement, `cout << "Input is okay";` is executed.

4. You should always use meaningful names for your constants and variables.

5. You should be consistent with your program layout, and make sure the indentation and spacing reflects the logical structure of your program. Notice how the statements under the if are indented.

## The WHILE Statement for conditional loops

Is used to repeat the execution of a sequence of program statements in a loop. The execution of the loop is controlled by a condition, which is tested before any of the statements in the loop are executed. The statements in the loop will only be executed if the condition is TRUE.

```
while ( <condition> )
{
      statement1;
             :
      statementN;
}                                  // { } not needed if only one statement
```

Sequence of events:

1. The condition is evaluated.

2. If the condition's value is TRUE
   a. the statements in the body of the loop are executed.
   b. step (1) is repeated, and the condition is re-evaluated.

3. If the condition's value is FALSE,
   a. the statements in the loop are skipped
   b. control goes to the next statement in the program.

**Example #1:** Display multiples of 5, from 5 to 50.

```
#include <stdlib.h>
#include <iostream.h>
void main()
{
  int Count, Mult;

  Count = 1;
  while (Count <= 10)
  {
      Mult = 5 * Count;
      cout << Mult << endl;
      Count = Count + 1;
  }

  cout << endl << endl;
  system("PAUSE");
}
```

NOTES ON PROGRAM.

1. The variable Count is initialized to the value 1.

2. The while loop condition tests to see if Count is less than or equal to 10.

   a. If the condition is TRUE, the program:
      - Muliplies 5 x Count, and stores the result in variable Mult
      - Displays the value of Mult to the screen
      - Adds one to the value stored in Count
      - Loops back to the condition to test it again (go back to note 2)

   b. If the condition is FALSE, the program skips over the statements in the while loop body and the program ends.

**Example #2:** Error check input, to be sure a positive number is entered.

```
#include <stdlib.h>
#include <iostream.h>

void main()
{
   int Num;

   cout << "Enter a positive number: ";
   cin >> Num;

   while (Num < 0)
   {
      cout << "Invalid entry.  Try Again." << endl;
      cout << "Positive number: ";
      cin >> Num;
   }

   cout << "You entered " << Num;

   cout << endl << endl;
   system("PAUSE");
}
```

NOTES ON PROGRAM.

1. The number entered by the user is stored in variable Num.

2. The while loop condition tests to see if the number entered (Num) is less than zero.

   a. If the condition is TRUE, the program:

- Prints out an error message
- Prompts the user for a positive number
- Reads the new number entered into variable Num
- Loops back to the condition to test it again (go back to note 2)

b. If the condition is FALSE, the program skips over the statements in the while loop body and goes to the next statement (go to note 3)

3. The last statement outputs a message and the number. For example, if the user entered the number 25, the output would be:

```
You entered 25
```

**Common Beginning C++ Programming Errors**

When compiling C++ code, the compiler will attempt to tell you which line the error appears upon. Note however that C++ compilers often read ahead in the code before they notice an error, and therefore you may have to look back several lines in the program to find the actual error.

1) Omitting a "`#include`" at the beginning of a program. The compiler will give you an error saying common library functions (like **cin** and **cout**) are unidentified.

2) Typing the wrong case in constant/variable names. Remember that "`NUM`", "`num`" and "`Num`" are all different identifiers.

3) Forgetting a semi-colon ";" at the end of a code statement, particularly before a closing curly brace "}".

4) Putting the variable name on the wrong side of the assignment statement.
For example, typing:

```
10 = Num;        //incorrect
```

Instead of:

```
Num = 10;        //correct
```

5) Omitting parentheses around a conditional test.
For example, typing:

```
if Num < 10           //incorrect
```

Instead of:

```
if (Num < 10)         //correct
```

**C++ VERSUS ASSEMBLY LANGUAGE.**

Now that we have some C++ fundamentals, let's look at how the summation program from Chapter 2, Section III (sample program #3) could be handled by C++.

```
#include <stdlib.h>
#include <iostream.h>

void main()
{
  int Value, Total;                 //Declare variables

  Total = 0;                        // Initialize total to 0

  cout << "Enter a positive value to add";
  cout << "or a negative value to stop: ";  // Prompt for input
  cin >> Value;                             // Read input

  while (Value >= 0)                // Test if value entered is positive
  {                                 // If condition TRUE do loop code
      Total = Total + Value;        // Add value entered to running total

      cout << endl << "Enter a positive value to add";
      cout << "or a negative value to stop: ";
      cin >> Value;                 // Prompt for and read another number
  }

  cout << endl << endl;                 // Display blank line
  cout << "Grand total is " << Total;   // Display Total

  cout << endl << endl;                 // Output a blank line
  system("PAUSE");                      // Pause so user can read output
}
```

NOTES FOR PROGRAM.

1. The repetition of the **cout** and **cin** statements before and in the "while" loop allow the loop to terminate immediately if the first value entered is less than zero (0) since the condition is tested BEFORE the loop is "executed". If the loop is entered, the value is added to total and the user is again asked to enter a value. This data entry and summation is repeated until a negative number is entered from the keyboard.

2. Note the use of "{" and "}" to mark the boundaries of the "while" loop. All statements between these curly braces are controlled by the loop. In other words, they are executed only as long as the loop is active. Once the condition for looping becomes FALSE, these statements will no longer execute.

# CHAPTER FIVE

# AN INTRODUCTION TO UNIX

# Section I: **A Brief History of UNIX**

An operating system is a control program for a computer. It allocates computer resources and schedules tasks. Computer resources include all the hardware: the central processing unit (CPU), main memory, disk and tape storage, printers, terminals, modems, and anything else connected to the computer. Task scheduling occurs so that the CPU is only working on one task at a given moment, although the computer may appear to be running many programs at the same time.

At the time UNIX[1] was developed, many computers still ran single jobs in batch mode. Programmers fed these computers input on punch cards and didn't see the program again until the printer produced the output. The software developers at AT&T's Bell Labs teamed with General Electric to develop a time-sharing operating system called Multics. Time-sharing systems allowed many users to interactively use the computer at the same time. At the end of the Multics project, Bell Labs was left without a convenient time-sharing system, so Ken Thompson and Dennis Ritchie design a file system on paper. They implemented their system design on a DEC PDP-7, and named it UNIX, as a pun on the name MULTICS. The "UNI" part of the name implied that it would do one thing well, as opposed to the "MULTI" part of MULTICS, which he felt tried to do too many things without great success in any of them.

The operating system was moved to a PDP-11 in 1971. Thompson set out to develop a Fortran compiler for the new system, but instead came up with the language B. B was an interpretive language, which meant it had performance drawbacks, so Ritchie further developed B into a language he called C. In 1973 it was unheard of to write an operating system in anything except assembly language, but Thompson and Ritchie rewrote the majority of UNIX in the new C language. This gave UNIX two distinct advantages over the operating systems of the time: its source code was understandable and it had the ability to be easily ported to different types of hardware.

Bell Labs began using this prototype version of UNIX in its patent department, for testing purposes. At the time, AT&T was not allowed to market computer products, so they provided free copies of the UNIX system to universities who requested it for educational purposes. In addition to introducing its students to the UNIX operating system, the Computer Science Department of the University of California at Berkeley (UCB) made significant additions and changes to it. UCB made so many popular changes, that they eventually began marketing their version of UNIX, BSD UNIX, to the public. The other major flavor of UNIX is AT&T UNIX, System V, the continued enhancement of AT&T's original. Many variations of these two versions of UNIX have since evolved.

Several reasons have been suggested for the popularity of the UNIX system. The system is written in a high-level language, making it easy to understand and change, and making it very portable. It has a simple, albeit terse, user-selectable interface. It uses a hierarchical file system that permits easy file maintenance. It provides an excellent environment for program development. For these and many other reasons, UNIX's popularity continues to grow.

[1] UNIX is a trademark of Bell Laboratories.

# Section II: **UNIX Basics**

LOGGING ON/OFF A UNIX SYSTEM.

If you are a first time user to the Regis UNIX system, the instructor will provide you with an account name and explain how to create a new password for use with your account. In general, it is common practice to have a password of at least eight characters (including one numeral) as a protective measure. Since you enter the password at the keyboard, the longer the length, the more difficult it is for someone looking over your shoulder to memorize the keystrokes - the password is not echoed (displayed) on the screen as it is entered. It is a good idea to write down your password before starting your first session with UNIX.

At the prompt **login**: [enter your user name]

At the prompt **password**: [enter the password provided by your instructor]

(Note: UNIX is case-sensitive, so you must enter your username and password using the same case each time. ie. Jdoe is not the same as JDOE)

If this is your first time on UNIX with a new account, you should immediately change your password.

At the prompt **$**, type: **passwd**

You will be prompted for your old password. Enter the original password your instructor gave you. You will then be prompted for the new password. Enter the new password you decided on in the classroom. You will be asked to verify the password. Again enter the new password. If you want to change the password again in the future type **passwd** anytime at the $ prompt.

*******PLEASE LOG OFF UNIX WHEN YOU ARE FINISHED WITH YOUR SESSION.** *****

To log off: Press **CTRL-D** or type **exit**

If you are connected to UNIX via a microcomputer, once you have disconnected, exit Windows, and turn off the machine.

THE .**profile** FILE

In order for your microcomputer to simulate a terminal recognized by UNIX, an executable file called .profile must be in your home directory and contain the line:

**TERM=vt100; export TERM**

This is particularly important for the proper operation of the **vi** full screen text editor. The .profile file is an executable file similar in function to the MS-DOS file AUTOEXEC.BAT. The system looks for this file on start-up and, if found, executes any UNIX commands found therein before displaying the $ prompt.

USING THE SHELL.

The Shell is the utility that processes your requests. When you enter a command at a terminal, the Shell interprets the command and calls the program you want. The three most popular shells in use today are the Bourne Shell, the Korn Shell, and the C Shell. The Bourne Shell is the default shell on the Regis UNIX systems. The shell will process many commands and utilities. Similar in many respects to MS-DOS, these commands can be used separately, or placed in a program-like structure in much the same manner as an MS-DOS batch file. A few of the more commonly used commands are discussed below. A longer list is included at the end of this section.

UNIX shell commands are processed in much the same manner as a BASIC language interpreter. That is, each command must be entered in a way which complies with the rules of the interpretive process. The command must be understood by the shell. In other words, each command is evaluated for syntactical correctness before being executed. The dollar sign indicates that the system is ready for the user to enter a command.

The ***** is a UNIX wildcard which, when used with certain commands, tells the system to accept all characters from the appearance of the * and to its right. For example, if there are three files in your directory:

file1 file2 file3

then the statement

$ ls file*

would list all three files, as well as any other files that began with "file", with or without **any** extension.

The **?** is a single character wildcard. Using the above files as an example, the command

$ ls file?

would display all three files as well as any other files that begin with "file" and have **any single** character following that.

UNIX filenames can have up to 14 characters in them, and may or may not include an extension. If fact, a UNIX filename may include several extensions. For example, the filename **s.source.c** is a perfectly valid UNIX filename.

We've been using the **ls** statement in the above examples, which is similar in function to the MS-DOS DIR statement. To see the contents of one of the above files, type and enter:

$ cat file1

If the contents of the file were long, the screen would scroll and you would see only the bottom part of the file. To view only a screen at time enter:

$ cat file1 | more

You can then view a screen at a time and continue by pressing the <space> bar.

Sometimes it is necessary to save a file under a different name (useful for keeping an original file safe). The copy command can be used to accomplish this:

$ cp file1 newfile1

Let's try a useful, but limited form of file creation. The **cat** command can be used with file redirection to create a file from the keyboard in the same manner as COPY CON in MS-DOS. The file is terminated by entering <CTRL><D>. Care must be taken to be sure each line is entered correctly - once the <Enter> key has been pressed, corrections cannot be made to a line.

```
Ex:   $ cat > first.c
      #include <stdio.h>
      main ()
      {
        printf ("Hello World");
      }
      <Ctrl><D>
```

While any kind of text file can be created, the above example is a simple C program. The file extension ".c" is conventionally used to identify the text as C source code. Other extensions that are commonly used include:

| | |
|---|---|
| .h | for C "include" files |
| .p | for Pascal source code |
| .o | for object code |

Note also the use of **#include <stdio.h>** in the heading. In C, any use of the keyboard or video display screen requires the stdio.h file to be included in the program heading.

Once the program has been saved you can compile, link, and run it as follows:

```
$ cc first.c -o first     (Compiles and links program and places executable in the file first)
$ first                   ( Runs the executable program)
```

At this stage, if you have made errors in typing your program, simply type it over using the **cat** command to create a new file. The error messages should be fairly easy to follow.

Let's end this section with a few definitions of concepts central to the UNIX system model:

**Process** - a specific execution of a program.
**File** - a sequence of bytes stored under a name (no predefined structure for files)

**Permissions** - control read, write, or execute access to the file

**Standard output** - the place commands/programs send results (default is terminal)
**Standard input** - the place commands/programs get user input (default is terminal)

**Pipe** - connects the standard output of one process to the standard input of another.

## Section III: **Creating UNIX Subdirectories**

As you create more and more files, it is convenient to categorize them and store them in different subdirectories. This not only makes searching for files more efficient, but it also makes it easier for the user to view files. There are no subdirectories when your account is first created. All new files are stored in your home directory, which is also the working directory. We'll illustrate a few commands for working with directories.

CREATING AND USING SUBDIRECTORIES.

You create a new subdirectory with the **mkdir** command (note: this command CANNOT be abbreviated to md, as in DOS). If, for example, you wanted to keep different programming language files in separate directories, you might issue the following command:

```
$ mkdir  cprogs
```

You can then move all program files with the extension **.c** to the new directory by using the **mv** command:

```
$ mv  *.c  cprogs
```

This command actually **moves** all commands with the .c extension to the cprogs directory. They are no longer in the main directory. The same concept can be applied to programs developed in other languages, or data files, or any classifications you want to develop.

If you set up more than one directory, you must have the capability to **navigate** among them. The first step is to determine which directory is currently active. This is done by issuing the command:

```
$ pwd
```

Your current working directory will be displayed. If you are not in the desired directory, you can change the default with the command:

```
$ cd  cprogs
```

You can move back to your home directory by entering the command:

```
$ cd
```

As in DOS, every directory contains two predefined files, **.** and **..**. The single dot refers to the current directory, and the double dots refer to the parent directory. Subdirectory levels are separated by slashes (note: DOS uses backslashes -- different!). For example, if you had a subdirectory beneath cprogs called project1, the following command would take you from your home directory to project1:

```
$ cd cprogs/project1
```

To move back up one level, to cprogs:

```
$ cd ..
```

REMOVING SUBDIRECTORIES.

You remove a subdirectory you no longer need with the **rmdir** command (note: this command CANNOT be abbreviated to rd, as in DOS). If, for example, you were done with the project1 subdirectory:

```
$ rm cprogs/project1/*          ( to remove the files in project1 )
$ rmdir cprogs/project1         ( to remove the subdirectory )
```

Or you can remove a subdirectory and all files and subdirectories below it with the recursive remove command:

```
$ rm -r cprogs/project1
```

Be very careful using the recursive remove command!

## Section IV: **Selected UNIX Commands**

Following, in alphabetical order, is a select list of UNIX commands and their descriptions which can be used at the $ prompt (Note: UNIX is case-sensitive. All commands must be typed in the same case as shown below -- mostly lowercase).

**cat** *filename(s)* Displays file(s) contents

Ex: $ cat hellofile
Hello there world

**cd** *directoryname* Changes your current working directory
(if no directoryname given, changes to user's home directory)

**chmod** *octal-permission filename(s)*
Sets file permissions (Read-Write-Execute for User-Group-Others)

Ex: $ chmod 777 script.sh

**clear** Clears screen

**cp** *oldfilename newfilename* Creates a copy of an existing file, optionally changing its name.

Ex: $ cp file1 file2

**cp** *filename(s) directoryname* Copies a list of files to a different directory

Ex: $ cp *.c /usr/smallwood/cprogs

**echo** *text* Displays text on screen

Ex: $ echo Hello
Hello

**head -**# *filename* Displays first # lines of a file

Ex: $ head -2 file.mine.x
Line 1
Line 2

**ls** Lists names of all files in current directory
**ls -l** Lists names, permissions, owner, last mod, etc. of all files in current directory

**man** *subject* Provides manual help on subject specified.

Ex: $ man echo

**mkdir** *newDirectoryName* Creates a new directory

Ex: mkdir docs

In the above example, the subdirectory **docs** could be used to separate text files from programs, etc. Use the **pwd** command to display the current active directory. Your home directory will appear if you have not changed directories. To activate the subdirectory use the **cd** command as follows:

cd docs

If one directory is your current working directory, and you want to work with a file in another directory, you must specify the full path to that directory (in a manner similar to that of MS-DOS).

**mkdir -p** *newDirectoryPathName* Creates all directories in path that do not exist

Ex: $ mkdir cprogs\proj1 { Creates both cprogs **and** proj1 }

**more** *filename(s)* Like **cat**, but displays file(s) contents, one screenful at a time.

**mv** *oldfilename newfilename* Moves/renames a file

Ex: $ mv study.dat archive.dat
$ mv onefile /usr/joe/pamfile

**mv** *oldDIRname newDIRname* Moves a directory (and all its contents)

Ex: $ mv /usr/jones /usr/smith

**passwd** Changes your password. Will prompt you for the old and new passwords.

**ps** Displays status information for all your processes.

**pwd** Displays (current) working directory

**rm** *filename(s)* Deletes a file or files

Ex: $ rm file1

**rm -r** *directoryname* Deletes the directory and all files and subdirectories beneath it. USE WITH CARE!

Ex: $ rm -r smallwood

**rmdir** *directoryname(s)* Removes empty directories.

With the exception of the command used to remove a directory and the need to use an ownership privilege, the process to eliminate a directory proceeds much the same as in MS-DOS:- Remove all the files in the subdirectory.

- The working directory should be a parent directory of the one to be deleted.
- Delete the directory: $rmdir docs

**vi** *filename* Places file in the vi editor for editing.

**wc -l** *filename* Counts the lines in a file or files
**wc -w** *filename* Counts the words in a file or files
**wc -c** *filename* Counts the characters in a file or files

Ex: $ wc -c myfile
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**who** Lists currently logged in users, along with their terminals and the time they logged on.

*command* > *filename* Redirects command output to a file

Ex: $ ls -l > dirfile { Saves directory listing to file **dirfile** }

*command* < *filename* Redirects a file to command input

Ex: $ wc -l < dirfile { Saves number of lines in dirfile }

# CHAPTER SIX

# ETHICS IN COMPUTING

## Section I: **Computer Abuse/Computer Crime**

Computer abuse encompasses computer viruses and worms, denial of service, hoaxes and pranks, spamming, cybersquatting, and crackers. Computer crime includes theft of hardware, software, information and services, malice and destruction, and computer fraud.

**Viruses and Worms**

Worms and viruses are types of software written to gain unauthorized access to your system, and often cause damage to the software and/or data on a computer.

A **virus** is code, usually hidden within another seemingly harmless program, which can insert itself into other programs. When activated, it usually (but not always) performs a malicious act on your system.

How does a virus gain access to your system? It enters your system as part of an infected executable program file. Viruses were originally passed via the distribution of infected floppy disks that were passed among users on different computer systems. Today, however, viruses are more frequently downloaded from the Internet as part of demo program setup files, application program macros, or e-mail attachments.

A virus is an executable program and does not become active until it is run. Viruses will often automatically try to spread themselves to all the people in your email address book. An e-mail message, by itself, cannot be a virus. Viruses delivered as e-mail attachments do not become active until they are run, usually by double-clicking on the attachment. Friends won't generally send you a file unless you have asked for one. If you receive an attached executable file, ask the sender about it, and then scan the attachment with up-to-date anti-virus software before you run it. You should also beware of data files for programs that provide macro-writing features (Word, Excel, etc). Graphics, sound, or other data files are usually safe.

So a virus starts its life as a Trojan horse, hidden within another program. When you execute the program, the program jumps to the virus code, executes it, and then jumps back to the original harmless code. At this point the virus is active, and your system is infected. The virus may immediately perform its malicious acts, when it becomes active. Or, more commonly, it may stay in the background as a memory-resident program. A resident virus can be programmed to do pretty much anything the operating system can do. It can wait for events to trigger it (examples: a particular date, the disk becoming x% full, etc), and then go to work on your system. It can also scan your disks (including networked disks) for other running executable programs, then insert itself into those programs to infect them as well.

A **worm** is similar to a virus. But unlike viruses, worms exist as separate entities, and do not attach themselves to other files or programs.

When a worm gains access to a computer (usually via the Internet), it attempts to infect any computers networked to the original machine. Therefore, all machines attached to an infected machine are at risk of attack. Unlike viruses, the worm does not need user assistance (accidental or not) in order to start it running or to start copying itself. Once the worm discovers an Internet connection, it downloads a copy of itself to any connected computers and continues running as normal.

Antivirus software can detect and clean viruses and worms from a system. Antivirus software must be updated frequently because new viruses and worms are constantly being produced. And even if you run

up-to-date anti-virus programs, they don't protect perfectly against all viruses and worms. You must always exercise caution when accepting files and data from other people.

**Denial of Service Attacks**

A denial-of-service attack blocks or degrades access to a computer or network resource. The attacks don't necessarily **damage** data directly or permanently (although they could), but they intentionally compromise the **availability** of shared resources, such as system processes, shared files, disk space, and the CPU.

Denial of Service Attack Techniques:

- Destroy critical files needed to log into a system, like the **/etc/passwd** file on UNIX systems.

- Overload the host computer's CPU by:

    - Starting too many CPU-intensive processes.
    - Initiating multiple processes on the CPU, to the point where the host can no longer support starting any more new processes.
    - Sending a flood of network requests, causing the host to be so busy servicing interrupt requests and network packets that it cannot handle timely processing of any regular tasks.

- Consume all of the disk storage capacity on a host or network of hosts, by storing too many files on the system.

- Flood users with a huge number e-mail messages, very large e-mail messages, or messages with large attachments. Filling up one user's mailbox would prevent the user from having access to e-mail and perhaps all system services. Depending on how the system is configured, this could cause the system to run out of storage space and then stop processing for ALL users on the host or network. It may be impossible to determine the origin of the e-mail messages.

- Halt an important system process, or all processing, on a host or network. This method generally requires privileged access. Attackers also exploit known operating system bugs to cause shutdowns.

November 1988's Internet Worm caused the first widespread denial-of-service on the Internet. The worm copied itself over and over, rendering the infected hosts useless, because the multiple copies of the worm program used up their processing capability. Additionally, many non-infected computers disabled Internet access for several days as a defensive measure. Ironically, the intention of the 1988 Internet worm (judging from de-compiled versions of its code and the statements of its designer) was to do nothing visible. It was simply designed to spread itself to as many computers as possible, without giving the slightest indication of its existence. If the code worked correctly, it would have been only a tiny process continually running on computers across the Internet. But apparently the worm was released with a number of bugs in the code, and the programmer, Robert Morris, underestimated the degree to which the worm would propagate. Robert Morris received 400 hours of community service and a $10,000 fine for this attack.

The Morris worm pointed out a number of glaring security holes in UNIX networks which would probably have gone unknown, or at least been ignored as not very significant, had not the worm been so graphic in its exploitation of such "little" bugs. Security is often a trade off with convenience, and for most day-to-day users, convenience ranks pretty highly. Therefore, the temptation will always be to overlook security holes that would hamper legitimate users, thus leaving the door open for the next worm.

**Hoaxes and Pranks**

E-mail hoaxes and pranks exploit users who are not familiar with how the Internet and computer systems in general work.

Sample Hoaxes:

- The cookie recipe store (Mrs. Fields, Neimen Marcus, etc) is a myth. It has been circulating for at least 10 years in various forms.

- The federal government is NOT going to start charging to send e-mail.

- The dying kid who wants to see how many e-mail addresses he can collect before he dies is a myth.

- The "Good Times" virus warnings are a hoax. There is no virus by that name in existence today. These warnings have been circulating the Internet for years.

**Virus Hoaxes**

A virus hoax occurs when someone sends you a warning about a virus, but the virus does not actually exist. Some virus hoaxes succeed in convincing users to delete a necessary system file, by claiming that the particular file contains a virus. Virus hoaxes are most successful if they include technical sounding language and credible sources. Most people, including technically adept users, tend to believe the warning is real if it uses technical jargon. For example, the Good Times hoax says that "...if the program is not stopped, the computer's processor will be placed in an nth-complexity infinite binary loop which can severely damage the processor". The statement sound like it could be something real. Research reveals, however, that there is no such thing as an nth-complexity infinite binary loop and that processors are designed to run loops for weeks at a time without damage. Virus hoaxes also work when they come from a credible source. If a warning comes from a large technical organization, people tend to believe the warning, even if a janitor sent the message! The prestige of the company backs the warning and makes it appear real.

There are a couple of indicators you can watch for that often indicate that a virus alert is actually a virus hoax. First, when a virus alert urges you to pass the alert on to your friends, it may be a hoax. Second, if the virus alert urges you to delete specific system files. You should always run virus-scanning (anti-virus) software on the supposedly infected file, to verify that contains a virus. Third, when the warning indicates that it is a Federal Communication Commission (FCC) warning. The FCC does not disseminate warnings on viruses.

**Chain E-Mails**

Chain e-mails are also scams, and sometimes they are also a crime. Many e-mails attempt to convince their victims to forward a message to as many people as possible in order to get a reward for themselves or on behalf of some charity. The e-mail claims that if enough copies of the message get sent then something good will happen. Alternatively, some messages claim that unless enough messages are sent, than something bad will happen. But in reality, there is no way for anyone to count the number of copies of an email in circulation on the Internet, nor to count the number of times something has been forwarded.

On April 1st (April Fool's Day), many people send phony messages, pranks, and general amusing nonsense over the Internet. The messages can be funny, and you can enjoy them, but remember to ignore any messages from people you don't know. Also remember that it is easy to manipulate sound, pictures and video, so it is difficult to know if what you are hearing or seeing is actually as it appears.

**Cybersquatting**

Cybersquatting is the term applied to the act of registering a popular Internet address--usually a company name--with the intent of selling it to its rightful owner. Comparing cybersquatting to online extortion, Senator Spencer Abraham, a Michigan Republican, has introduced to Congress the Anti-Cybersquatting Consumer Protection Act. This bill, if enacted, would make cybersquatting illegal. Violators would be charged a fine of up to $300,000.

**Hackers and Crackers**

The word "hack" was coined at MIT, and originally meant an elegant, witty or inspired way of doing almost anything. **Hackers** are people who enjoy playing with computers. A hacker may occasionally circumvent security measures, but it is not generally malicious. Another group of people (mainly adolescent males) get a kick out of breaking into computers. Hackers call these people **crackers** and want nothing to do with them. Unfortunately, many journalists use the word "hacker" to describe a "cracker". A real hacker gets a basic thrill from solving problems, sharpening his/her skills, and exercising his/her intelligence. Hackers have an informal code of ethics, and revere competence above all.

In summary, "hackers" are people who just want to learn everything about a computer system, while "crackers" are the ones who are breaking into computer systems illegally and who use their skills with computers for illegal and immoral purposes. Regrettably, the general public has come to think of hackers as people who"hack into" computers to obtain information normal people cannot access and who destroy or damage computer systems. While the media caused the original confusion between the terms, the terms are now ingrained in our society. To most people, a hacker is the same as a cracker.

Example of ethical issues arising from hacking: When a hacker gains access to a system, but does not alter anything, what damage has been done?

**Spamming**

E-mail spammers collect lists of e-mail addresses and then send advertisements directly to individuals. Spammers routinely collect addresses from Internet bulletin board postings and subscription lists for newsgroups. Unscrupulous merchants also sell their mailing lists to spammers. Spammers use freedom of speech as an argument to disseminate their messages, and anti-spammers want the right to reject unwanted intrusions of junk mail.

Ways to avoid spam:

1) Maintain 2 e-mail accounts. Use one for public transactions such as Internet shopping, and reserve the other for personal use. Only give your personal e-mail address to friends and relatives.

2) If you post to a newsgroup, disguise your address. For example, if your address is:
   `joesmith@aol.com`
   Use the address:
   `joe<remove-this>smith@aol.com`
   when posting to a newsgroup. A real person will remove the extra characters before sending you e-mail, but an automated program will not be smart enough to do so.

3) If you have a personal web page, do not post your private e-mail address.

**Computer Crime**

Computers have created opportunities for crime that never existed before. It is always a challenge for society to stay one jump ahead of crime, especially in the case of crime that stems from new technology. Computer crime can be categorized as follows:

1) Hardware Theft – Physical removal of computers or computer parts from their location. Similar to theft of any other physical item. Hardware theft may go unnoticed if the criminal also alters computer records and inventories.

2) Theft of Computer Time and Services- Using computer resources for unauthorized activities. This includes running any programs for personal use, unless such usage has been authorized by the organization that owns the computer. The action being performed does not have to be an illegal action to constitute theft of time and services.

3) Software Theft – Software theft is called software piracy. Software piracy is the unauthorized copying and using of copyrighted software. Software piracy includes copying disks for distribution, using one licensed copy to install a program on multiple computers, taking advantage of an upgrade offer without having a legal copy of the version to be upgraded, purchasing counterfeit software, and using an academic or other non-retail copy illegally. A subcategory of software piracy, Network Piracy, occurs when software is downloaded from the Internet without paying for it.

   A company can be held liable for an employee installing unauthorized software copies on company computers or acquiring illegal software through the Internet, even if the company's management is unaware of the employee's actions. More often though, a company silently endorses the piracy. Disenchanted employees often report software piracy anonymously to the Business Software Alliance at 1-800-NOPIRACY. In 1992, the government passed the Software Copyright Protection Act, which provides for prosecution of software piracy that can result in fines up to $250,000, up to 5-year jail sentences, or both. In addition to holding companies accountable for software piracy, the act allows prosecution of any individual who makes at least 10 illegal copies of copyrighted software, or any combination of copies worth over $2500.

4) Information Theft - Copying of data (industrial espionage, credit card information etc.). Information itself seldom has any real value alone. Its value becomes apparent, however, when it is used.

5) Malice and Destruction – Destroying computer parts or data or purposely modifying data or programs so that they are inaccurate.

6) Fraud – Committing fraud via Internet scams. Internet fraud is usually occurs when merchandise is ordered over the Internet, and never delivered, or the item delivered is not the item that was ordered in good faith. The total loss in 2002 attributed to computer fraud was over 14 million dollars. Of that total, 90% of the fraud was committed via online auctions.

Experts believe that the incidence of computer crime is actually much greater than the number of computer crimes reported. Companies often do not report computer crimes, so they can avoid the negative publicity. They do not want their customers to realize that their security measures are fallible.

## Section II: **Privacy Issues**

### Privacy in Personal Communications

People should be able to communicate among themselves, without their communications being monitored by other people or organizations. The most common means of communication on the computer is e-mail. Motivations to read private e-mail can be numerous. A company might spy to gain professional secrets. Management might want to make sure employees are not planning anything or using company resources for personal gain. There could be a blackmailer at work. As always, information is power.

The most important point to remember is -- E-mail is NOT private!

> **Why?** E-mail messages travel from the originating host computer to the destination host computer, and often pass through several relaying hosts. Administrators of ANY these hosts can easily eavesdrop the mail traffic.
>
> If the mail bounces because it can't reach the addressee, a copy of the message is often sent to the postmaster of the originating system who can read the e-mail addresses of the sender and the addressee and the contents of the mail.
>
> Locally, your system administrator has access to network-monitoring tools, which allow reading of any files sent over the network. And complete system backups save all of the e-mail messages on a system, which can then be accessed at a later date.

On the Internet, the only way to ensure message privacy is to encrypt your message. Encryption involves modification of data, based a key and a formula. The Pretty Good Privacy (PGP) package is available for personal use worldwide. PGP is based on a pair of keys, the public key and the private key. The public key is widely known, but only the holder of the key knows the private key. A message can be encrypted using the public key and then decrypted using the private key. The sender can look up the public key of the recipient and use that key to encrypt the message. Only the recipient can decipher the message, using his private key. Pretty Good Privacy (PGP) can also be used to send a digital signature that can be used to verify that the message was not tampered with en route. Because the PGP method is based on arithmetic algorithms performed on very large numbers, the system is very secure. To date no one has demonstrated skill to crack the PGP methods.

### Internet Privacy - Anonymous Servers

If a person wants to send e-mail without revealing their identity, they can use an anonymous server. First they establish an anonymous ID and password with the server, which links to the user's e-mail address. When the user wants to send anonymous mail, he sends the message to the server and supplies the password and the address where the mail should be sent in the beginning of the message. The server will strip the sender's address in the "From" field of the message header and replace it with the anonymous ID, so that the message seems to originate from the anonymous server. If the recipient answers to the anonymized mail by replying to the anonymous address, the server will automatically translate the ID to the real e-mail address and forward the message there. Unfortunately, spammers often use anonymous servers.

**Internet Privacy - Cookies**

Cookies are small scripts or applications, which are automatically sent to you when you visit a site, often without you even knowing it. These scripts are files stored in your browser's directories. When you visit a site that uses cookies, that site is able to monitor or track your browsing habits, by determining what pages you have visited within their site, and how many times you have visited the site. Cookies allow a company's marketers to build a profile of your interests. This allows the site to direct advertisements to match your profile.

Cookies can also be used to keep track of a user's password for a site. On subsequent visits the cookie may automatically allow you access to the site, without your having to enter your password.

The biggest problem with Cookies is that they are being used often times without the user even knowing about it. The newer browsers do allow you some control in that arena. You can choose to reject all cookies, accept all cookies, or be notified whenever a cookie is being stored. The problem with rejecting all cookies is that some sites will not allow you to browse their sites at all without accepting a cookie. So probably the best setting is one of notification, so at least you know when cookies are being stored on your machine.

**Privacy of Personal Data**

Personal data about an individual should not be automatically available to other individuals and organizations. You should be able to exercise some control over that data and its use, even when someone else possesses the data. And the party possessing your data has an obligation to protect access to the data and to conceal it from unauthorized individuals.

In most cases, this means protecting the data in databases, protecting the data from unauthorized transmission over the Internet, and ensuring the accuracy of the data. In a much-publicized case involving unauthorized access to private data, actress Rebecca Schaeffer was murdered by an obsessed fan who obtained her home address from the California Department of Motor Vehicles database. Computer databases have also been responsible for some terrible errors. Credit applications have been denied, people have been arrested, jobs have been denied, etc, based upon false information in databases. Of course, the majority of database errors are not catastrophic, but they can cause lots of frustration.

Your credit rating is instrumental in your ability to get a loan, and often determines the interest rate you will pay. Additionally, more and more insurance companies and prospective employers are using your credit rating to judge you. Most credit reports are obtained from the top three credit bureaus: TRW, Equifax, and Trans Union. By Colorado Law, you may request one free credit report per year. It is important for people to verify the information in their credit files before they need to use it.

The Data Protection Act in the United Kingdom is based upon the following data privacy rules:

1) Data can only be obtained by lawful means, with the data subject's knowledge and consent. The purpose for the data collection must be disclosed and data may not be used beyond this purpose.
2) Only relevant data may be collected, and it must be kept up-to-date, accurate and complete.
3) Data may not be disclosed by the collector to outsiders without the consent of the data subject, unless required by law.
4) Data collectors must take reasonable precautions against loss, destruction, unauthorized use, modification and disclosure of the data.

5) Data subjects should be able to determine the whereabouts, use, and purpose of any personal data relating to them.
6) Data subjects have the right to inspect any data about themselves, and the right to challenge the accuracy of the data and have it corrected or deleted.

Enforcement of these rules, or similar rules, would be a good first step in protecting our individual privacy.

## Section III: **Computers in Society**

### Monopolies

The United States operates a free market economy, on the theory that it is the best way to ensure efficient allocation of resources. Monopolies are illegal. Market dominance of one company in a specific area can lead to monopolistic practices.

Most recently, the government has been examining Microsoft, because they controls 95% of the desktop operating system (OS) market, and a monopoly is defined as controlling over 70% of a market. Microsoft has allegedly engaged in anticompetitive practices, by denying third-party vendor access. An analogy would be the owner of a toll bridge, which is the only bridge across a river, paying the owner of land to deny access to a site where a competitive bridge is partly built. Microsoft is accused of using exclusionary contracts to deny access.

On the other hand, Microsoft's defenders argue that all software companies are either wildly successful or lose big based on the quality of their idea, not any physical product. Once the upfront costs are recouped, every additional sale is pure profit, but the advent of a better competing product can easily stem sales. This creates a situation where successful companies become monopolies, as in Microsoft's case. They claim that Microsoft is being punished for being successful, for making products that people want to purchase.

### Hardware/Software Reliability

Our society has come to rely on computers for the most basic of day-to-day activities. Computer companies, therefore, have an obligation to make computers, both the hardware and the software, as reliable as technically possible.

**Example**

> Approximately 800 customers of the First National Bank of Chicago were credited with $924 million each. The cause was a change in a computer program. According to The American Bankers Association, the total of $763.9 billion was the largest such error in US banking history.

In the above example, the bank was embarrassed by the error, but there was no permanent damage done. But we also rely on computer's to control traffic lights, space vehicles, nuclear power stations, weapons systems, medical devices, etc. We would like to be sure that these systems are completely reliable.

There have been cases of medical systems that either under treated (Stroke-on-Trent) or over treated (Therac-25) patients, resulting in both injuries and death. In fact, failures in computer system development and use are commonplace. Even systems with good performance records have occasional failures. Programmers admit that it is virtually impossible to write a non-trivial program that is bug-free.

Software reliability is ultimately dependent upon extensive (and expensive) testing, debugging, quality control, and product proving.

Ethical questions: If it is theoretically impossible to determine the correctness of a program, is the programmer immune from ethical obligation? What is the ethical status of existing warranties and/or disclaimers?

## Equity of Access

The number of Americans accessing the Internet has grown rapidly in the last years, but the "digital divide" between information "haves" and "have nots" continues to widen. Income level is a strong determinant of a person or household's Internet access. While a predictor of overall Internet use, income level also influences where and how a person uses the Internet. Persons with incomes of less than $35,000 more often use the Internet outside the home, while those making over $75,000 predominantly use the Internet at home. Public resources available to date have not alleviated the significant Internet use gap between rich and poor, so the gap continues to grow. There is a concern that people who do not have access to computers will be at a great disadvantage as technology progresses.

## Pollution/Energy Usage

The extensive packaging of computer products and the many non-recyclable parts inside computers causes environmental pollution. Energy usage is high, due to the electricity consumed by the machines.

## Ergonomic Issues

Using a computer is not always good for your body. First, the increasing number of jobs involving computers is raising the stress level in the workplace. Second, computers have introduced new health and safety issues. Use of video display terminals cause eyestrain, headaches, backaches, and stiff necks. Use of keyboards and mice cause repetitive strain injuries that occur from repeated physical movements doing damage to tendons, nerves, muscles, and other soft body tissues. Thousands of repeated keystrokes and long periods of clutching and dragging with mice slowly causes damage to the body. The strain is caused by degree of force, repetition, and a fast pace of work.

Proper Use of Computers (to prevent physical problems):

- Use adjustable chairs, detachable keyboards, and non-glare screens.
- Sit straight up (no slouching), with thighs and forearms level (or sloping slightly down, away from the body)
- Wrists straight and level, not bent
- Do NOT rest your wrists on anything when you are typing (only use the rests when pausing). Use a light touch (don’t pound the keys)
- Tilt the keyboard down, away from you.
- Hold the mouse lightly (don’t squeeze it).
- Increase your font sizes so you don’t hunch forward to read the monitor.
- Keep your hands and arms warm. Cold muscles & tendons are at much greater risk for overuse injuries, and many offices are over-air-conditioned.
- **MOVE** and shift positions frequently. Take LOTS of BREAKS to STRETCH and RELAX. This means both momentary breaks every few minutes and longer breaks every hour or so.

## Section IV: **Codes of Conduct**

**User Responsibilities**

If you use computing resources or facilities, you have the following responsibilities:

- Use the computing facilities and information resources, including hardware, software, networks, and computer accounts, responsibly and appropriately, respecting the rights of other computing users and respecting all contractual and license agreements.
- Use only those computers and computer accounts for which you have authorization. Be responsible for all use of your accounts and for protecting each account's password.
    - In other words, do not share computer accounts. If someone else learns your password, you must change it.
- Report unauthorized use of your accounts to the appropriate authority.
- Be responsible for your own computing and work using a computer. Remember to make backup copies of their data, files, and programs, particularly those created on microcomputers.
- If you are a supervisor whose staff use computers, you must help your staff learn more about ethical computing practices, good computing practices and data management.

## Online Codes of Ethics

Many organizations have established a code of ethics. Examinining a few of them may give you a better understanding to some of the issues in today's world. Below are links to the codes:

1) ACM Code of Ethics and Professional Conduct
   http://info.acm.org/constitution/code.html

2) IEEE Code of Ethics
   http://www.ieeeusa.org/documents/CAREER/CAREER_LIBRARY/ethics.html

3) Software Engineering Code Of Ethics And Professional Practice from the IEEE-CS/ACM Joint Task Force on Software Engineering Ethics and Professional Practices
   http://www.computer.org/tab/seprof/code.htm

4) Australian Computer Society Code of Ethics
   http://www.acs.org.au/national/pospaper/acs131.htm

5) The Ten Commandments of Computer Ethics by the Computer Ethics Institute
   http://www.cpsr.org/program/ethics/cei.html

Case studies, for discussion, can be accessed at: www.computingcases.org