# CSCI1050 – Hands-On Introduction to MATLAB

Flow of Control

## Section 4.1 Relational Operators and Logical Variables

Table 4.1–1 Relational Operators

| Operator | Meaning |
| --- | --- |
| < | Less than. |
| <= | Less than or equal to. |
| > | Greater than. |
| >= | Greater than or equal to. |
| == | Equal to. |
| ~= | Not equal to. |

For example, suppose that `x = [6,3,9]` and `y = [14,2,9]`. The following MATLAB session shows some examples.

```
>>z = (x < y)
z =
    1    0    0
>>z = (x ~= y)
z =
    1    1    0
>>z = (x > 8)
z =
    0    0    1
```

The relational operators can be used for array addressing.

For example, with `x = [6,3,9]` and `y = [14,2,9]`, typing

```
z = x(x<y)
```

finds all the elements in x that are less than the corresponding elements in y. The result is `z = 6`.

The arithmetic operators +, -, *, /, and \ have precedence over the relational operators. Thus the statement

```
z = 5 > 2 + 7
```

is equivalent to

```
z = 5 >(2+7)
```

and returns the result `z = 0`.

We can use parentheses to change the order of precedence; for example, `z = (5 > 2) + 7` evaluates to `z = 8`.

## The logical Class

When the relational operators are used, such as

```
x = (5 > 2)
```

they create a *logical* variable, in this case, `x`.

Prior to MATLAB 6.5 *logical* was an attribute of any numeric data type. Now logical is a first-class data type and a MATLAB class, and so logical is now equivalent to other first-class types such as character and cell arrays.

Logical variables may have only the values 1 (true) and 0 (false).

Just because an array contains only 0s and 1s, however, it is not necessarily a logical array. For example, in the following session `k` and `w` appear the same, but `k` is a logical array and `w` is a numeric array, and thus an error message is issued.

```
>>x = [-2:2]; k = (abs(x)>1)
k =
   1    0    0     0     1
>>z = x(k)
z =
   -2   2
>>w = [1,0,0,0,1]; v = x(w)
??? Subscript indices must either be real
  positive... integers or logicals.
```

## Accessing Arrays Using Logical Arrays

When a logical array is used to address another array, it extracts from that array the elements in the locations where the logical array has 1s.

So typing A(B), where B is a logical array of the same size as A, returns the values of A at the indices where B is 1.

Specifying array subscripts with logical arrays extracts the elements that correspond to the true (1) elements in the logical array.

Given `A =[5,6,7;8,9,10;11,12,13]` and `B = logical(eye(3))`, we can extract the diagonal elements of `A` by typing `C = A(B)` to obtain `C = [5;9;13]`.

# Section 4.2 Logical Operators and Functions

## Table 4.2–1 Logical operators:

| Operator | Name | Definition |
|---|---|---|
| `~` | NOT | `~A` returns an array the same dimension as `A`; the new array has ones where `A` is zero and zeros where `A` is nonzero. |
| `&` | AND | `A & B` returns an array the same dimension as `A` and `B`; the new array has ones where both `A` and `B` have nonzero elements and zeros where either `A` or `B` is zero. |
| `\|` | OR | `A \| B` returns an array the same dimension as `A` and `B`; the new array has ones where at least one element in `A` or `B` is nonzero and zeros where `A` and `B` are both zero. |

# Table 4.2–1 (continued)

| Operator | Name | Definition |
|---|---|---|
| `&&` | Short-Circuit AND | Operator for scalar logical expressions. `A && B` returns true if both `A` and `B` evaluate to true, and false if they do not. |
| `\|\|` | Short-Circuit OR | Operator for scalar logical expressions. `A \|\| B` returns true if either `A` or `B` or both evaluate to true, and false if they do not. |

## **Order of precedence for operator types.** Table 4.2–2

| **Precedence** | **Operator type** |
|---|---|
| First | Parentheses; evaluated starting with the innermost pair. |
| Second | Arithmetic operators and logical NOT (~); evaluated from left to right. |
| Third | Relational operators; evaluated from left to right. |
| Fourth | Logical AND. |
| Fifth | Logical OR. |

# **Logical functions:** Table 4.2–4

| Logical function | Definition |
|---|---|
| `all(x)` | Returns a scalar, which is 1 if all the elements in the vector `x` are nonzero and 0 otherwise. |
| `all(A)` | Returns a row vector having the same number of columns as the matrix `A` and containing ones and zeros, depending on whether or not the corresponding column of `A` has all nonzero elements. |
| `any(x)` | Returns a scalar, which is 1 if any of the elements in the vector `x` is nonzero and 0 otherwise. |
| `any(A)` | Returns a row vector having the same number of columns as `A` and containing ones and zeros, depending on whether or not the corresponding column of the matrix `A` contains any nonzero elements. |
| `finite(A)` | Returns an array of the same dimension as `A` with ones where the elements of `A` are finite and zeros elsewhere. |

Table 4.2–4 (continued)

| **Logical function** | **Definition** |
|---|---|
| `ischar(A)` | Returns a 1 if `A` is a character array and 0 otherwise. |
| `isempty(A)` | Returns a 1 if `A` is an empty matrix and 0 otherwise. |
| `isinf(A)` | Returns an array of the same dimension as `A`, with ones where `A` has ‘`inf`’ and zeros elsewhere. |
| `isnan(A)` | Returns an array of the same dimension as `A` with ones where `A` has ‘`NaN`’ and zeros elsewhere. (‘`NaN`’ stands for “not a number,” which means an undefined result.) |

Table 4.2–4 (continued)

| | |
|---|---|
| `isnumeric(A)` | Returns a 1 if A is a numeric array and 0 otherwise. |
| `isreal(A)` | Returns a 1 if A has no elements with imaginary parts and 0 otherwise. |
| `logical(A)` | Converts the elements of the array A into logical values. |
| `xor(A,B)` | Returns an array the same dimension as A and B; the new array has ones where either A or B is nonzero, but not both, and zeros where A and B are either both nonzero or both zero. |

# The `find` Function

`find(A)`

Computes an array containing the indices of the nonzero elements of the array `A`.

`[u,v,w] = find(A)`

Computes the arrays `u` and `v` containing the row and column indices of the nonzero elements of the array `A` and computes the array `w` containing the values of the nonzero elements. The array `w` may be omitted.

## Logical Operators and the `find` Function

Consider the session

```
>>x = [5, -3, 0, 0, 8]; y = [2, 4, 0, 5, 7];
>>z = find(x&y)
z =
   1     2     5
```

Note that the find function returns the *indices*, and not the *values*.

Note that the find function returns the *indices,* and not the *values*.

In the following session, note the difference between the result obtained by `y(x&y)` and the result obtained by `find(x&y)` in the previous slide.

```
>>x = [5, -3, 0, 0, 8];y = [2, 4, 0, 5, 7];
>>values = y(x&y)
values =
   2    4     7
>>how_many = length(values)
how_many =
   3
```

## Section 4.3 Conditional Statements

### The `if` Statement

The `if` statement's basic form is

`if` *logical expression*
    *statements*
`end`

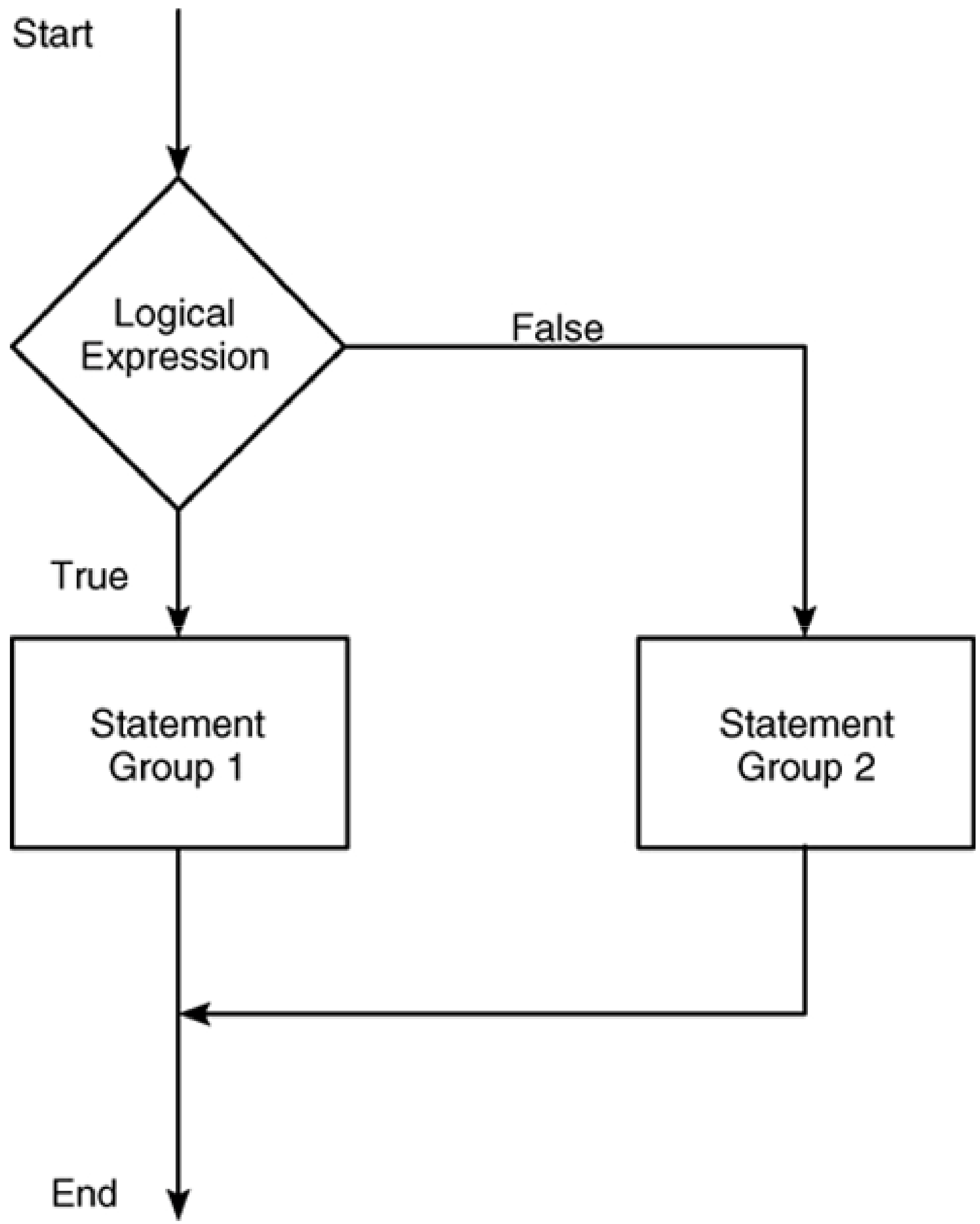
Every `if` statement must have an accompanying end statement. The end statement marks the end of the *statements* that are to be executed if the *logical expression* is true.

## The `else` Statement

The basic structure for the use of the `else` statement is

```
if logical expression
  statement group 1
else
  statement group 2
end
```

# Flowchart of the else structure.



When the test, if *logical expression,* is performed, where the logical expression may be an *array,* the test returns a value of true only if *all* the elements of the logical expression are true!

For example, if we fail to recognize how the test works, the following statements do not perform the way we might expect.

```
x = [4,-9,25];
if x < 0
   disp('Some of the elements of x are negative.')
else
   y = sqrt(x)
end
```

When this program is run it gives the result

```
y =
 2   0 + 3.000i   5
```

Instead, consider what happens if we test for `x` positive.

```
x = [4,-9,25];
if x >= 0
  y = sqrt(x)
else
  disp('Some of the elements of x are negative.')
end
```

When executed, it produces the following message:

```
Some of the elements of x are negative.
```

The test if `x < 0` is false, and the test if `x >= 0` also returns a false value because `x >= 0` returns the vector `[1,0,1]`.

The statements

```
if logical expression 1
   if logical expression 2
    statements
  end
end
```

can be replaced with the more concise program

```
if logical expression 1 & logical expression 2
  statements
end
```

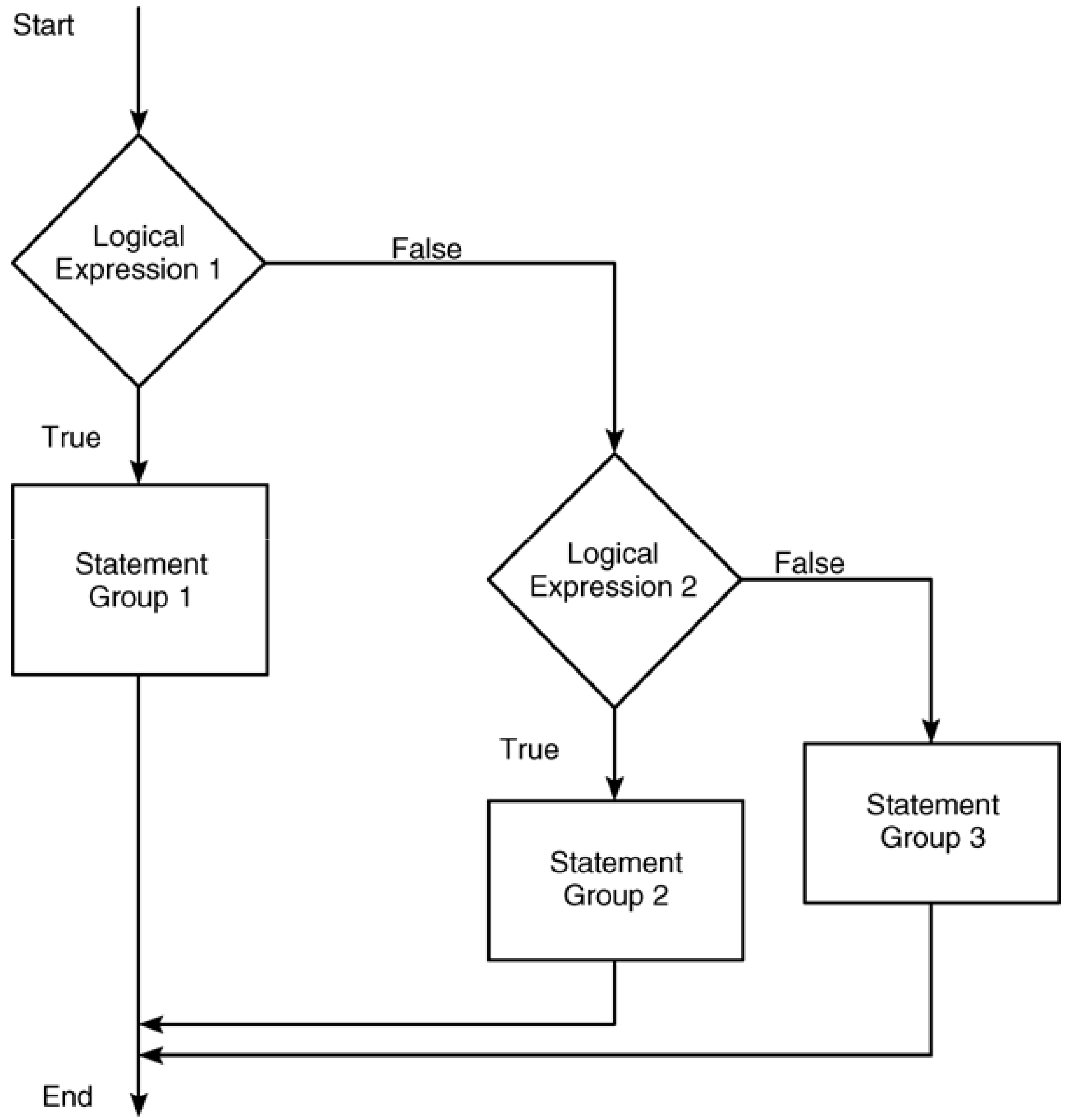
## The `elseif` Statement

The general form of the `if` statement is

```
if logical expression 1
     statement group 1
elseif logical expression 2
     statement group 2
else
     statement group 3
end
```

The `else` and `elseif` statements may be omitted if not required. However, if both are used, the `else` statement must come after the `elseif` statement to take care of all conditions that might be unaccounted for.

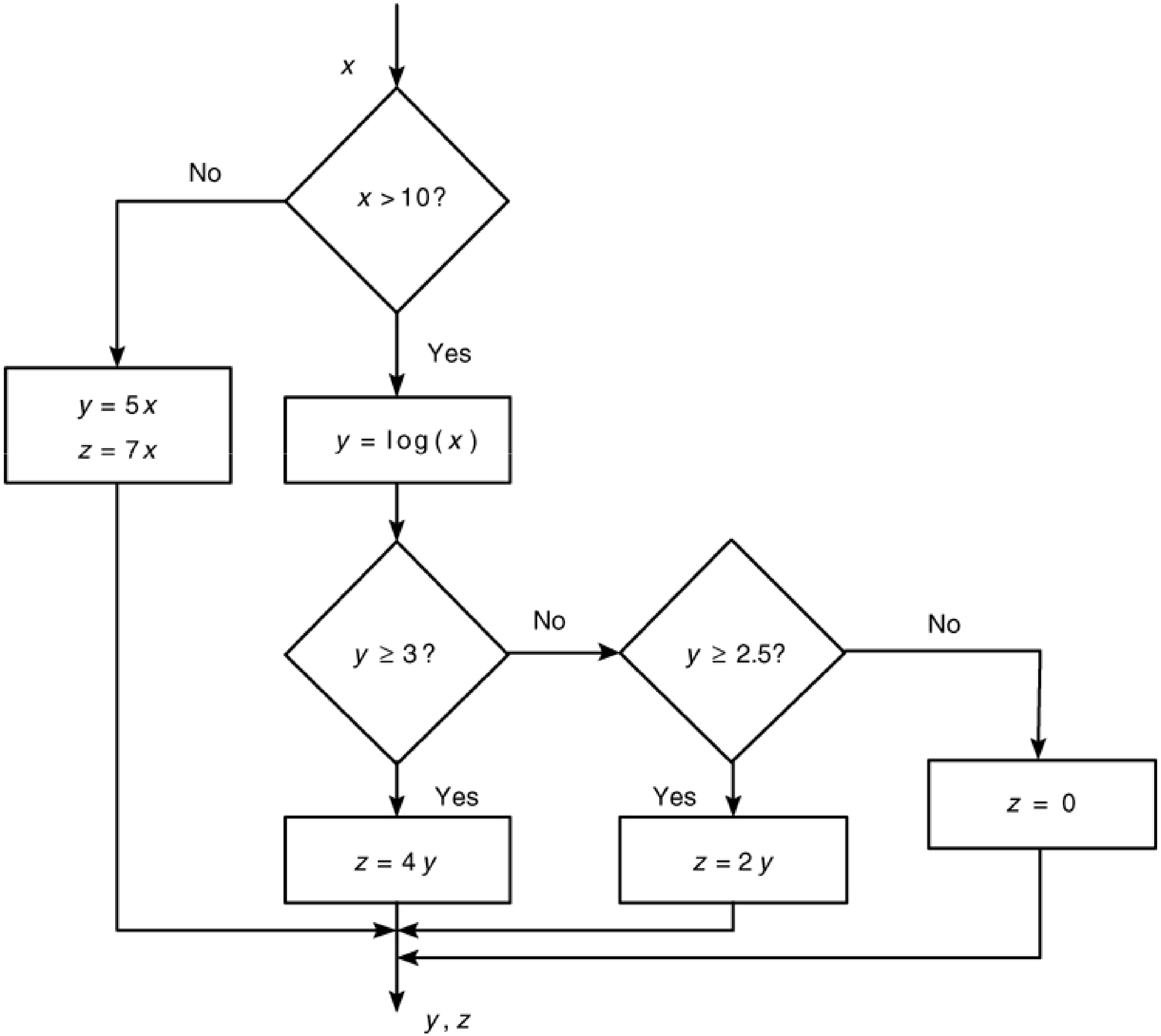
**Flowchart for the general `if-elseif-else` structure.**



For example, suppose that `y = log(x)` for $x$ `> 10`, $y$ `=sqrt(`$x$`)` for `0 <= x <= 10`, and `y = exp(x) - 1` for `x < 0`. The following statements will compute `y` if `x` already has a scalar value.

```
if x > 10
  y = log(x)
elseif x >= 0
  y = sqrt(x)
else
  y = exp(x) - 1
end
```

# Flowchart illustrating nested if statements.



## Strings and Conditional Statements

A *string* is a variable that contains characters. Strings are useful for creating input prompts and messages and for storing and operating on data such as names and addresses.

To create a string variable, enclose the characters in single quotes. For example, the string variable name is created as follows:

```
>>name = 'Leslie Student'
name =
    Leslie Student
```

The following string, `number`, is *not* the same as the variable number created by typing number = 123.

```
>>number = '123'
number =
    123
```

The following prompt program uses the `isempty(x)` function, which returns a 1 if the array `x` is empty and 0 otherwise.

It also uses the input function, whose syntax is

```
x = input('prompt', 's')
```

This function displays the string *prompt* on the screen, waits for input from the keyboard, and returns the entered value in the string variable `x`.

The function returns an empty matrix if you press the **Enter** key without typing anything.

The following prompt program is a script file that allows the user to answer *Yes* by typing either `Y` or `y` or by pressing the **Enter** key. Any other response is treated as a No answer.

```
response = input('Do you want to continue? Y/N
[Y]: ','s');
if (isempty(response))|(response
== 'Y')|(response == 'y')
  response = 'Y'
else
  response = 'N'
end
```

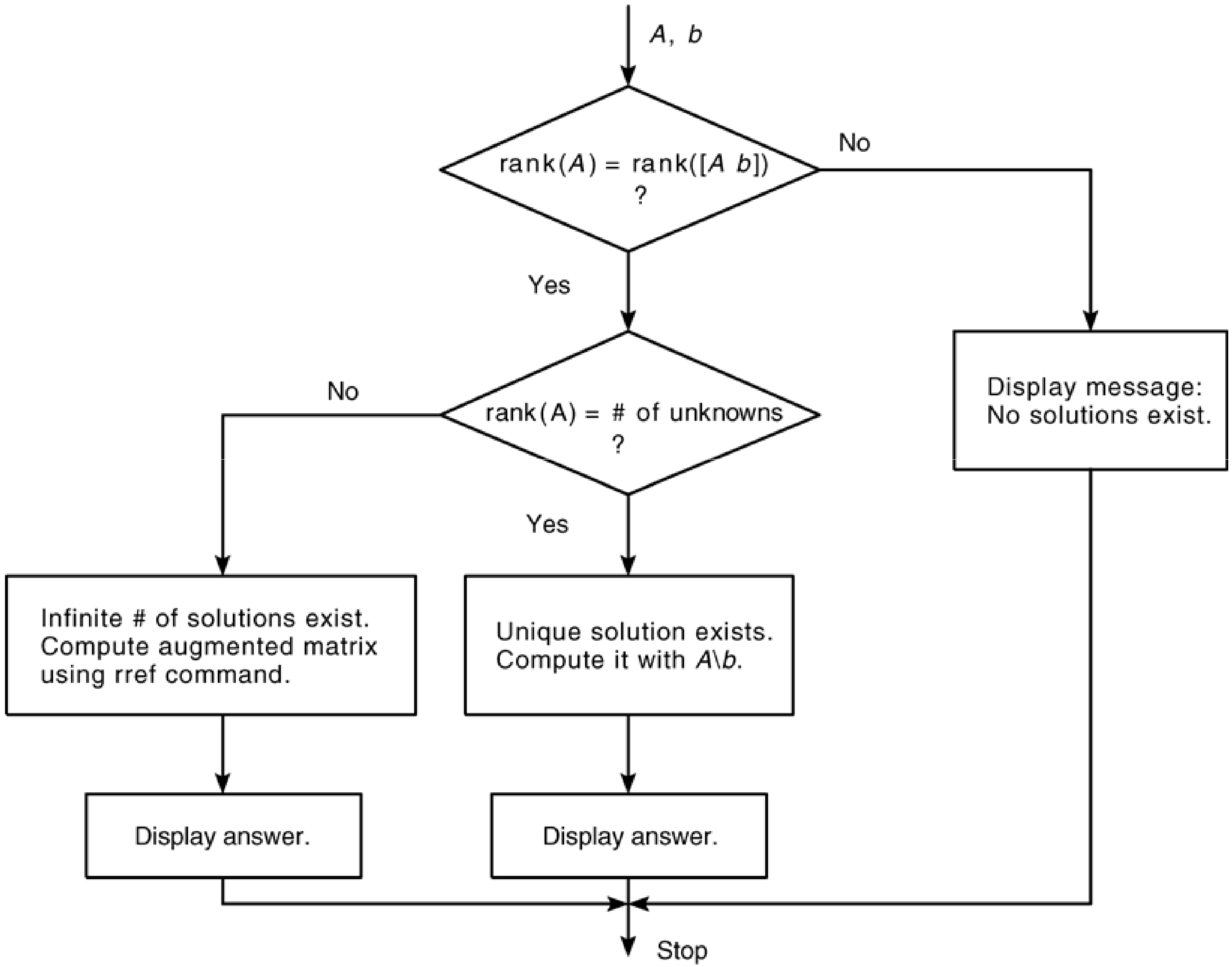
**Pseudocode for the linear equation solver.** **T**able 4.3-1

1. If the rank of **A** equals the rank of [**A b**], then determine whether the rank of **A** equals the number of unknowns. If so, there is a unique solution, which can be computed using left division. Display the results and stop.

2. Otherwise, there is an infinite number of solutions, which can be found from the augmented matrix. Display the results and stop.

3. Otherwise (if the rank of **A** does not equal the rank of [**A b**]), then there are no solutions. Display this message and stop.

**Flowchart of the linear equation solver.** Figure 4.3-1



**MATLAB program to solve linear equations.** Table 6.6–3

```
% Script file lineq.m
% Solves the set Ax = b, given A and b.
% Check the ranks of A and [A b].
if rank(A) == rank([A b])
   % The ranks are equal.
   size_A = size(A);
   % Does the rank of A equal the number of
     unknowns?
   if rank(A) == size_A(2)
      % Yes. Rank of A equals the number of  unknowns.
      disp('There is a unique solution,which is:')
      x = A\b % Solve using left division.
```

## Linear equation solver (continued)

```
    else
      % Rank of A does not equal the number of unknowns.
      disp('There is an infinite number of solutions.')
      disp('The augmented matrix of the reduced system is:')
      rref([A b]) % Compute the augmented matrix.
    end
else
    % The ranks of A and [A b] are not equal.
    disp('There are no solutions.')
end
```

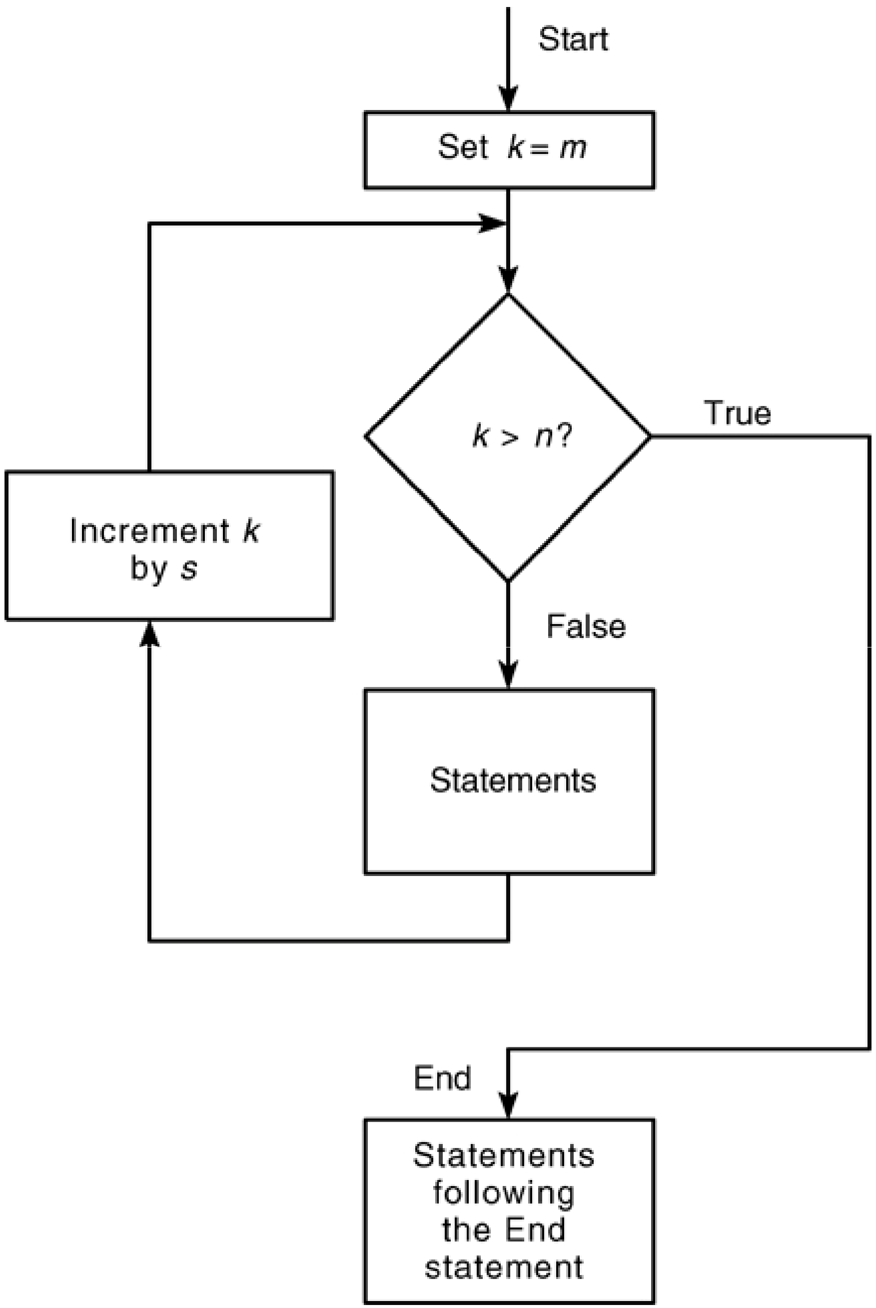
## Section 4.4 Loops

**for Loops:** A simple example of a `for` loop is

```
for k = 5:10:35
  x = k^2
end
```

The *loop variable* `k` is initially assigned the value 5, and `x` is calculated from `x = k^2`. Each successive pass through the loop increments `k` by 10 and calculates x until k exceeds 35. Thus `k` takes on the values 5, 15, 25, and 35, and `x` takes on the values 25, 225, 625, and 1225. The program then continues to execute any statements following the end statement.

# Flowchart of a for Loop.



Note the following rules when using for loops with the loop variable expression `k = m:s:n`:

- The step value `s` may be negative. Example: `k = 10:-2:4` produces `k` = 10, 8, 6, 4.
- If `s` is omitted, the step value defaults to one.
- If `s` is positive, the loop will not be executed if `m` is greater than `n`.
- If `s` is negative, the loop will not be executed if `m` is less than `n`.
- If `m` equals `n`, the loop will be executed only once.
- If the step value s is not an integer, round-off errors can cause the loop to execute a different number of passes than intended.

For example, the following code uses a continue statement to avoid computing the logarithm of a negative number.

```
x = [10,1000,-10,100];
y = NaN*x;
for k = 1:length(x)
  if x(k) < 0
    continue
  end
  y(k) = log10(x(k));
end
y
```

The result is `y = 1, 3, NaN, 2`.

Use of Logical Arrays as Masks: We can often avoid the use of loops and branching and thus create simpler and faster programs by using a logical array as a *mask* that selects elements of another array. Any elements not selected will remain unchanged.

The following session creates the logical array `C` from the numeric array `A` given previously.

```
>>A = [0, -1, 4; 9, -14, 25; -34, 49, 64];
>>C = (A >= 0);
```

The result is

$$\mathbf{C} = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

We can use this mask technique to compute the square root of only those elements of `A` given in the previous program that are no less than 0 and add 50 to those elements that are negative. The program is

```
A = [0, -1, 4; 9, -14, 25; -34, 49, 64];
C = (A >= 0);
A(C) = sqrt(A(C))
A(~C) = A(~C) + 50
```

## `while` Loops

The `while` loop is used when the looping process terminates because a specified condition is satisfied, and thus the number of passes is not known in advance. A simple example of a while loop is

```
x = 5;
while x < 25
   disp(x)
   x = 2*x - 1;
end
```

The results displayed by the `disp` statement are 5, 9, and 17.

The typical structure of a while loop follows.

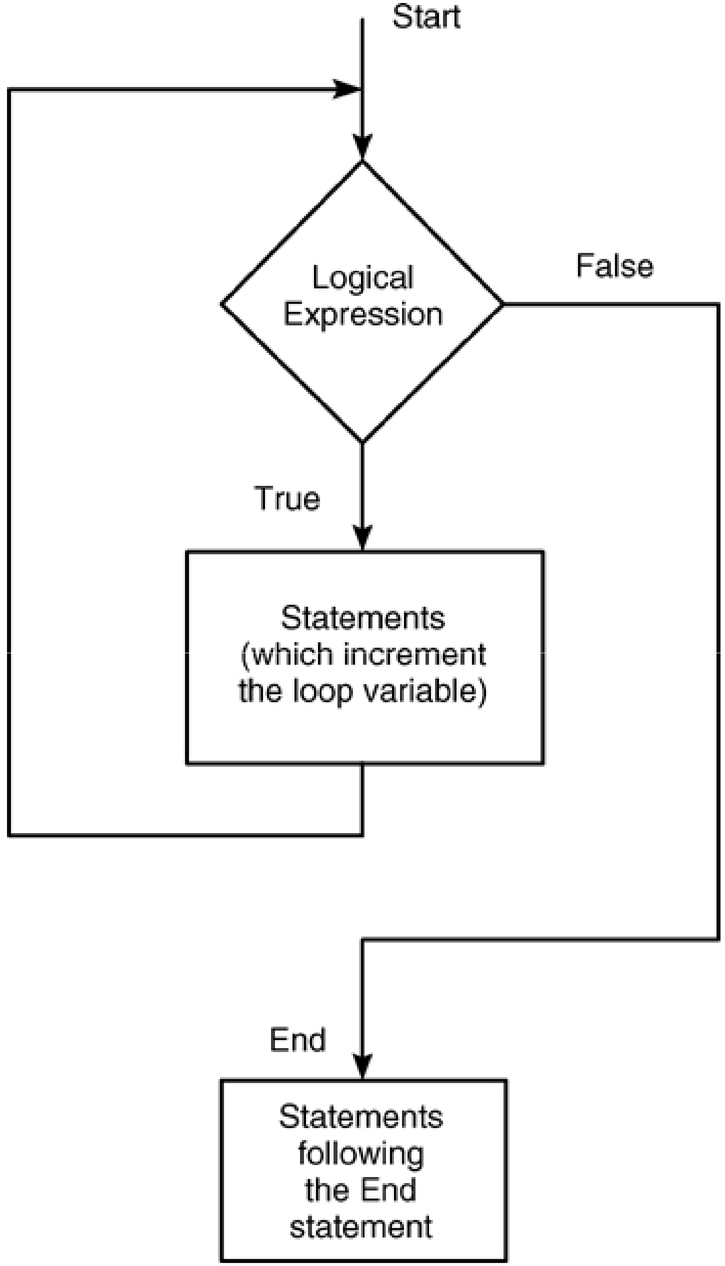
```
while logical expression
    statements
end
```

For the `while` loop to function properly, the following two conditions must occur:

1. The loop variable must have a value before the while statement is executed.

**2.** The loop variable must be changed somehow by the *statements.*

# Flowchart of the while loop.



## Section 4.5 The `switch` Structure

The `switch` structure provides an alternative to using the `if`, `elseif`, and `else` commands.Anything programmed using `switch` can also be programmed using `if` structures.

However, for some applications the `switch` structure is more readable than code using the `if` structure.

## Syntax of the switch structure

```
switch input expression   (a scalar or a string).
  case value1
      statement group 1
  case value2
      statement group 2
  .
  .
  .
  otherwise
      statement group n
end
```

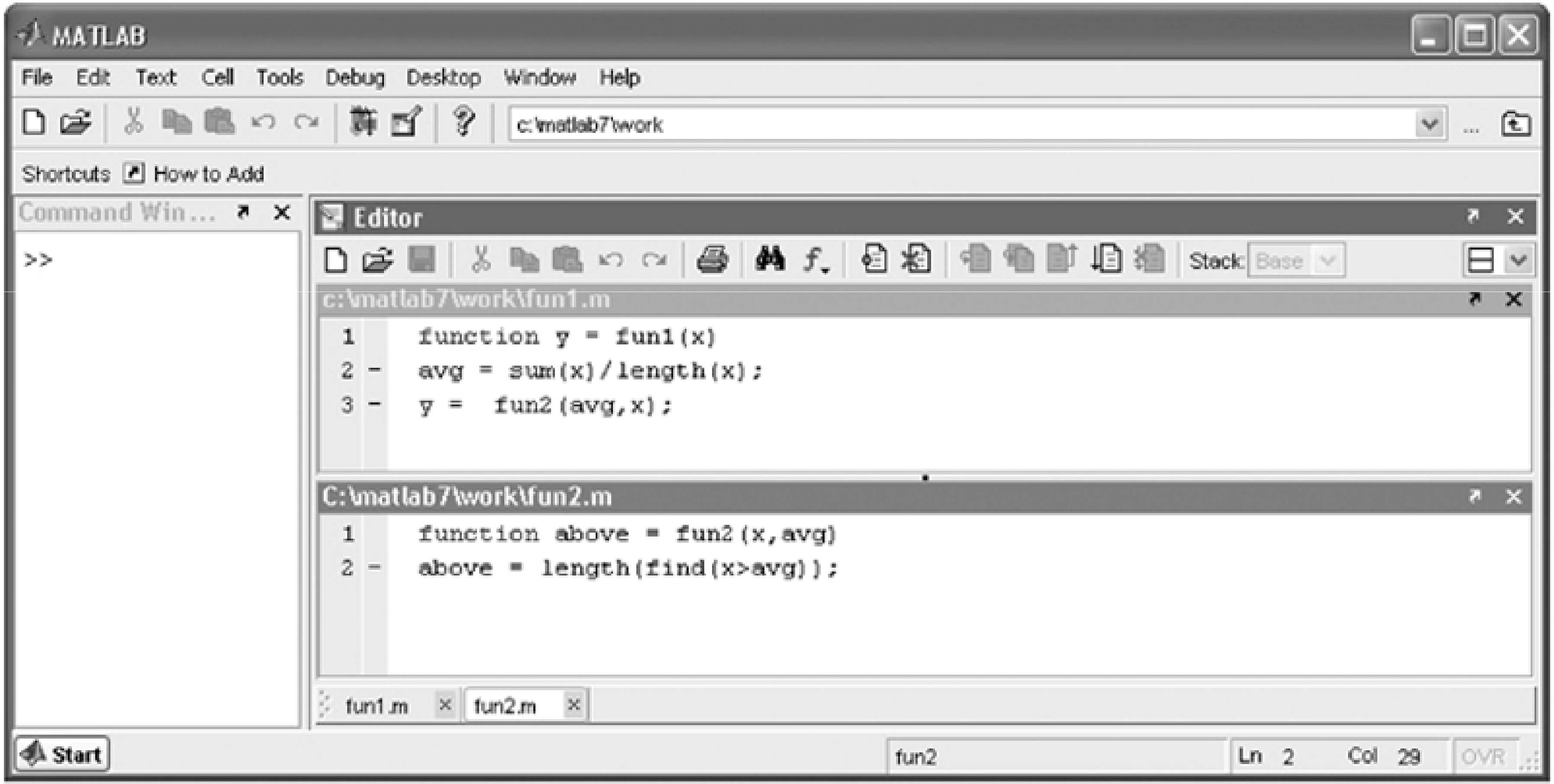
The following switch block displays the point on the compass that corresponds to that angle.

```
switch angle
 case 45
   disp('Northeast')
 case 135
   disp('Southeast')
 case 225
   disp('Southwest')
 case 315
   disp('Northwest')
 otherwise
   disp('Direction Unknown')
end
```

## Section 4.6 Debugging MATLAB Programs

**The Editor/Debugger containing two programs to be analyzed.**

Figure 4.6–1



# Use of the Cell Mode

- The cell mode in the debugger can be used to debug programs and to generate reports.
- Breakpoints are points in the program file where execution stops temporarily so that you ca examine the values of variables up to that point.  Breakpoints can be set from the Debug menu