LEARN FORTRAN

formula translating system

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About the Tutorial

Fortran was originally developed by a team at IBM in 1957 for scientific calculations. Later developments made it into a high level programming language. In this tutorial, we will learn the basic concepts of Fortran and its programming code.

Audience

This tutorial is designed for the readers who wish to learn the basics of Fortran.

Prerequisites

This tutorial is designed for beginners. A general awareness of computer programming languages is the only prerequisite to make the most of this tutorial.

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1. OVERVIEW

Fortran, as derived from Formula Translating System, is a general-purpose, imperative programming language. It is used for numeric and scientific computing.

Fortran was originally developed by IBM in the 1950s for scientific and engineering applications. Fortran ruled this programming area for a long time and became very popular for high performance computing, because.

It supports:

- Numerical analysis and scientific computation
- Structured programming
- Array programming
- Modular programming
- Generic programming
- High performance computing on supercomputers
- Object oriented programming
- Concurrent programming
- Reasonable degree of portability between computer systems

Facts about Fortran

- Fortran was created by a team, led by John Backus at IBM in 1957.
- Initially the name used to be written in all capital, but current standards and implementations only require the first letter to be capital.
- Fortran stands for FORmula TRANslator.
- Originally developed for scientific calculations, it had very limited support for character strings and other structures needed for general purpose programming.
- Later extensions and developments made it into a high level programming language with good degree of portability.
- Original versions, Fortran I, II and III are considered obsolete now.
- Oldest version still in use is Fortran IV, and Fortran 66.

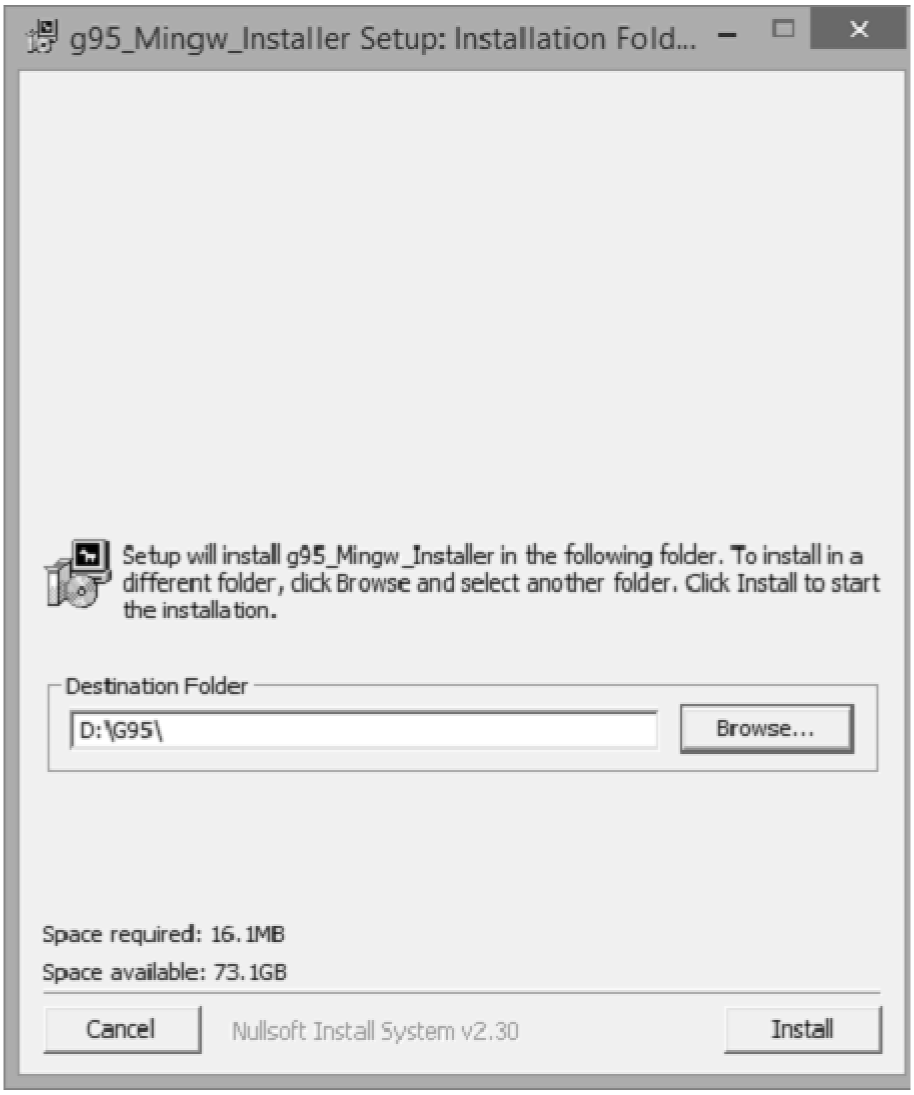
- Most commonly used versions today are : Fortran 77, Fortran 90, and Fortran 95.
- Fortran 77 added strings as a distinct type.
- Fortran 90 added various sorts of threading, and direct array processing.

2. ENVIRONMENT SETUP

Setting up Fortran in Windows

G95 is the GNU Fortran multi-architechtural compiler, used for setting up Fortran in Windows. The windows version emulates a unix environment using MingW under windows. The installer takes care of this and automatically adds g95 to the windows PATH variable.

You can get the stable version of G95 from here :


g95_Mingw_Installer Setup: Installation Fold...

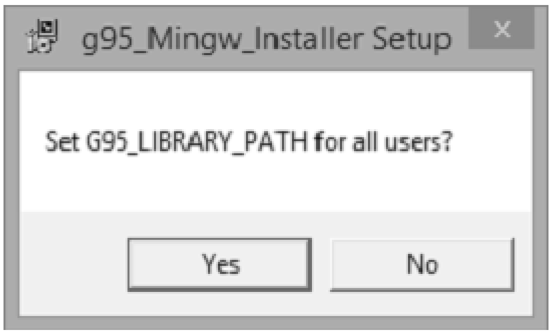
Setup will install g95_Mingw_Installer in the following folder. To install in a different folder, click Browse and select another folder. Click Install to start the installation.

Destination Folder: D:\G95\

Space required: 16.1MB

Space available: 73.1GB

Cancel
Nullsoft Install System v2.30
Install


g95_Mingw_Installer Setup

Set G95_LIBRARY_PATH for all users?

How to Use G95

During installation, **g95** is automatically added to your PATH variable if you select the option "RECOMMENDED". This means that you can simply open a new Command Prompt window and type "g95" to bring up the compiler. Find some basic commands below to get you started.

Command	**Description**
g95 –c hello.f90	Compiles hello.f90 to an object file named hello.o
g95 hello.f90	Compiles hello.f90 and links it to produce an executable a.out
g95 -c h1.f90 h2.f90 h3.f90	Compiles multiple source files. If all goes well, object files h1.o, h2.o and h3.o are created
g95 -o hello h1.f90 h2.f90 h3.f90	Compiles multiple source files and links them together to an executable file named 'hello'

Command line options for G95:

```
-c Compile only, do not run the linker.
-o Specify the name of the output file, either an object file or the
executable.
```

Multiple source and object files can be specified at once. Fortran files are indicated by names ending in ".f", ".F", ".for", ".FOR", ".f90", ".F90", ".f95", ".F95", ".f03" and ".F03". Multiple source files can be specified. Object files can be specified as well and will be linked to form an executable file.

3. BASIC SYNTAX

A Fortran program is made of a collection of program units like a main program, modules, and external subprograms or procedures.

Each program contains one main program and may or may not contain other program units. The syntax of the main program is as follows:

```
program program_name
implicit none

! type declaration statements
! executable statements

end program program_name
```

A Simple Program in Fortran

Let's write a program that adds two numbers and prints the result:

```
program addNumbers

! This simple program adds two numbers
   implicit none

! Type declarations
   real :: a, b, result

! Executable statements
   a = 12.0
   b = 15.0
   result = a + b
   print *, 'The total is ', result

end program addNumbers
```

When you compile and execute the above program, it produces the following result:

```
The total is 27.0000000
```

Please note that:

- All Fortran programs start with the keyword **program** and end with the keyword**end program,** followed by the name of the program.
- The **implicit none** statement allows the compiler to check that all your variable types are declared properly. You must always use **implicit none** at the start of every program.
- Comments in Fortran are started with the exclamation mark (!), as all characters after this (except in a character string) are ignored by the compiler.
- The **print *** command displays data on the screen.
- Indentation of code lines is a good practice for keeping a program readable.
- Fortran allows both uppercase and lowercase letters. Fortran is case-insensitive, except for string literals.

Basics

The **basic character set** of Fortran contains:

- the letters A ... Z and a ... z
- the digits 0 ... 9
- the underscore (_) character
- the special characters = : + blank - * / ( ) [ ] , . $ ' ! " % & ; < > ?

Tokens are made of characters in the basic character set. A token could be a keyword, an identifier, a constant, a string literal, or a symbol.

Program statements are made of tokens.

Identifier

An identifier is a name used to identify a variable, procedure, or any other user-defined item. A name in Fortran must follow the following rules:

- It cannot be longer than 31 characters.
- It must be composed of alphanumeric characters (all the letters of the alphabet, and the digits 0 to 9) and underscores (_).

- First character of a name must be a letter.
- Names are case-insensitive

Keywords

Keywords are special words, reserved for the language. These reserved words cannot be used as identifiers or names.

The following table, lists the Fortran keywords:

Non-I/O keywords				
allocatable	allocate	assign	assignment	block data
call	case	character	common	complex
contains	continue	cycle	data	deallocate
default	do	double precision	else	else if
elsewhere	end block data	end do	end function	end if
end interface	end module	end program	end select	end subroutine
end type	end where	entry	equivalence	exit
external	function	go to	if	implicit
in	inout	integer	intent	interface
intrinsic	kind	len	logical	module
namelist	nullify	only	operator	optional
out	parameter	pause	pointer	private

program	public	real	recursive	result
return	save	select case	stop	subroutine
target	then	type	type()	use
Where	While			
I/O related keywords				
backspace	close	endfile	format	inquire
open	print	read	rewind	Write

4. DATA TYPES

Fortran provides five intrinsic data types, however, you can derive your own data types as well. The five intrinsic types are:

- Integer type
- Real type
- Complex type
- Logical type
- Character type

Integer Type

The integer types can hold only integer values. The following example extracts the largest value that can be held in a usual four byte integer:

```
program testingInt
implicit none

   integer :: largeval
   print *, huge(largeval)

end program testingInt
```

When you compile and execute the above program it produces the following result:

```
2147483647
```

Note that the **huge()** function gives the largest number that can be held by the specific integer data type. You can also specify the number of bytes using the **kind** specifier. The following example demonstrates this:

```
program testingInt
implicit none

   !two byte integer
   integer(kind=2) :: shortval
   !four byte integer
   integer(kind=4) :: longval

   !eight byte integer
   integer(kind=8) :: verylongval

   !sixteen byte integer
   integer(kind=16) :: veryverylongval

   !default integer
   integer :: defval

   print *, huge(shortval)
   print *, huge(longval)
   print *, huge(verylongval)
   print *, huge(veryverylongval)
   print *, huge(defval)

end program testingInt
```

When you compile and execute the above program, it produces the following result:

```
32767
2147483647
9223372036854775807
170141183460469231731687303715884105727
2147483647
```

Real Type

It stores the floating point numbers, such as 2.0, 3.1415, -100.876, etc.

Traditionally there are two different real types, the default **real** type and **double precision**type.

However, Fortran 90/95 provides more control over the precision of real and integer data types through the**kind**specifier, which we will study in the chapter on Numbers.

The following example shows the use of real data type:

```
program division
implicit none

   ! Define real variables
   real :: p, q, realRes

   ! Define integer variables
   integer :: i, j, intRes

   ! Assigning  values
   p = 2.0
   q = 3.0
   i = 2
   j = 3

   ! floating point division
   realRes = p/q
   intRes = i/j

   print *, realRes
   print *, intRes

end program division
```

When you compile and execute the above program it produces the following result:

```
0.666666687
0
```

Complex Type

This is used for storing complex numbers. A complex number has two parts, the real part and the imaginary part. Two consecutive numeric storage units store these two parts.

For example, the complex number (3.0, -5.0) is equal to 3.0 – 5.0i

We will discuss Complex types in more detail, in the Numbers chapter.

Logical Type

There are only two logical values: **.true.** and **.false.**

Character Type

The character type stores characters and strings. The length of the string can be specified by len specifier. If no length is specified, it is 1.

For example,

```
character (len=40) :: name

name = “Zara Ali”
```

The expression, **name(1:4)** would give the substring “Zara”.

Implicit Typing

Older versions of Fortran allowed a feature called implicit typing, i.e., you do not have to declare the variables before use. If a variable is not declared, then the first letter of its name will determine its type.

Variable names starting with i, j, k, l, m, or n, are considered to be for integer variable and others are real variables. However, you must declare all the variables as it is good programming practice. For that you start your program with the statement:

```
implicit none
```

This statement turns off implicit typing.

5. VARIABLES

A variable is nothing but a name given to a storage area that our programs can manipulate. Each variable should have a specific type, which determines the size and layout of the variable's memory; the range of values that can be stored within that memory; and the set of operations that can be applied to the variable.

The name of a variable can be composed of letters, digits, and the underscore character. A name in Fortran must follow the following rules:

- It cannot be longer than 31 characters.
- It must be composed of alphanumeric characters (all the letters of the alphabet, and the digits 0 to 9) and underscores (_).
- First character of a name must be a letter.
- Names are case-insensitive.

Based on the basic types explained in previous chapter, following are the variable types:

Type	**Description**
Integer	It can hold only integer values.
Real	It stores the floating point numbers.
Complex	It is used for storing complex numbers.
Logical	It stores logical Boolean values.
Character	It stores characters or strings.

Variable Declaration

Variables are declared at the beginning of a program (or subprogram) in a type declaration statement.

Syntax for variable declaration is as follows:

```
type-specifier :: variable_name
```

For example,

```
integer :: total
real :: average
complex :: cx
logical :: done
character(len=80) :: message ! a string of 80 characters
```

Later you can assign values to these variables, like,

```
total = 20000
average = 1666.67
done = .true.
message = “A big Hello from Tutorials Point”
cx = (3.0, 5.0) ! cx = 3.0 + 5.0i
```

You can also use the intrinsic function **cmplx,** to assign values to a complex variable:

```
cx = cmplx (1.0/2.0, -7.0) ! cx = 0.5 – 7.0i
cx = cmplx (x, y) ! cx = x + yi
```

Example

The following example demonstrates variable declaration, assignment and display on screen:

```
program variableTesting
implicit none

   ! declaring variables
   integer :: total
   real :: average
   complex :: cx
   logical :: done
   character(len=80) :: message ! a string of 80 characters

   !assigning values
   total = 20000
   average = 1666.67
   done = .true.
   message = "A big Hello from Tutorials Point"
   cx = (3.0, 5.0) ! cx = 3.0 + 5.0i

   Print *, total
   Print *, average
   Print *, cx
   Print *, done
   Print *, message

end program variableTesting
```

When the above code is compiled and executed, it produces the following result:

```
20000
1666.67004
(3.00000000, 5.00000000 )
T
A big Hello from Tutorials Point
```

6. CONSTANTS

The constants refer to the fixed values that the program cannot alter during its execution. These fixed values are also called **literals**.

Constants can be of any of the basic data types like an integer constant, a floating constant, a character constant, a complex constant, or a string literal. There are only two logical constants : **.true.** and **.false.**

The constants are treated just like regular variables, except that their values cannot be modified after their definition.

Named Constants and Literals

There are two types of constants:

- Literal constants
- Named constants

A literal constant have a value, but no name.

For example, following are the literal constants:

Type	**Example**
Integer constants	0 1 -1 300 123456789
Real constants	0.0 1.0 -1.0 123.456 7.1E+10 -52.715E-30
Complex constants	(0.0, 0.0) (-123.456E+30, 987.654E-29)
Logical constants	.true. .false.
Character constants	"PQR" "a" "123'abc$%#@!" " a quote "" " 'PQR' 'a' '123"abc$%#@!' ' an apostrophe '' '

A named constant has a value as well as a name.

Named constants should be declared at the beginning of a program or procedure, just like a variable type declaration, indicating its name and type. Named constants are declared with the parameter attribute. For example,

```
real, parameter :: pi = 3.1415927
```

Example

The following program calculates the displacement due to vertical motion under gravity.

```
program gravitationalDisp

! this program calculates vertical motion under gravity
implicit none

   ! gravitational acceleration
   real, parameter :: g = 9.81

   ! variable declaration
   real :: s ! displacement
   real :: t ! time
   real :: u ! initial speed

   ! assigning values
   t = 5.0
   u = 50

   ! displacement
   s = u * t - g * (t**2) / 2

   ! output
   print *, "Time = ", t
   print *, 'Displacement = ',s

end program gravitationalDisp
```

When the above code is compiled and executed, it produces the following result:

```
Time = 5.00000000
Displacement = 127.374992
```

7. OPERATORS

An operator is a symbol that tells the compiler to perform specific mathematical or logical manipulations. Fortran provides the following types of operators:

- Arithmetic Operators
- Relational Operators
- Logical Operators

Let us look at all these types of operators one by one.

Arithmetic Operators

Following table shows all the arithmetic operators supported by Fortran. Assume variable **A**holds 5 and variable **B** holds 3 then:

Operator	Description	Example
+	Addition Operator, adds two operands.	A + B will give 8
-	Subtraction Operator, subtracts second operand from the first.	A - B will give 2
*	Multiplication Operator, multiplies both operands.	A * B will give 15
/	Division Operator, divides numerator by de-numerator.	A / B will give 1
**	Exponentiation Operator, raises one operand to the power of the other.	A ** B will give 125

Example

Try the following example to understand all the arithmetic operators available in Fortran:

```
program arithmeticOp


! this program performs arithmetic calculation
```

```
implicit none

   ! variable declaration
   integer :: a, b, c

   ! assigning values
   a = 5
   b = 3

   ! Exponentiation
   c = a ** b

   ! output
   print *, "c = ", c

   ! Multiplication
   c = a * b

   ! output
   print *, "c = ", c

   ! Division
   c = a / b

   ! output
   print *, "c = ", c

   ! Addition
   c = a + b

   ! output
   print *, "c = ", c
   ! Subtraction
   c = a - b

   ! output
   print *, "c = ", c

end program arithmeticOp
```

When you compile and execute the above program, it produces the following result:

```
c = 125
c = 15
c = 1
c = 8
c = 2
```

Relational Operators

Following table shows all the relational operators supported by Fortran. Assume variable **A**holds 10 and variable **B** holds 20, then:

Operator	Equivalent	Description	Example
==	.eq.	Checks if the values of two operands are equal or not, if yes then condition becomes true.	(A == B) is not true.
/=	.ne.	Checks if the values of two operands are equal or not, if values are not equal then condition becomes true.	(A != B) is true.
>	.gt.	Checks if the value of left operand is greater than the value of right operand, if yes then condition becomes true.	(A > B) is not true.
<	.lt.	Checks if the value of left operand is less than the value of right operand, if	(A < B) is true.

		yes then condition becomes true.	
>=	.ge.	Checks if the value of left operand is greater than or equal to the value of right operand, if yes then condition becomes true.	(A >= B) is not true.
<=	.le.	Checks if the value of left operand is less than or equal to the value of right operand, if yes then condition becomes true.	(A <= B) is true.

Example

Try the following example to understand all the logical operators available in Fortran:

```
program logicalOp

! this program checks logical operators
implicit none

   ! variable declaration
   logical :: a, b

   ! assigning values
   a = .true.
   b = .false.

   if (a .and. b) then
      print *, "Line 1 - Condition is true"
   else
      print *, "Line 1 - Condition is false"
   end if

   if (a .or. b) then
      print *, "Line 2 - Condition is true"
   else
      print *, "Line 2 - Condition is false"
   end if

   ! changing values
   a = .false.
   b = .true.

   if (.not.(a .and. b)) then
      print *, "Line 3 - Condition is true"
   else
      print *, "Line 3 - Condition is false"
   end if

   if (b .neqv. a) then
      print *, "Line 4 - Condition is true"
   else
      print *, "Line 4 - Condition is false"
   end if

   if (b .eqv. a) then
      print *, "Line 5 - Condition is true"
   else
      print *, "Line 5 - Condition is false"
   end if

end program logicalOp
```

When you compile and execute the above program it produces the following result:

```
Line 1 - Condition is false
Line 2 - Condition is true
Line 3 - Condition is true
Line 4 - Condition is true
Line 5 - Condition is false
```

Logical Operators

Logical operators in Fortran work only on logical values .true. and .false.

The following table shows all the logical operators supported by Fortran. Assume variable A holds **.true.** and variable B holds **.false.** , then:

Operator	Description	Example
.and.	Called Logical AND operator. If both the operands are non-zero, then condition becomes true.	(A .and. B) is false.
.or.	Called Logical OR Operator. If any of the two operands is non-zero, then condition becomes true.	(A .or. B) is true.
.not.	Called Logical NOT Operator. Use to reverses the logical state of its operand. If a condition is true then Logical NOT operator will make false.	!(A .and. B) is true.
.eqv.	Called Logical EQUIVALENT Operator. Used to check equivalence of two logical values.	(A .eqv. B) is false.
.neqv.	Called Logical NON-EQUIVALENT Operator. Used to check non-equivalence of two logical values.	(A .neqv. B) is true.

Example

Try the following example to understand all the logical operators available in Fortran:

```
program logicalOp
! this program checks logical operators
implicit none
   ! variable declaration
   logical :: a, b
   ! assigning values
   a = .true.
   b = .false.
   if (a .and. b) then
      print *, "Line 1 - Condition is true"
   else
      print *, "Line 1 - Condition is false"
   end if

    if (a .or. b) then
      print *, "Line 2 - Condition is true"
   else
      print *, "Line 2 - Condition is false"
   end if


   ! changing values
   a = .false.
   b = .true.

   if (.not.(a .and. b)) then
      print *, "Line 3 - Condition is true"
   else
      print *, "Line 3 - Condition is false"
   end if

   if (b .neqv. a) then
      print *, "Line 4 - Condition is true"
   else
      print *, "Line 4 - Condition is false"
   end if
   if (b .eqv. a) then
      print *, "Line 5 - Condition is true"
   else
      print *, "Line 5 - Condition is false"
   end if


end program logicalOp
```

When you compile and execute the above program it produces the following result:

```
Line 1 - Condition is false
Line 2 - Condition is true
Line 3 - Condition is true
Line 4 - Condition is true
Line 5 - Condition is false
```

Operators Precedence in Fortran

Operator precedence determines the grouping of terms in an expression. This affects how an expression is evaluated. Certain operators have higher precedence than others; for example, the multiplication operator has higher precedence than the addition operator.

For example, x = 7 + 3 * 2; here, x is assigned 13, not 20 because operator * has higher precedence than +, so it first gets multiplied with 3*2 and then adds into 7.

Here, operators with the highest precedence appear at the top of the table, those with the lowest appear at the bottom. Within an expression, higher precedence operators will be evaluated first.

Category	**Operator**	**Associativity**
Logical NOT and negative sign	.not. (-)	Left to right
Exponentiation	**	Left to right
Multiplicative	* /	Left to right
Additive	+ -	Left to right
Relational	< <= > >=	Left to right

Equality	== !=	Left to right
Logical AND	.and.	Left to right
Logical OR	.or.	Left to right
Assignment	=	Right to left

Example

Try the following example to understand the operator precedence in Fortran:

```
program precedenceOp
! this program checks logical operators

implicit none

   ! variable declaration
   integer :: a, b, c, d, e

   ! assigning values
   a = 20
   b = 10
   c = 15
   d = 5

   e = (a + b) * c / d      ! ( 30 * 15 ) / 5
   print *, "Value of (a + b) * c / d is :    ",  e

   e = ((a + b) * c) / d    ! (30 * 15 ) / 5
   print *, "Value of ((a + b) * c) / d is  : ",  e

   e = (a + b) * (c / d);   ! (30) * (15/5)
   print *, "Value of (a + b) * (c / d) is  : ",  e
   e = a + (b * c) / d;      !  20 + (150/5)
   print *, "Value of a + (b * c) / d is  :   " ,  e

end program precedenceOp
```

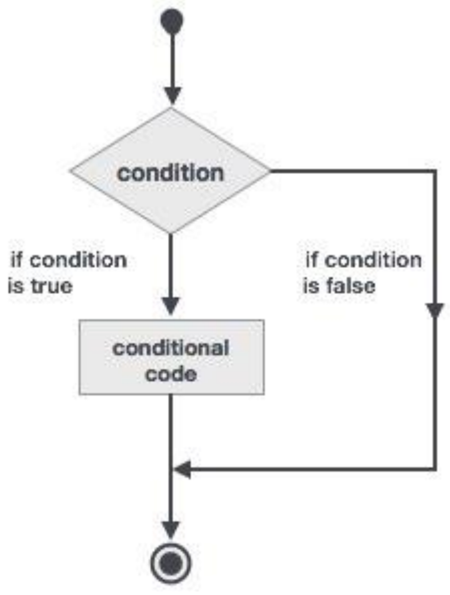
When you compile and execute the above program it produces the following result:

```
Value of (a + b) * c / d is : 90
Value of ((a + b) * c) / d is : 90
Value of (a + b) * (c / d) is : 90
Value of a + (b * c) / d is : 50
```

8. DECISIONS

Decision making structures require that the programmer specify one or more conditions to be evaluated or tested by the program, along with a statement or statements to be executed, if the condition is determined to be true, and optionally, other statements to be executed if the condition is determined to be false.

Following is the general form of a typical decision making structure found in most of the programming languages:



Fortran provides the following types of decision making constructs.

Statement	Description
If… then construct	An if… then… end if statement consists of a logical expression followed by one or more statements.
If… then...else construct	An if… then statement can be followed by an optional else statement, which executes when the logical expression is false.
nested if construct	You can use one if or else if statement inside another if or else if statement(s).

select case construct	A select case statement allows a variable to be tested for equality against a list of values.
nested select case construct	You can use one select case statement inside another select case statement(s).

If…then Construct

An **if… then** statement consists of a logical expression followed by one or more statements and terminated by an **end if** statement.

Syntax

The basic syntax of an **if… then** statement is:

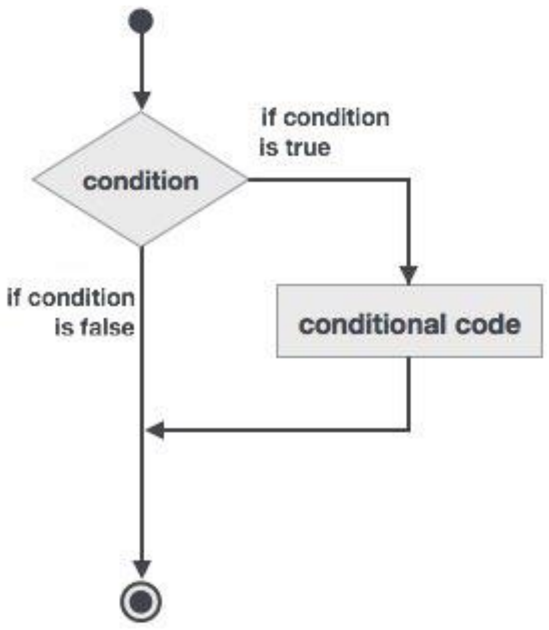
```
if (logical expression) then
   statement
end if
```

However, you can give a name to the **if** block, then the syntax of the named **if** statement would be, like:

```
[name:] if (logical expression) then
   ! various statements
   . . .
end if [name]
```

If the logical expression evaluates to **true**, then the block of code inside the **if…then** statement will be executed. If logical expression evaluates to **false**, then the first set of code after the **end if** statement will be executed.

Flow Diagram



Example 1

```
program ifProg
implicit none
   ! local variable declaration
   integer :: a = 10

   ! check the logical condition using if statement
   if (a < 20 ) then

       ! if condition is true then print the following
       print*, "a is less than 20"
   end if

   print*, "value of a is ", a

end program ifProg
```

When the above code is compiled and executed, it produces the following result:

```
a is less than 20
 value of a is     10
```

Example 2

This example demonstrates a named **if** block:

```
program markGradeA
implicit none
  real :: marks
  ! assign marks
  marks = 90.4
  ! use an if statement to give grade

  gr: if (marks > 90.0) then
  print *, " Grade A"
  end if gr
 end program markGradeA
```

When the above code is compiled and executed, it produces the following result:

```
Grade A
```

If… then… else Construct

An **if… then** statement can be followed by an optional **else statement**, which executes when the logical expression is false.

Syntax

The basic syntax of an **if… then… else** statement is:

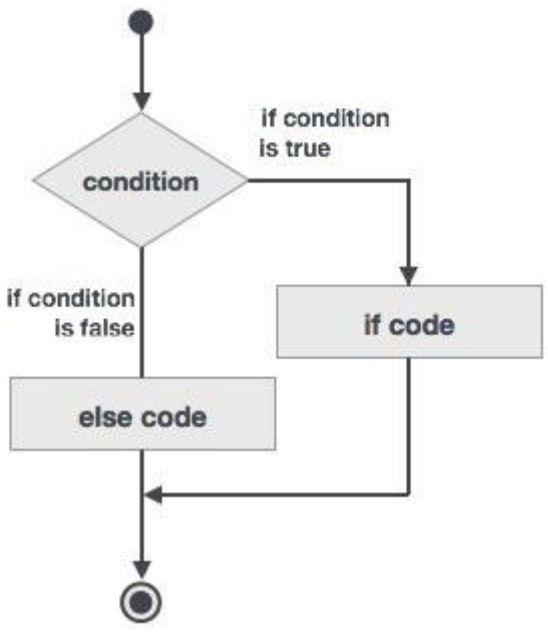
```
if (logical expression) then
   statement(s)
else
   other_statement(s)
end if
```

However, if you give a name to the **if** block, then the syntax of the named **if-else** statement would be, like:

```
[name:] if (logical expression) then
      ! various statements
   . . .
   else
      !other statement(s)
   . . .
end if [name]
```

If the logical expression evaluates to **true**, then the block of code inside the **if**…**then** statement will be executed, otherwise the block of code inside the **else** block will be executed.

Flow Diagram



Example

```
program ifElseProg
implicit none
   ! local variable declaration
   integer :: a = 100

   ! check the logical condition using if statement
   if (a < 20 ) then

      ! if condition is true then print the following
      print*, "a is less than 20"
   else
      print*, "a is not less than 20"
   end if

   print*, "value of a is ", a

end program ifElseProg
```

When the above code is compiled and executed, it produces the following result:

```
a is not less than 20
 value of a is       100
```

if...else if...else Statement

An **if** statement construct can have one or more optional **else-if** constructs. When the **if**condition fails, the immediately followed **else-if** is executed. When the **else-if** also fails, its successor **else-if** statement (if any) is executed, and so on.

The optional else is placed at the end and it is executed when none of the above conditions hold true.

- All else statements (else-if and else) are optional.
- **else-if** can be used one or more times
- **else** must always be placed at the end of construct and should appear only once.

Syntax

The syntax of an **if...else if...else** statement is:

```
[name:]
if (logical expression 1) then
   ! block 1
else if (logical expression 2) then
   ! block 2
else if (logical expression 3) then
   ! block 3
else
```

```
   ! block 4
end if [name]
```

Example

```
program ifElseIfElseProg
implicit none

   ! local variable declaration
   integer :: a = 100

   ! check the logical condition using if statement
   if( a == 10 ) then

      ! if condition is true then print the following
      print*, "Value of a is 10"

   else if( a == 20 ) then

      ! if else if condition is true
      print*, "Value of a is 20"

   else if( a == 30 ) then

      ! if else if condition is true
      print*, "Value of a is 30"

   else

      ! if none of the conditions is true
      print*, "None of the values is matching"

   end if

   print*, "exact value of a is ", a

end program ifElseIfElseProg
```

When the above code is compiled and executed, it produces the following result:

```
None of the values is matching
exact value of a is 100
```

Nested If Construct

You can use one **if** or **else if** statement inside another **if** or **else if** statement(s).

Syntax

The syntax for a nested **if** statement is as follows:

```
if ( logical_expression 1) then
   !Executes when the boolean expression 1 is true
   …
   if(logical_expression 2)then
      ! Executes when the boolean expression 2 is true
        …
   end if
end if
```

Example

```
program nestedIfProg
implicit none
   ! local variable declaration
   integer :: a = 100, b= 200

   ! check the logical condition using if statement
   if( a == 100 ) then

       ! if condition is true then check the following

```

```
      if( b == 200 ) then

         ! if inner if condition is true
         print*, "Value of a is 100 and b is 200"

      end if
   end if

   print*, "exact value of a is ", a
   print*, "exact value of b is ", b

end program nestedIfProg
```

When the above code is compiled and executed, it produces the following result:

```
Value of a is 100 and b is 200
exact value of a is          100
exact value of b is          200
```

Select Case Construct

A **select case** statement allows a variable to be tested for equality against a list of values. Each value is called a case, and the variable being selected on is checked for each **select case**.

Syntax

The syntax for the **select case** construct is as follows:

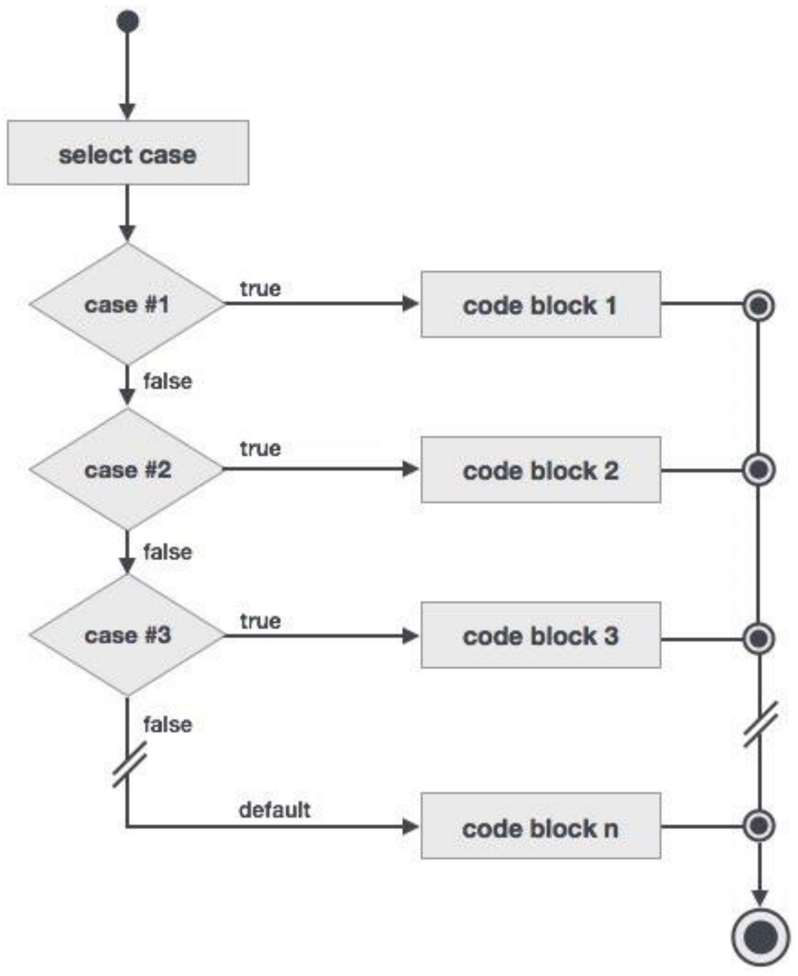
```
[name:] select case (expression)
      case (selector1)
       ! some statements
       ...        case (selector2)
      ! other statements
       ...
      case default
     ! more statements
       ...
```

```
end select [name]
```

The following rules apply to a **select** statement:

- The logical expression used in a select statement could be logical, character, or integer (but not real) expression.
- You can have any number of case statements within a select. Each case is followed by the value to be compared to and could be logical, character, or integer (but not real) expression and determines which statements are executed.
- The constant-expression for a case, must be the same data type as the variable in the select, and it must be a constant or a literal.
- When the variable being selected on, is equal to a case, the statements following that case will execute until the next case statement is reached.
- The case default block is executed if the expression in select case (expression) does not match any of the selectors.

Flow Diagram



Example 1

```
program selectCaseProg
implicit none
   ! local variable declaration
   character :: grade = 'B'

   select case (grade)

   case ('A')
      print*, "Excellent!"

   case ('B')
   case ('C')
      print*, "Well done"
   case ('D')
      print*, "You passed"

   case ('F')
      print*, "Better try again"

   case default
      print*, "Invalid grade"
   end select
   print*, "Your grade is ", grade

end program selectCaseProg
```

When the above code is compiled and executed, it produces the following result:

```
Your grade is B
```

Specifying a Range for the Selector

You can specify a range for the selector, by specifying a lower and upper limit separated by a colon:

```
case (low:high)
```

The following example demonstrates this:

Example 2

```
program selectCaseProg
implicit none
   ! local variable declaration
   integer :: marks = 78

   select case (marks)

   case (91:100)
      print*, "Excellent!"

   case (81:90)
      print*, "Very good!"

   case (71:80)
      print*, "Well done!"

   case (61:70)
      print*, "Not bad!"

   case (41:60)
      print*, "You passed!"

   case (:40)
      print*, "Better try again!"

   case default
      print*, "Invalid marks"
   end select
   print*, "Your marks is ", marks

end program selectCaseProg
```

When the above code is compiled and executed, it produces the following result:

```
Well done!
Your marks is           78
```

Nested Select Case Construct

You can use one **select case** statement inside another **select case** statement(s).

Syntax

```
select case(a)
      case (100)
         print*, "This is part of outer switch", a
         select case(b)
            case (200)
               print*, "This is part of inner switch", a
         end select
   end select
```

Example

```
program nestedSelectCase
   ! local variable definition
   integer :: a = 100
   integer :: b = 200

   select case(a)
      case (100)
         print*, "This is part of outer switch", a
         select case(b)
            case (200)
               print*, "This is part of inner switch", a
         end select
   end select
   print*, "Exact value of a is : ", a
   print*, "Exact value of b is : ", b

end program nestedSelectCase
```

When the above code is compiled and executed, it produces the following result:

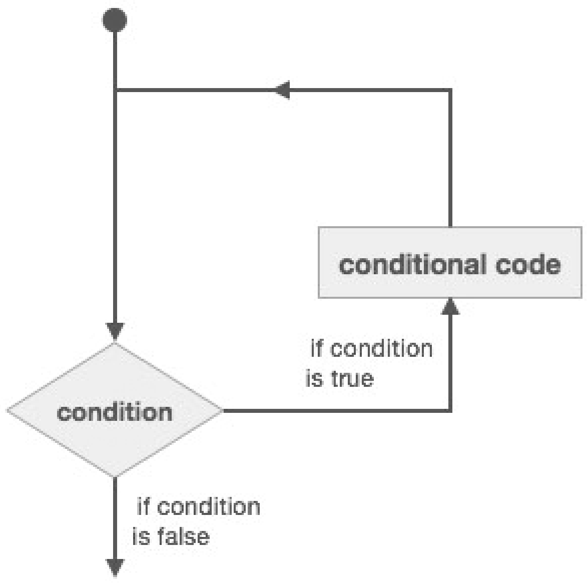
```
This is part of outer switch         100
This is part of inner switch         100
Exact value of a is :          100
Exact value of b is :          200
```

9. LOOPS

There may be a situation, when you need to execute a block of code several number of times. In general, statements are executed sequentially : The first statement in a function is executed first, followed by the second, and so on.

Programming languages provide various control structures that allow for more complicated execution paths.

A loop statement allows us to execute a statement or group of statements multiple times and following is the general form of a loop statement in most of the programming languages:



Fortran provides the following types of loop constructs to handle looping requirements. Click the following links to check their detail.

Loop Type	Description
do loop	This construct enables a statement, or a series of statements, to be carried out iteratively, while a given condition is true.
do while loop	Repeats a statement or group of statements while a given condition is true. It tests the condition before executing the loop body.
nested loops	You can use one or more loop construct inside any other loop

	construct.

do Loop

The do loop construct enables a statement, or a series of statements, to be carried out iteratively, while a given condition is true.

Syntax

The general form of the do loop is:

```
do var = start, stop [,step]
   ! statement(s)
   …
end do
```

Where,

- the loop variable var should be an integer
- start is initial value
- stop is the final value
- step is the increment, if this is omitted, then the variable var is increased by unity

For example:

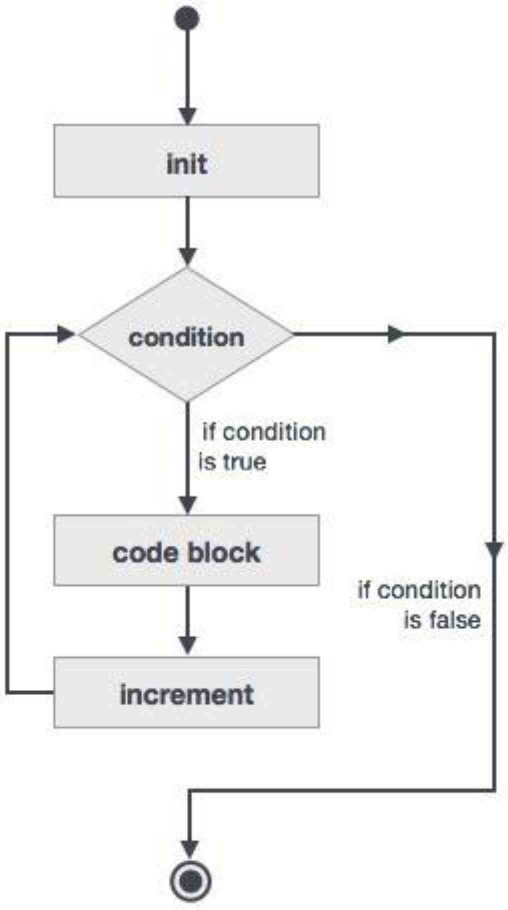
```
! compute factorials
do n = 1, 10
   nfact = nfact * n
   ! printing the value of n and its factorial
   print*,  n, " ", nfact
end do
```

Flow Diagram

Here is the flow of control for the do loop construct:

- The initial step is executed first, and only once. This step allows you to declare and initialize any loop control variables. In our case, the variable var is initialised with the value start.

- Next, the condition is evaluated. If it is true, the body of the loop is executed. If it is false, the body of the loop does not execute and flow of control jumps to the next statement just after the loop. In our case, the condition is that the variable var reaches its final value stop.
- After the body of the loop executes, the flow of control jumps back up to the increment statement. This statement allows you to update the loop control variable var.
- The condition is now evaluated again. If it is true, the loop executes and the process repeats itself (body of loop, then increment step, and then again condition). After the condition becomes false, the loop terminates.



Example 1

This example prints the numbers 11 to 20:

```
program printNum
implicit none


   ! define variables
   integer :: n
   do n = 11, 20
      ! printing the value of n
      print*,  n
   end do

end program printNum
```

When the above code is compiled and executed, it produces the following result:

```
11
12
13
14
15
16
17
18
19
20
```

Example 2

This program calculates the factorials of numbers 1 to 10:

```
program factorial
implicit none

   ! define variables
   integer :: nfact = 1
   integer :: n

   ! compute factorials
   do n = 1, 10
      nfact = nfact * n
      ! print values
      print*,  n, " ", nfact
   end do

end program factorial
```

When the above code is compiled and executed, it produces the following result:

```
1          1
2          2
3          6
4         24
5        120
6        720
7       5040
8      40320
9     362880
10   3628800
```

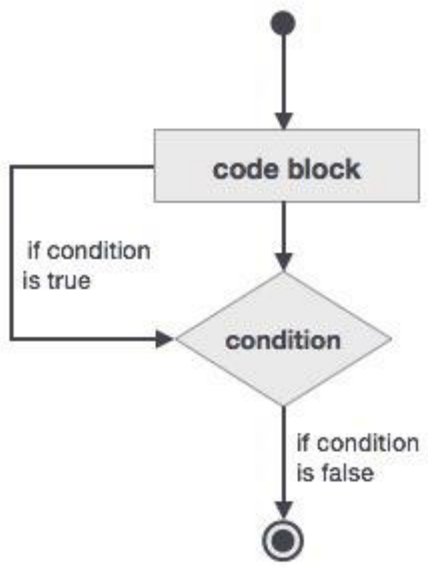
do-while Loop

It repeats a statement or a group of statements while a given condition is true. It tests the condition before executing the loop body.

Syntax

```
do while (logical expr)
   statements
end do
```

Flow Diagram



Example

```
program factorial
implicit none

   ! define variables
   integer :: nfact = 1
   integer :: n = 1

   ! compute factorials
   do while (n <= 10)
      nfact = nfact * n
      n = n + 1
      print*,  n, " ", nfact
   end do
end program factorial
```

When the above code is compiled and executed, it produces the following result:

```
1          1
2          2
3          6
4         24
5        120
```

```
6       720
7      5040
8     40320
9    362880
10  3628800
```

Nested Loops

You can use one or more loop construct inside any another loop construct. You can also put labels on loops.

Syntax

```
iloop: do i = 1, 3
   print*, "i: ", i

   jloop: do j = 1, 3
      print*, "j: ", j

      kloop: do k = 1, 3
         print*, "k: ", k

      end do kloop
   end do jloop
end do iloop
```

Example

```
program nestedLoop
implicit none

   integer:: i, j, k

   iloop: do i = 1, 3
      jloop: do j = 1, 3
```

```
         kloop: do k = 1, 3

            print*, "(i, j, k): ", i, j, k

         end do kloop
      end do jloop
   end do iloop

end program nestedLoop
```

When the above code is compiled and executed, it produces the following result:

```
(i, j, k): 1  1  1
(i, j, k): 1  1  2
(i, j, k): 1  1  3
(i, j, k): 1  2  1
(i, j, k): 1  2  2
(i, j, k): 1  2  3
(i, j, k): 1  3  1
(i, j, k): 1  3  2
(i, j, k): 1  3  3
(i, j, k): 2  1  1
(i, j, k): 2  1  2
(i, j, k): 2  1  3
(i, j, k): 2  2  1
(i, j, k): 2  2  2
(i, j, k): 2  2  3
(i, j, k): 2  3  1
(i, j, k): 2  3  2
(i, j, k): 2  3  3
(i, j, k): 3  1  1
(i, j, k): 3  1  2
(i, j, k): 3  1  3
(i, j, k): 3  2  1
```

```
(i, j, k): 3   2   2
```

Loop Control Statements

Loop control statements change execution from its normal sequence. When execution leaves a scope, all automatic objects that were created in that scope are destroyed.

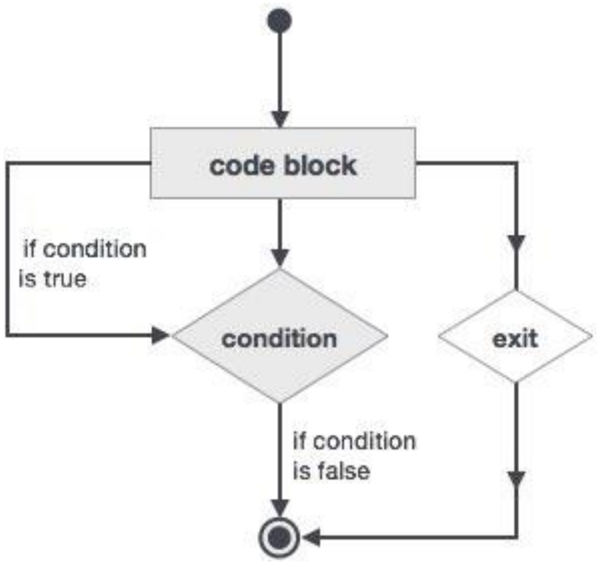
Fortran supports the following control statements. Click the following links to check their detail.

Control Statement	Description
exit	If the exit statement is executed, the loop is exited, and the execution of the program continues at the first executable statement after the end do statement.
cycle	If a cycle statement is executed, the program continues at the start of the next iteration.
stop	If you wish execution of your program to stop, you can insert a stop statement

Exit Statement

Exit statement terminates the loop or select case statement, and transfers execution to the statement immediately following the loop or select.

Flow Diagram



Example

```
program nestedLoop
implicit none

integer:: i, j, k
   iloop: do i = 1, 3
      jloop: do j = 1, 3
         kloop: do k = 1, 3

         print*, "(i, j, k): ", i, j, k

         if (k==2) then
            exit jloop
         end if

         end do kloop
      end do jloop
   end do iloop

end program nestedLoop
```

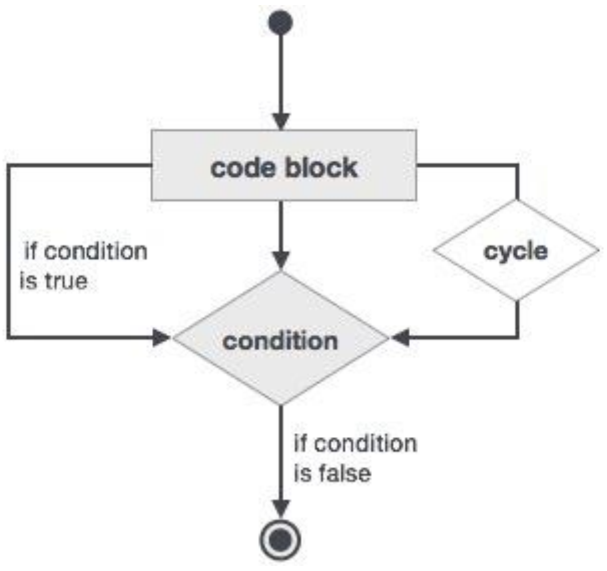
When the above code is compiled and executed, it produces the following result:

```
(i, j, k): 1  1  1
(i, j, k): 1  1  2
(i, j, k): 2  1  1
(i, j, k): 2  1  2
(i, j, k): 3  1  1
(i, j, k): 3  1  2
```

Cycle Statement

The cycle statement causes the loop to skip the remainder of its body, and immediately retest its condition prior to reiterating.

Flow diagram



Example

```
program cycle_example
implicit none

   integer :: i

   do i = 1, 20

      if (i == 5) then
```

```
         cycle
      end if

   print*, i
   end do

end program cycle_example
```

When the above code is compiled and executed, it produces the following result:

```
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
```

Stop Statement

If you wish execution of your program to cease, you can insert a stop statement.

Example

```
program stop_example
implicit none

   integer :: i
   do i = 1, 20

      if (i == 5) then
         stop
      end if

      print*, i
   end do

end program stop_example
```

When the above code is compiled and executed, it produces the following result:

```
1
2
3
4
```

10. NUMBERS

Numbers in Fortran are represented by three intrinsic data types:

- Integer type
- Real type
- Complex type

Integer Type

The integer types can hold only integer values. The following example extracts the largest value that could be hold in a usual four byte integer:

```
program testingInt
implicit none

   integer :: largeval
   print *, huge(largeval)

end program testingInt
```

When you compile and execute the above program it produces the following result:

```
2147483647
```

Please note that the **huge()** function gives the largest number that can be held by the specific integer data type. You can also specify the number of bytes using the **kind** specifier. The following example demonstrates this:

```
program testingInt
implicit none

   !two byte integer
   integer(kind=2) :: shortval

   !four byte integer
   integer(kind=4) :: longval
   !eight byte integer
   integer(kind=8) :: verylongval

   !sixteen byte integer
   integer(kind=16) :: veryverylongval

   !default integer
   integer :: defval

   print *, huge(shortval)
   print *, huge(longval)
   print *, huge(verylongval)
   print *, huge(veryverylongval)
   print *, huge(defval)

end program testingInt
```

When you compile and execute the above program it produces the following result:

```
32767
2147483647
9223372036854775807
170141183460469231731687303715884105727
2147483647
```

Real Type

It stores the floating point numbers, such as 2.0, 3.1415, -100.876, etc.

Traditionally there were two different **real** types : the default real type and **double precision** type.

However, Fortran 90/95 provides more control over the precision of real and integer data types through the **kind** specifier, which we will study shortly.

The following example shows the use of real data type:

```
program division
implicit none

   ! Define real variables
   real :: p, q, realRes

   ! Define integer variables
   integer :: i, j, intRes

   ! Assigning  values
   p = 2.0
   q = 3.0
   i = 2
   j = 3

   ! floating point division
   realRes = p/q
   intRes = i/j

   print *, realRes
   print *, intRes

end program division
```

When you compile and execute the above program it produces the following result:

```
0.666666687
0
```

Complex Type

This is used for storing complex numbers. A complex number has two parts : the real part and the imaginary part. Two consecutive numeric storage units store these two parts.

For example, the complex number (3.0, -5.0) is equal to 3.0 – 5.0i

The generic function **cmplx()** creates a complex number. It produces a result who's real and imaginary parts are single precision, irrespective of the type of the input arguments.

```
program createComplex
implicit none

   integer :: i = 10
   real :: x = 5.17
   print *, cmplx(i, x)

end program createComplex
```

When you compile and execute the above program it produces the following result:

```
(10.0000000, 5.17000008)
```

The following program demonstrates complex number arithmetic:

```
program ComplexArithmatic
implicit none

   complex, parameter :: i = (0, 1)   ! sqrt(-1)
   complex :: x, y, z

   x = (7, 8);
   y = (5, -7)
   write(*,*) i * x * y

   z = x + y
   print *, "z = x + y = ", z

   z = x - y
   print *, "z = x - y = ", z

   z = x * y
   print *, "z = x * y = ", z

   z = x / y
   print *, "z = x / y = ", z

end program ComplexArithmatic
```

When you compile and execute the above program it produces the following result:

```
(9.00000000, 91.0000000)
z = x + y = (12.0000000, 1.00000000)
z = x - y = (2.00000000, 15.0000000)
z = x * y = (91.0000000, -9.00000000)
z = x / y = (-0.283783793, 1.20270276)
```

The Range, Precision, and Size of Numbers

The range on integer numbers, the precision and the size of floating point numbers depends on the number of bits allocated to the specific data type.

The following table displays the number of bits and range for integers:

Number of bits	Maximum value	Reason
64	9,223,372,036,854,774,807	(2**63)–1
32	2,147,483,647	(2**31)–1

The following table displays the number of bits, smallest and largest value, and the precision for real numbers.

Number of bits	Largest value	Smallest value	Precision
64	0.8E+308	0.5E–308	15–18
32	1.7E+38	0.3E–38	6-9

The following examples demonstrate this:

```
program rangePrecision
implicit none

   real:: x, y, z
   x = 1.5e+40
   y = 3.73e+40
   z = x * y
   print *, z

end program rangePrecision
```

When you compile and execute the above program it produces the following result:

```
x = 1.5e+40
    1
Error : Real constant overflows its kind at (1)
main.f95:5.12:

y = 3.73e+40
    1
Error : Real constant overflows its kind at (1)
```

Now let us use a smaller number:

```
program rangePrecision
implicit none

   real:: x, y, z
   x = 1.5e+20
   y = 3.73e+20
   z = x * y
   print *, z

   z = x/y
   print *, z

end program rangePrecision
```

When you compile and execute the above program it produces the following result:

```
Infinity
0.402144760
```

Now let's watch underflow:

```
program rangePrecision
implicit none

   real:: x, y, z
   x = 1.5e-30
   y = 3.73e-60
   z = x * y
   print *, z

   z = x/y
   print *, z

end program rangePrecision
```

When you compile and execute the above program it produces the following result:

```
y = 3.73e-60
    1
Warning : Real constant underflows its kind at (1)

Executing the program....
$demo

0.00000000E+00
```

```
Infinity
```

The Kind Specifier

In scientific programming, one often needs to know the range and precision of data of the hardware platform on which the work is being done.

The intrinsic function **kind()** allows you to query the details of the hardware's data representations before running a program.

```
program kindCheck
implicit none

   integer :: i
   real :: r
   complex :: cp
   print *,' Integer ', kind(i)
   print *,' Real ', kind(r)
   print *,' Complex ', kind(cp)

end program kindCheck
```

When you compile and execute the above program it produces the following result:

```
Integer 4
Real 4
Complex 4
```

You can also check the kind of all data types:

```
program checkKind
implicit none

   integer :: i
   real :: r
   character*1 :: c
   logical :: lg
   complex :: cp

   print *,' Integer ', kind(i)
   print *,' Real ', kind(r)
   print *,' Complex ', kind(cp)
   print *,' Character ', kind(c)
   print *,' Logical ', kind(lg)

end program checkKind
```

When you compile and execute the above program it produces the following result:

```
Integer 4
Real 4
Complex 4
Character 1
Logical 4
```

11. CHARACTERS

The Fortran language can treat characters as single character or contiguous strings.

Characters could be any symbol taken from the basic character set, i.e., from the letters, the decimal digits, the underscore, and 21 special characters.

A character constant is a fixed valued character string.

The intrinsic data type **character** stores characters and strings. The length of the string can be specified by **len** specifier. If no length is specified, it is 1. You can refer individual characters within a string referring by position; the left most character is at position 1.

Character Declaration

Declaring a character type data is same as other variables:

```
type-specifier :: variable_name
```

For example,

```
character :: reply, sex
```

you can assign a value like,

```
reply = ‘N’
sex = ‘F’
```

The following example demonstrates declaration and use of character data type:

```
program hello
implicit none

   character(len=15) :: surname, firstname
   character(len=6) :: title
   character(len=25)::greetings

   title = 'Mr. '
   firstname = 'Rowan '
```

```
    surname = 'Atkinson'
    greetings = 'A big hello from Mr. Beans'

    print *, 'Here is ', title, firstname, surname
    print *, greetings

end program hello
```

When you compile and execute the above program it produces the following result:

```
Here is Mr. Rowan Atkinson
A big hello from Mr. Bean
```

Concatenation of Characters

The concatenation operator //, concatenates characters.

The following example demonstrates this:

```
program hello
implicit none

    character(len=15) :: surname, firstname
    character(len=6) :: title
    character(len=40):: name
    character(len=25)::greetings

    title = 'Mr. '
    firstname = 'Rowan '
    surname = 'Atkinson'

    name = title//firstname//surname
    greetings = 'A big hello from Mr. Beans'

    print *, 'Here is ', name
    print *, greetings
```

```

end program hello
```

When you compile and execute the above program it produces the following result:

```
Here is Mr.Rowan Atkinson

A big hello from Mr.Bean
```

Some Character Functions

The following table shows some commonly used character functions along with the description:

Function	Description
len(string)	It returns the length of a character string
index(string,sustring)	It finds the location of a substring in another string, returns 0 if not found.
achar(int)	It converts an integer into a character
iachar(c)	It converts a character into an integer
trim(string)	It returns the string with the trailing blanks removed.
scan(string, chars)	It searches the "string" from left to right (unless back=.true.) for the first occurrence of any character contained in "chars". It returns an integer giving the position of that character, or zero if none of the characters in "chars" have been found.
verify(string, chars)	It scans the "string" from left to right (unless back=.true.) for the first occurrence of any character not contained in "chars". It returns an integer giving the position of that character, or zero if only the characters in "chars" have been found
adjustl(string)	It left justifies characters contained in the "string"

adjustr(string)	It right justifies characters contained in the "string"
len_trim(string)	It returns an integer equal to the length of "string" (len(string)) minus the number of trailing blanks
repeat(string,ncopy)	It returns a string with length equal to "ncopy" times the length of "string", and containing "ncopy" concatenated copies of "string"

Example 1

This example shows the use of the **index** function:

```
program testingChars
implicit none

   character (80) :: text
   integer :: i

   text = 'The intrinsic data type character stores characters and
strings.'
   i=index(text,'character')

   if (i /= 0) then
      print *, ' The word character found at position ',i
      print *, ' in text: ', text
   end if

end program testingChars
```

When you compile and execute the above program it produces the following result:

```
The word character found at position 25
in text : The intrinsic data type character stores characters and
strings.
```

Example 2

This example demonstrates the use of the **trim** function:

```
program hello
implicit none

   character(len=15) :: surname, firstname
   character(len=6) :: title
   character(len=25)::greetings

   title = 'Mr.'
   firstname = 'Rowan'
   surname = 'Atkinson'

   print *, 'Here is', title, firstname, surname
   print *, 'Here is', trim(title),' ',trim(firstname),' ', trim(surname)

end program hello
```

When you compile and execute the above program it produces the following result:

```
Here is Mr. Rowan Atkinson
Here is Mr. Rowan Atkinson
```

Example 3

This example demonstrates the use of **achar** function

```
program testingChars
implicit none

   character:: ch
   integer:: i

   do i=65, 90
      ch = achar(i)
      print*, i, ' ', ch
   end do

end program testingChars
```

When you compile and execute the above program it produces the following result:

```
65   A
66   B
67   C
68   D
69   E
70   F
71   G
72   H
73   I
74   J
75   K
76   L
77   M
78   N
79   O
80   P
81   Q
82   R
83   S
84   T
85   U
86   V
87   W
88   X
89   Y
90   Z
```

Checking Lexical Order of Characters

The following functions determine the lexical sequence of characters:

Function	Description
lle(char, char)	Compares whether the first character is lexically less than or equal to the second
lge(char, char)	Compares whether the first character is lexically greater than or equal to the second
lgt(char, char)	Compares whether the first character is lexically greater than the second
llt(char, char)	Compares whether the first character is lexically less than the second

Example 4

The following function demonstrates the use:

```
program testingChars
implicit none

   character:: a, b, c
   a = 'A'
   b = 'a'
   c = 'B'

   if(lgt(a,b)) then
      print *, 'A is lexically greater than a'
   else
      print *, 'a is lexically greater than A'
   end if

   if(lgt(a,c)) then
      print *, 'A is lexically greater than B'
   else
      print *, 'B is lexically greater than A'
   end if

   if(llt(a,b)) then
      print *, 'A is lexically less than a'
   end if

   if(llt(a,c)) then
      print *, 'A is lexically less than B'
   end if

end program testingChars
```

When you compile and execute the above program it produces the following result:

```
a is lexically greater than A
B is lexically greater than A
A is lexically less than a
A is lexically less than B
```

12. STRINGS

The Fortran language can treat characters as single character or contiguous strings.

A character string may be only one character in length, or it could even be of zero length. In Fortran, character constants are given between a pair of double or single quotes.

The intrinsic data type **character** stores characters and strings. The length of the string can be specified by **len specifier**. If no length is specified, it is 1. You can refer individual characters within a string referring by position; the left most character is at position 1.

String Declaration

Declaring a string is same as other variables:

```
type-specifier :: variable_name
```

For example,

```
Character(len=20) :: firstname, surname
```

you can assign a value like,

```
character (len=40) :: name
name = “Zara Ali”
```

The following example demonstrates declaration and use of character data type:

```
program hello
implicit none

   character(len=15) :: surname, firstname
   character(len=6) :: title
   character(len=25)::greetings

   title = 'Mr.'
   firstname = 'Rowan'
   surname = 'Atkinson'
   greetings = 'A big hello from Mr. Beans'

   print *, 'Here is', title, firstname, surname
   print *, greetings

end program hello
```

When you compile and execute the above program it produces the following result:

```
Here is Mr. Rowan Atkinson
A big hello from Mr. Bean
```

String Concatenation

The concatenation operator //, concatenates strings.

The following example demonstrates this:

```
program hello
implicit none

   character(len=15) :: surname, firstname
   character(len=6) :: title
   character(len=40):: name
   character(len=25)::greetings

   title = 'Mr.'
   firstname = 'Rowan'
   surname = 'Atkinson'

   name = title//firstname//surname
   greetings = 'A big hello from Mr. Beans'

   print *, 'Here is', name
   print *, greetings

```

```
end program hello
```

When you compile and execute the above program it produces the following result:

```
Here is Mr. Rowan Atkinson

A big hello from Mr. Bean
```

Extracting Substrings

In Fortran, you can extract a substring from a string by indexing the string, giving the start and the end index of the substring in a pair of brackets. This is called extent specifier.

The following example shows how to extract the substring 'world' from the string 'hello world':

```
program subString


   character(len=11)::hello

   hello = "Hello World"

   print*, hello(7:11)


end program subString
```

When you compile and execute the above program it produces the following result:

```
World
```

Example

The following example uses the **date_and_time** function to give the date and time string. We use extent specifiers to extract the year, date, month, hour, minutes and second information separately.

```
program  datetime

implicit none


   character(len = 8) :: dateinfo ! ccyymmdd

   character(len = 4) :: year, month*2, day*2
   character(len = 10) :: timeinfo ! hhmmss.sss
   character(len = 2)  :: hour, minute, second*6

   call  date_and_time(dateinfo, timeinfo)

   !  let’s break dateinfo into year, month and day.
   !  dateinfo has a form of ccyymmdd, where cc = century, yy = year
   !  mm = month and dd = day

   year  = dateinfo(1:4)
   month = dateinfo(5:6)
   day   = dateinfo(7:8)

   print*, 'Date String:', dateinfo
   print*, 'Year:', year
   print *,'Month:', month
   print *,'Day:', day

   !  let’s break timeinfo into hour, minute and second.
   !  timeinfo has a form of hhmmss.sss, where h = hour, m = minute
   !  and s = second

   hour   = timeinfo(1:2)
   minute = timeinfo(3:4)
   second = timeinfo(5:10)

   print*, 'Time String:', timeinfo
   print*, 'Hour:', hour
   print*, 'Minute:', minute
   print*, 'Second:', second

end program  datetime
```

When you compile and execute the above program, it gives the detailed date and time information:

```
Date String: 20140803
   Year: 2014
   Month: 08
   Day: 03
   Time String: 075835.466
   Hour: 07
   Minute: 58
   Second: 35.466
```

Trimming Strings

The **trim** function takes a string, and returns the input string after removing all trailing blanks.

Example

```
program trimString
implicit none

   character (len=*), parameter :: fname="Susanne", sname="Rizwan"
   character (len=20) :: fullname

   fullname=fname//" "//sname !concatenating the strings

   print*,fullname,", the beautiful dancer from the east!"
   print*,trim(fullname),", the beautiful dancer from the east!"

end program trimString
```

When you compile and execute the above program it produces the following result:

```
Susanne Rizwan, the beautiful dancer from the east!
Susanne Rizwan, the beautiful dancer from the east!
```

Left and Right Adjustment of Strings

The function **adjustl** takes a string and returns it by removing the leading blanks and appending them as trailing blanks.

The function **adjustr** takes a string and returns it by removing the trailing blanks and appending them as leading blanks.

Example

```
program hello
implicit none

   character(len=15) :: surname, firstname
   character(len=6) :: title
   character(len=40):: name
   character(len=25):: greetings

   title = 'Mr. '
   firstname = 'Rowan'
   surname = 'Atkinson'
   greetings = 'A big hello from Mr. Beans'

   name = adjustl(title)//adjustl(firstname)//adjustl(surname)
   print *, 'Here is', name
   print *, greetings

   name = adjustr(title)//adjustr(firstname)//adjustr(surname)
   print *, 'Here is', name
   print *, greetings

   name = trim(title)//trim(firstname)//trim(surname)
   print *, 'Here is', name
   print *, greetings

end program hello
```

When you compile and execute the above program it produces the following result:

```
Here is Mr. Rowan  Atkinson
A big hello from Mr. Bean
Here is Mr. Rowan Atkinson
A big hello from Mr. Bean
Here is Mr.RowanAtkinson
A big hello from Mr. Bean
```

Searching for a Substring in a String

The index function takes two strings and checks if the second string is a substring of the first string. If the second argument is a substring of the first argument, then it returns an integer which is the starting index of the second string in the first string, else it returns zero.

Example

```
program hello
implicit none

   character(len=30) :: myString
   character(len=10) :: testString

   myString = 'This is a test'
   testString = 'test'

   if(index(myString, testString) == 0)then
      print *, 'test is not found'
   else
      print *, 'test is found at index: ', index(myString, testString)
   end if

end program hello
```

When you compile and execute the above program it produces the following result:

```
test is found at index: 11
```

13. ARRAYS

Arrays can store a fixed-size sequential collection of elements of the same type. An array is used to store a collection of data, but it is often more useful to think of an array as a collection of variables of the same type.

All arrays consist of contiguous memory locations. The lowest address corresponds to the first element and the highest address to the last element.

Numbers(1)	Numbers(2)	Numbers(3)	Numbers(4)	…

Arrays can be one-dimensional (like vectors), two-dimensional (like matrices) and Fortran allows you to create up to 7-dimensional arrays.

Declaring Arrays

Arrays are declared with the **dimension** attribute.

For example, to declare a one-dimensional array named number, of real numbers containing 5 elements, you write,

```
real, dimension(5) :: numbers
```

The individual elements of arrays are referenced by specifying their subscripts. The first element of an array has a subscript of one. The array numbers contains five real variables –numbers(1), numbers(2), numbers(3), numbers(4), and numbers(5).

To create a 5 x 5 two-dimensional array of integers named matrix, you write:

```
integer, dimension (5,5) :: matrix
```

You can also declare an array with some explicit lower bound, for example:

```
real, dimension(2:6) :: numbers
integer, dimension (-3:2,0:4) :: matrix
```

Assigning Values

You can either assign values to individual members, like,

```
numbers(1) = 2.0
```

or, you can use a loop,

```
do i=1,5
   numbers(i) = i * 2.0
end do
```

One-dimensional array elements can be directly assigned values using a short hand symbol, called array constructor, like,

```
numbers = (/1.5, 3.2,4.5,0.9,7.2 /)
```

please note that there are no spaces allowed between the brackets '('and the back slash '/'

Example

The following example demonstrates the concepts discussed above.

```
program arrayProg

   real :: numbers(5) !one dimensional integer array
   integer :: matrix(3,3), i , j !two dimensional real array

   !assigning some values to the array numbers
   do i=1,5
      numbers(i) = i * 2.0
   end do

   !display the values
   do i = 1, 5
      Print *, numbers(i)
   end do

   !assigning some values to the array matrix
   do i=1,3
      do j = 1, 3
         matrix(i, j) = i+j
      end do
   end do

   !display the values
   do i=1,3
      do j = 1, 3
         Print *, matrix(i,j)
      end do
   end do

   !short hand assignment
   numbers = (/1.5, 3.2,4.5,0.9,7.2 /)

   !display the values
   do i = 1, 5
      Print *, numbers(i)
   end do

end program arrayProg
```

When the above code is compiled and executed, it produces the following result:

```
 2.00000000
 4.00000000
 6.00000000
 8.00000000
 10.0000000
         2
         3
         4
         3
         4
         5
         4
         5
         6
 1.50000000
 3.20000005
 4.50000000
0.899999976
 7.19999981
```

Some Array Related Terms

The following table gives some array related terms:

Term	Meaning
Rank	It is the number of dimensions an array has. For example, for the array named matrix, rank is 2, and for the array named numbers, rank is 1.
Extent	It is the number of elements along a dimension. For example, the array numbers has extent 5 and the array named matrix has extent 3 in both dimensions.
Shape	The shape of an array is a one-dimensional integer array, containing the number of elements (the extent) in each dimension. For example, for the array matrix, shape is (3, 3) and the array numbers it is (5).
Size	It is the number of elements an array contains. For the array matrix, it is 9, and for the array numbers, it is 5.

Passing Arrays to Procedures

You can pass an array to a procedure as an argument. The following example demonstrates the concept:

```
program arrayToProcedure
implicit none


   integer, dimension (5) :: myArray
   integer :: i


   call fillArray (myArray)
   call printArray(myArray)

end program arrayToProcedure



subroutine fillArray (a)
implicit none

   integer, dimension (5), intent (out) :: a

   ! local variables
   integer :: i
   do i = 1, 5
      a(i) = i
   end do

end subroutine fillArray



subroutine printArray(a)

   integer, dimension (5) :: a
   integer::i

   do i = 1, 5
      Print *, a(i)
   end do

end subroutine printArray
```

When the above code is compiled and executed, it produces the following result:

```
1
2
3
```

```
4
5
```

In the above example, the subroutine fillArray and printArray can only be called with arrays with dimension 5. However, to write subroutines that can be used for arrays of any size, you can rewrite it using the following technique:

```
program arrayToProcedure
implicit  none

   integer, dimension (10) :: myArray
   integer :: i

   interface
      subroutine fillArray (a)
         integer, dimension(:), intent (out) :: a
         integer :: i
      end subroutine fillArray

      subroutine printArray (a)
         integer, dimension(:) :: a
         integer :: i
      end subroutine printArray
   end interface

   call fillArray (myArray)
   call printArray(myArray)

end program arrayToProcedure



subroutine fillArray (a)
implicit none
   integer,dimension (:), intent (out) :: a
   ! local variables
   integer :: i, arraySize
   arraySize = size(a)

   do i = 1, arraySize
      a(i) = i
   end do

end subroutine fillArray

subroutine printArray(a)
implicit none

   integer,dimension (:) :: a
   integer::i, arraySize
   arraySize = size(a)

   do i = 1, arraySize
     Print *, a(i)
   end do

end subroutine printArray
```

Please note that the program is using the **size** function to get the size of the array.

When the above code is compiled and executed, it produces the following result:

```
1
2
3
4
5
6
7
8
```

```
9
10
```

Array Sections

So far we have referred to the whole array, Fortran provides an easy way to refer several elements, or a section of an array, using a single statement.

To access an array section, you need to provide the lower and the upper bound of the section, as well as a stride (increment), for all the dimensions. This notation is called a**subscript triplet:**

```
array ([lower]:[upper][:stride], ...)
```

When no lower and upper bounds are mentioned, it defaults to the extents you declared, and stride value defaults to 1.

The following example demonstrates the concept:

```
program arraySubsection

   real, dimension(10) :: a, b
   integer:: i, asize, bsize

   a(1:7) = 5.0 ! a(1) to a(7) assigned 5.0
   a(8:) = 0.0  ! rest are 0.0
   b(2:10:2) = 3.9
   b(1:9:2) = 2.5

   !display
   asize = size(a)
   bsize = size(b)

   do i = 1, asize
      Print *, a(i)
   end do

   do i = 1, bsize
      Print *, b(i)
   end do

end program arraySubsection
```

When the above code is compiled and executed, it produces the following result:

```
5.00000000
5.00000000
5.00000000
5.00000000
5.00000000
5.00000000
5.00000000
0.00000000E+00
0.00000000E+00
0.00000000E+00
2.50000000
3.90000010
2.50000000
3.90000010
2.50000000
3.90000010
2.50000000
3.90000010
2.50000000
3.90000010
```

Array Intrinsic Functions

Fortran 90/95 provides several intrinsic procedures. They can be divided into 7 categories:

- Vector and matrix multiplication
- Reduction
- Inquiry
- Construction

- Reshape
- Manipulation
- Location

Vector and Matrix Multiplication

The following table describes the vector and matrix multiplication functions:

Function	Description
dot_product(vector_a, vector_b)	This function returns a scalar product of two input vectors, which must have the same length.
matmul (matrix_a, matrix_b)	It returns the matrix product of two matrices, which must be consistent, i.e. have the dimensions like (m, k) and (k, n)

Example

The following example demonstrates dot product:

```
program arrayDotProduct


   real, dimension(5) :: a, b
   integer:: i, asize, bsize

   asize = size(a)
   bsize = size(b)

   do i = 1, asize
      a(i) = i
   end do

   do i = 1, bsize
      b(i) = i*2
   end do
   do i = 1, asize
      Print *, a(i)
   end do

   do i = 1, bsize
      Print *, b(i)
   end do

   Print*, 'Vector Multiplication: Dot Product:'
   Print*, dot_product(a, b)

end program arrayDotProduct
```

When the above code is compiled and executed, it produces the following result:

```
1.00000000
2.00000000
3.00000000
4.00000000
5.00000000
2.00000000
4.00000000
6.00000000
8.00000000
10.0000000
Vector Multiplication: Dot Product:
110.000000
```

Example

The following example demonstrates matrix multiplication:

```
program matMulProduct


   integer, dimension(3,3) :: a, b, c
   integer :: i, j
```

```
do i = 1, 3
   do j = 1, 3
      a(i, j) = i+j
   end do
end do

print *, 'Matrix Multiplication: A Matrix'

do i = 1, 3
   do j = 1, 3
      print*, a(i, j)
   end do
end do

do i = 1, 3
   do j = 1, 3
      b(i, j) = i*j
   end do
end do

Print*, 'Matrix Multiplication: B Matrix'

do i = 1, 3
   do j = 1, 3
      print*, b(i, j)
   end do
end do

c = matmul(a, b)
Print*, 'Matrix Multiplication: Result Matrix'

do i = 1, 3
```

```
      do j = 1, 3
         print*, c(i, j)
      end do
   end do

end program matMulProduct
```

When the above code is compiled and executed, it produces the following result:

```
Matrix Multiplication: A Matrix
2
3
4
3
4
5
4
5
6
 Matrix Multiplication: B Matrix
1
2
3
2
4
6
3
6
9
Matrix Multiplication: Result Matrix
20
40
60
26
52
```

```
78
32
64
96
```

Reduction

The following table describes the reduction functions:

Function	Description
all(mask, dim)	It returns a logical value that indicates whether all relations in mask are .true., along with only the desired dimension if the second argument is given.
any(mask, dim)	It returns a logical value that indicates whether any relation in mask is .true., along with only the desired dimension if the second argument is given.
count(mask, dim)	It returns a numerical value that is the number of relations in mask which are .true., along with only the desired dimension if the second argument is given.
maxval(array, dim, mask)	It returns the largest value in the array array, of those that obey the relation in the third argument mask, if that one is given, along with only the desired dimension if the second argument dim is given.
minval(array, dim, mask)	It returns the smallest value in the array array, of those that obey the relation in the third argument mask, if that one is given, along with only the desired dimension if the second argument DIM is given.
product(array, dim, mask)	It returns the product of all the elements in the array array, of those that obey the relation in the third argument mask, if that one is given, along with only the desired dimension if the second argument dim is given.

sum (array, dim, mask)	It returns the sum of all the elements in the array array, of those that obey the relation in the third argument mask, if that one is given, along with only the desired dimension if the second argument dim is given.

Example

The following example demonstrates the concept:

```
program arrayReduction


   real, dimension(3,2) :: a
   a = reshape( (/5,9,6,10,8,12/), (/3,2/) )


   Print *, all(a>5)
   Print *, any(a>5)
   Print *, count(a>5)
   Print *, all(a>=5 .and. a<10)


end program arrayReduction
```

When the above code is compiled and executed, it produces the following result:

```
F
T
5
F
```

Example

The following example demonstrates the concept:

```
program arrayReduction
implicit none


   real, dimension(1:6) :: a = (/ 21.0, 12.0,33.0, 24.0, 15.0, 16.0 /)
   Print *, maxval(a)
   Print *, minval(a)
   Print *, sum(a)
   Print *, product(a)

end program arrayReduction
```

When the above code is compiled and executed, it produces the following result:

```
33.0000000
12.0000000
121.000000
47900160.0
```

Inquiry

The following table describes the inquiry functions:

Function	**Description**
allocated(array)	It is a logical function which indicates if the array is allocated.
lbound(array, dim)	It returns the lower dimension limit for the array. If dim (the dimension) is not given as an argument, you get an integer vector, if dim is included, you get the integer value with exactly that lower dimension limit, for which you asked.
shape(source)	It returns the shape of an array source as an integer vector.
size(array, dim)	It returns the number of elements in an array. If dim is not given, and the number of elements in the relevant dimension if dim is included.
ubound(array, dim)	It returns the upper dimensional limits.

Example

The following example demonstrates the concept:

```
program arrayInquiry
```

```
   real, dimension(3,2) :: a
   a = reshape( (/5,9,6,10,8,12/), (/3,2/) )

   Print *, lbound(a, dim=1)
   Print *, ubound(a, dim=1)
   Print *, shape(a)
   Print *, size(a,dim=1)

end program arrayInquiry
```

When the above code is compiled and executed, it produces the following result:

```
1
3
3 2
3
```

Construction

The following table describes the construction functions:

Function	Description
merge(tsource, fsource, mask)	This function joins two arrays. It gives the elements in tsource if the condition in mask is .true. and fsource if the condition in mask is .false. The two fields tsource and fsource have to be of the same type and the same shape. The result also is of this type and shape. Also mask must have the same shape.
pack(array, mask, vector)	It packs an array to a vector with the control of mask. The shape of the logical array mask, has to agree with the one for array, or else mask must be a scalar. If vector is included, it has to be an array of rank 1 (i.e. a vector) with at least as many elements as those that are true in mask, and have the same type as array. If mask is a scalar with the value .true. then

	vector instead must have the same number of elements as array.
spread(source, dim, ncopies)	It returns an array of the same type as the argument source with the rank increased by one. The parameters dim and ncopies are integer. if ncopies is negative the value zero is used instead. If source is a scalar, then spread becomes a vector with ncopies elements that all have the same value as source. The parameter dim indicates which index is to be extended. it has to be within the range 1 and 1+(rank of source), if source is a scalar then dim has to be one. The parameter ncopies is the number of elements in the new dimensions.
unpack(vector, mask, array)	It scatters a vector to an array under control of mask. The shape of the logical array mask has to agree with the one for array. The array vector has to have the rank 1 (i.e. it is a vector) with at least as many elements as those that are true in mask, and also has to have the same type as array. If array is given as a scalar then it is considered to be an array with the same shape as mask and the same scalar elements everywhere. The result will be an array with the same shape as mask and the same type as vector. The values will be those from vector that are accepted, while in the remaining positions in array the old values are kept.

Example

The following example demonstrates the concept:

```
program arrayConstruction
implicit none
   interface
      subroutine write_array (a)
         real :: a(:,:)
      end subroutine write_array
      subroutine write_l_array (a)
         logical :: a(:,:)
      end subroutine write_l_array
   end interface

   real, dimension(2,3) :: tsource, fsource, result
   logical, dimension(2,3) :: mask

   tsource = reshape( (/ 35, 23, 18, 28, 26, 39 /), &
                    (/ 2, 3 /) )
   fsource = reshape( (/ -35, -23, -18, -28, -26, -39 /), &
                    (/ 2,3 /) )
   mask = reshape( (/ .true., .false., .false., .true., &
                 .false., .false. /), (/ 2,3 /) )

   result = merge(tsource, fsource, mask)
   call write_array(tsource)
   call write_array(fsource)
   call write_l_array(mask)
   call write_array(result)

end program arrayConstruction



subroutine write_array (a)

   real :: a(:,:)
   do i = lbound(a,1), ubound(a,1)
      write(*,*) (a(i, j), j = lbound(a,2), ubound(a,2) )
   end do
   return
```

```

end subroutine write_array


subroutine write_l_array (a)

   logical :: a(:,:)
   do i = lbound(a,1), ubound(a,1)
      write(*,*) (a(i, j), j= lbound(a,2), ubound(a,2))
   end do
   return

end subroutine write_l_array
```

When the above code is compiled and executed, it produces the following result:

```
35.0000000   18.0000000   26.0000000
23.0000000   28.0000000   39.0000000
-35.0000000  -18.0000000  -26.0000000
-23.0000000  -28.0000000  -39.0000000
T F F
F T F
35.0000000   -18.0000000  -26.0000000
-23.0000000  28.0000000   -39.0000000
```

Reshape

The following table describes the reshape function:

Function	Description
reshape(source, shape, pad, order)	It constructs an array with a specified shape shape starting from the elements in a given array source. If pad is not included then the size of source has to be at least product (shape). If pad is included, it has to have

	the same type as source. If order is included, it has to be an integer array with the same shape as shape and the values must be a permutation of (1,2,3,...,n), where n is the number of elements in shape , it has to be less than, or equal to 7.

Example

The following example demonstrates the concept:

```
program arrayReshape
implicit none

interface
   subroutine write_matrix(a)
   real, dimension(:,:) :: a
   end subroutine write_matrix
   end interface

   real, dimension (1:9) :: b = (/ 21, 22, 23, 24, 25, 26, 27, 28, 29 /)
   real, dimension (1:3, 1:3) :: c, d, e
   real, dimension (1:4, 1:4) :: f, g, h

   integer, dimension (1:2) :: order1 = (/ 1, 2 /)
   integer, dimension (1:2) :: order2 = (/ 2, 1 /)
   real, dimension (1:16) :: pad1 = (/ -1, -2, -3, -4, -5, -6, -7, -8, &
                                 & -9, -10, -11, -12, -13, -14, -15, -16
/)

   c = reshape( b, (/ 3, 3 /) )
   call write_matrix(c)

   d = reshape( b, (/ 3, 3 /), order = order1)
   call write_matrix(d)
   e = reshape( b, (/ 3, 3 /), order = order2)
   call write_matrix(e)

   f = reshape( b, (/ 4, 4 /), pad = pad1)
   call write_matrix(f)

   g = reshape( b, (/ 4, 4 /), pad = pad1, order = order1)
   call write_matrix(g)

   h = reshape( b, (/ 4, 4 /), pad = pad1, order = order2)
   call write_matrix(h)

end program arrayReshape


subroutine write_matrix(a)
   real, dimension(:,:) :: a
   write(*,*)

   do i = lbound(a,1), ubound(a,1)
      write(*,*) (a(i,j), j = lbound(a,2), ubound(a,2))
   end do
end subroutine write_matrix
```

When the above code is compiled and executed, it produces the following result:

```
21.0000000  24.0000000  27.0000000
22.0000000  25.0000000  28.0000000
23.0000000  26.0000000  29.0000000

21.0000000  24.0000000  27.0000000
22.0000000  25.0000000  28.0000000
23.0000000  26.0000000  29.0000000
```

```
21.0000000  22.0000000  23.0000000
24.0000000  25.0000000  26.0000000
27.0000000  28.0000000  29.0000000

21.0000000  25.0000000  29.0000000   -4.00000000
22.0000000  26.0000000  -1.00000000  -5.00000000
23.0000000  27.0000000  -2.00000000  -6.00000000
24.0000000  28.0000000  -3.00000000  -7.00000000

21.0000000  25.0000000  29.0000000   -4.00000000
22.0000000  26.0000000  -1.00000000  -5.00000000
23.0000000  27.0000000  -2.00000000  -6.00000000
24.0000000  28.0000000  -3.00000000  -7.00000000

21.0000000  22.0000000  23.0000000   24.0000000
25.0000000  26.0000000  27.0000000   28.0000000
29.0000000  -1.00000000 -2.00000000  -3.00000000
-4.00000000 -5.00000000 -6.00000000  -7.00000000
```

Manipulation

Manipulation functions are shift functions. The shift functions return the shape of an array unchanged, but move the elements.

Function	Description
cshift(array, shift, dim)	It performs circular shift by shift positions to the left, if shift is positive and to the right if it is negative. If array is a vector the shift is being done in a natural way, if it is an array of a higher rank then the shift is in all sections along the dimension dim. If dim is missing it is considered to be 1, in other cases it has to be a scalar integer number between 1 and n (where n equals the rank of array). The argument shift is a scalar integer or an integer array

	of rank n-1 and the same shape as the array, except along the dimension dim (which is removed because of the lower rank). Different sections can therefore be shifted in various directions and with various numbers of positions.
eoshift(array, shift, boundary, dim)	It is end-off shift. It performs shift to the left if shift is positive and to the right if it is negative. Instead of the elements shifted out new elements are taken from boundary. If array is a vector the shift is being done in a natural way, if it is an array of a higher rank, the shift on all sections is along the dimension dim. if dim is missing, it is considered to be 1, in other cases it has to have a scalar integer value between 1 and n (where n equals the rank of array). The argument shift is a scalar integer if array has rank 1, in the other case it can be a scalar integer or an integer array of rank n-1 and with the same shape as the array array except along the dimension dim (which is removed because of the lower rank).
transpose (matrix)	It transposes a matrix, which is an array of rank 2. It replaces the rows and columns in the matrix.

Example

The following example demonstrates the concept:

```
program arrayShift
implicit none

   real, dimension(1:6) :: a = (/ 21.0, 22.0, 23.0, 24.0, 25.0, 26.0 /)
   real, dimension(1:6) :: x, y
   write(*,10) a

   x = cshift ( a, shift = 2)
   write(*,10) x

   y = cshift (a, shift = -2)
   write(*,10) y

   x = eoshift ( a, shift = 2)
   write(*,10) x

   y = eoshift ( a, shift = -2)
   write(*,10) y

   10 format(1x,6f6.1)

end program arrayShift
```

When the above code is compiled and executed, it produces the following result:

```
21.0  22.0  23.0  24.0  25.0  26.0
23.0  24.0  25.0  26.0  21.0  22.0
25.0  26.0  21.0  22.0  23.0  24.0
23.0  24.0  25.0  26.0   0.0   0.0
0.0    0.0  21.0  22.0  23.0  24.0
```

Example

The following example demonstrates transpose of a matrix:

```
program matrixTranspose
implicit none

   interface
      subroutine write_matrix(a)
         integer, dimension(:,:) :: a
      end subroutine write_matrix
   end interface
   integer, dimension(3,3) :: a, b
   integer :: i, j

   do i = 1, 3
      do j = 1, 3
         a(i, j) = i
      end do
   end do

   print *, 'Matrix Transpose: A Matrix'

   call write_matrix(a)
   b = transpose(a)
   print *, 'Transposed Matrix:'

   call write_matrix(b)
end program matrixTranspose



subroutine write_matrix(a)

   integer, dimension(:,:) :: a
   write(*,*)

   do i = lbound(a,1), ubound(a,1)
      write(*,*) (a(i,j), j = lbound(a,2), ubound(a,2))
   end do

end subroutine write_matrix
```

When the above code is compiled and executed, it produces the following result:

```
Matrix Transpose: A Matrix
```

```
1   1   1
2   2   2
3   3   3
Transposed Matrix:

1   2   3
1   2   3
1   2   3
```

Location

The following table describes the location functions:

Function	Description
maxloc(array, mask)	It returns the position of the greatest element in the array array, if mask is included only for those which fulfil the conditions in mask, position is returned and the result is an integer vector.
minloc(array, mask)	It returns the position of the smallest element in the array array, if mask is included only for those which fulfil the conditions in mask, position is returned and the result is an integer vector.

Example

The following example demonstrates the concept:

```
program arrayLocation
implicit none

   real, dimension(1:6) :: a = (/ 21.0, 12.0,33.0, 24.0, 15.0, 16.0 /)
   Print *, maxloc(a)
   Print *, minloc(a)

end program arrayLocation
```

When the above code is compiled and executed, it produces the following result:

```
3
2
```

14. DYNAMIC ARRAYS

A **dynamic array** is an array, the size of which is not known at compile time, but will be known at execution time.

Dynamic arrays are declared with the attribute **allocatable**.

For example,

```
real, dimension (:,:), allocatable :: darray
```

The rank of the array, i.e., the dimensions has to be mentioned however, to allocate memory to such an array, you use the **allocate** function.

```
allocate ( darray(s1,s2) )
```

After the array is used, in the program, the memory created should be freed using the**deallocate** function

```
deallocate (darray)
```

Example

The following example demonstrates the concepts discussed above.

```
program dynamic_array
implicit none

   !rank is 2, but size not known
   real, dimension (:,:), allocatable :: darray
   integer :: s1, s2
   integer :: i, j

   print*, "Enter the size of the array:"
   read*, s1, s2

   ! allocate memory
   allocate ( darray(s1,s2) )
   do i = 1, s1
      do j = 1, s2
         darray(i,j) = i*j
         print*, "darray(",i,",",j,") = ", darray(i,j)
      end do
   end do

   deallocate (darray)
end program dynamic_array
```

When the above code is compiled and executed, it produces the following result:

```
Enter the size of the array: 3,4
darray( 1 , 1 ) = 1.00000000
darray( 1 , 2 ) = 2.00000000
darray( 1 , 3 ) = 3.00000000
darray( 1 , 4 ) = 4.00000000
darray( 2 , 1 ) = 2.00000000
darray( 2 , 2 ) = 4.00000000
darray( 2 , 3 ) = 6.00000000
darray( 2 , 4 ) = 8.00000000
darray( 3 , 1 ) = 3.00000000
darray( 3 , 2 ) = 6.00000000
darray( 3 , 3 ) = 9.00000000
darray( 3 , 4 ) = 12.0000000
```

Use of Data Statement

The **data** statement can be used for initialising more than one array, or for array section initialisation.

The syntax of data statement is:

```
data variable / list / ...
```

Example

The following example demonstrates the concept:

```
program dataStatement
implicit none

   integer :: a(5), b(3,3), c(10),i, j
   data a /7,8,9,10,11/

   data b(1,:) /1,1,1/
   data b(2,:)/2,2,2/
   data b(3,:)/3,3,3/
   data (c(i),i=1,10,2) /4,5,6,7,8/
   data (c(i),i=2,10,2)/5*2/

   Print *, 'The A array:'
   do j = 1, 5
      print*, a(j)
   end do

   Print *, 'The B array:'
   do i = lbound(b,1), ubound(b,1)
      write(*,*) (b(i,j), j = lbound(b,2), ubound(b,2))
   end do

   Print *, 'The C array:'
   do j = 1, 10
      print*, c(j)
   end do

end program dataStatement
```

When the above code is compiled and executed, it produces the following result:

```
The A array:
7
8
9
```

```
10

11

The B array:

1  1  1

2  2  2

3  3  3

The C array:

4

2

5

2

6

2

7

2

8

2
```

Use of Where Statement

The **where** statement allows you to use some elements of an array in an expression, depending on the outcome of some logical condition. It allows the execution of the expression, on an element, if the given condition is true.

Example

The following example demonstrates the concept:

```
program whereStatement
implicit none


   integer :: a(3,5), i , j


   do i = 1,3
      do j = 1, 5
         a(i,j) = j-i
      end do
   end do

   Print *, 'The A array:'

   do i = lbound(a,1), ubound(a,1)
      write(*,*) (a(i,j), j = lbound(a,2), ubound(a,2))
   end do

   where( a<0 )
      a = 1
   elsewhere
      a = 5
   end where

   Print *, 'The A array:'
   do i = lbound(a,1), ubound(a,1)
      write(*,*) (a(i,j), j = lbound(a,2), ubound(a,2))
   end do

end program whereStatement
```

When the above code is compiled and executed, it produces the following result:

```
The A array:
0   1   2  3  4
-1  0   1  2  3
-2  -1  0  1  2
The A array:
5   5   5  5  5
1   5   5  5  5
1   1   5  5  5
```

15. DERIVED DATA TYPES

Fortran allows you to define derived data types. A derived data type is also called a structure, and it can consist of data objects of different types.

Derived data types are used to represent a record. E.g. you want to keep track of your books in a library, you might want to track the following attributes about each book:

- Title
- Author
- Subject
- Book ID

Defining a Derived data type

To define a derived data **type**, the type and **end type** statements are used. . The type statement defines a new data type, with more than one member for your program. The format of the type statement is this:

```
type type_name
   declarations
end type
```

Here is the way you would declare the Book structure:

```
type Books
   character(len=50) :: title
   character(len=50) :: author
   character(len=150) :: subject
   integer :: book_id
end type Books
```

Accessing Structure Members

An object of a derived data type is called a structure

A structure of type Books can be created in a type declaration statement like:

```
type(Books) :: book1
```

The components of the structure can be accessed using the component selector character (%):

```
book1%title = "C Programming"
book1%author = "Nuha Ali"
book1%subject = "C Programming Tutorial"
book1%book_id = 6495407
```

Note that there are no spaces before and after the % symbol.

Example

The following program illustrates the above concepts:

```
program deriveDataType

   !type declaration
   type Books
      character(len=50) :: title
      character(len=50) :: author
      character(len=150) :: subject
      integer :: book_id
   end type Books

   !declaring type variables
   type(Books) :: book1
   type(Books) :: book2

   !accessing the components of the structure

   book1%title = "C Programming"
   book1%author = "Nuha Ali"
   book1%subject = "C Programming Tutorial"
   book1%book_id = 6495407

   book2%title = "Telecom Billing"
   book2%author = "Zara Ali"
   book2%subject = "Telecom Billing Tutorial"
   book2%book_id = 6495700

   !display book info

   Print *, book1%title
   Print *, book1%author
   Print *, book1%subject
   Print *, book1%book_id

   Print *, book2%title
   Print *, book2%author
   Print *, book2%subject
   Print *, book2%book_id

end program deriveDataType
```

When the above code is compiled and executed, it produces the following result:

```
 C Programming
 Nuha Ali
 C Programming Tutorial
     6495407
 Telecom Billing
 Zara Ali
 Telecom Billing Tutorial
     6495700
```

Array of Structures

You can also create arrays of a derived type:

```
type(Books), dimension(2) :: list
```

Individual elements of the array could be accessed as:

```
list(1)%title = "C Programming"
list(1)%author = "Nuha Ali"
list(1)%subject = "C Programming Tutorial"
list(1)%book_id = 6495407
```

The following program illustrates the concept:

```
program deriveDataType

   !type declaration
   type Books
      character(len=50) :: title
      character(len=50) :: author
      character(len=150) :: subject
      integer :: book_id
   end type Books

   !declaring array of books
   type(Books), dimension(2) :: list

   !accessing the components of the structure

   list(1)%title = "C Programming"
   list(1)%author = "Nuha Ali"
   list(1)%subject = "C Programming Tutorial"
   list(1)%book_id = 6495407

   list(2)%title = "Telecom Billing"
   list(2)%author = "Zara Ali"
   list(2)%subject = "Telecom Billing Tutorial"
   list(2)%book_id = 6495700

   !display book info

   Print *, list(1)%title
   Print *, list(1)%author
   Print *, list(1)%subject
   Print *, list(1)%book_id

   Print *, list(1)%title
   Print *, list(2)%author
   Print *, list(2)%subject
   Print *, list(2)%book_id

end program deriveDataType
```

When the above code is compiled and executed, it produces the following result:

```
C Programming
Nuha Ali
C Programming Tutorial
   6495407
C Programming
Zara Ali
Telecom Billing Tutorial
   6495700
```

16. POINTERS

In most programming languages, a pointer variable stores the memory address of an object. However, in Fortran, a pointer is a data object that has more functionalities than just storing the memory address. It contains more information about a particular object, like type, rank, extents, and memory address.

A pointer is associated with a target by allocation or pointer assignment.

Declaring a Pointer Variable

A pointer variable is declared with the pointer attribute.

The following examples shows declaration of pointer variables:

```
integer, pointer :: p1 ! pointer to integer
real, pointer, dimension (:) :: pra ! pointer to 1-dim real array
real, pointer, dimension (:,:) :: pra2 ! pointer to 2-dim real array
```

A pointer can point to:

- an area of dynamically allocated memory
- a data object of the same type as the pointer, with the **target** attribute

Allocating Space for a Pointer

The **allocate** statement allows you to allocate space for a pointer object. For example:

```
program pointerExample
implicit none

   integer, pointer :: p1
   allocate(p1)

   p1 = 1
   Print *, p1

   p1 = p1 + 4
   Print *, p1

end program pointerExample
```

When the above code is compiled and executed, it produces the following result:

```
1
5
```

You should empty the allocated storage space by the **deallocate** statement when it is no longer required and avoid accumulation of unused and unusable memory space.

Targets and Association

A target is another normal variable, with space set aside for it. A target variable must be declared with the **target** attribute.

You associate a pointer variable with a target variable using the association operator (=>).

Let us rewrite the previous example, to demonstrate the concept:

```
program pointerExample
implicit none

   integer, pointer :: p1
   integer, target :: t1

   p1=>t1
   p1 = 1

   Print *, p1
   Print *, t1

   p1 = p1 + 4

   Print *, p1
   Print *, t1
   t1 = 8


   Print *, p1
   Print *, t1


end program pointerExample
```

When the above code is compiled and executed, it produces the following result:

```
1
1
5
5
8
8
```

A pointer can be:

- Undefined
- Associated
- Disassociated

In the above program, we have **associated** the pointer p1, with the target t1, using the => operator. The function associated, tests a pointer's association status.

The **nullify** statement disassociates a pointer from a target.

Nullify does not empty the targets as there could be more than one pointer pointing to the same target. However, emptying the pointer implies nullification also.

Example 1

The following example demonstrates the concepts:

```
program pointerExample
implicit none


   integer, pointer :: p1
   integer, target :: t1
   integer, target :: t2
   p1=>t1
   p1 = 1

   Print *, p1
   Print *, t1

   p1 = p1 + 4
   Print *, p1
   Print *, t1

   t1 = 8
   Print *, p1
   Print *, t1

   nullify(p1)
   Print *, t1

   p1=>t2
   Print *, associated(p1)
   Print*, associated(p1, t1)
   Print*, associated(p1, t2)

   !what is the value of p1 at present
   Print *, p1
   Print *, t2

   p1 = 10
   Print *, p1
   Print *, t2

end program pointerExample
```

When the above code is compiled and executed, it produces the following result:

```
1
1
5
5
8
8
8
T
F
T
952754640
952754640
10
10
```

Please note that each time you run the code, the memory addresses will be different.

Example 2

```
program pointerExample
implicit none

   integer, pointer :: a, b
   integer, target :: t
   integer :: n

   t= 1
   a=>t
   t = 2
   b => t
   n = a + b

   Print *, a, b, t, n

```

```
end program pointerExample
```

When the above code is compiled and executed, it produces the following result:

```
2  2  2  4
```

17. BASIC INPUT OUTPUT

We have so far seen that we can read data from keyboard using the **read *** statement, and display output to the screen using the **print*** statement, respectively. This form of input-output is **free format** I/O, and it is called **list-directed** input-output.

The free format simple I/O has the form:

```
read(*,*) item1, item2, item3...

print *, item1, item2, item3

write(*,*) item1, item2, item3...
```

However the formatted I/O gives you more flexibility over data transfer.

Formatted Input Output

Formatted input output has the syntax as follows:

```
read fmt, variable_list

print fmt, variable_list

write fmt, variable_list
```

Where,

- fmt is the format specification
- variable-list is a list of the variables to be read from keyboard or written on screen

Format specification defines the way in which formatted data is displayed. It consists of a string, containing a list of **edit descriptors** in parentheses.

An **edit descriptor** specifies the exact format, for example, width, digits after decimal point etc., in which characters and numbers are displayed.

For example:

```
Print "(f6.3)", pi
```

The following table describes the descriptors:

Descriptor	Description	Example
I	This is used for integer output. This takes the form 'rIw.m' where the meanings of r, w and m are given in the table below. Integer values are right justified in their fields. If the field width is not large enough to accommodate an integer then the field is filled with asterisks.	print "(3i5)", i, j, k
F	This is used for real number output. This takes the form 'rFw.d' where the meanings of r, w and d are given in the table below. Real values are right justified in their fields. If the field width is not large enough to accommodate the real number then the field is filled with asterisks.	print "(f12.3)",pi
E	This is used for real output in exponential notation. The 'E' descriptor statement takes the form 'rEw.d' where the meanings of r, w and d are given in the table below. Real values are right justified in their fields. If the field width is not large enough to accommodate the real number then the field is filled with asterisks. Please note that, to print out a real number with three decimal places a field width of at least ten is needed. One for the sign of the mantissa, two for the zero, four for the mantissa and two for the exponent itself. In	print "(e10.3)",123456.0 gives '0.123e+06'

	general, w ≥ d + 7.	
ES	This is used for real output (scientific notation). This takes the form 'rESw.d' where the meanings of r, w and d are given in the table below. The 'E' descriptor described above differs slightly from the traditional well known 'scientific notation'. Scientific notation has the mantissa in the range 1.0 to 10.0 unlike the E descriptor which has the mantissa in the range 0.1 to 1.0. Real values are right justified in their fields. If the field width is not large enough to accommodate the real number then the field is filled with asterisks. Here also, the width field must satisfy the expression w ≥ d + 7	print "(es10.3)",123456.0 gives '1.235e+05'
A	This is used for character output. This takes the form 'rAw' where the meanings of r and w are given in the table below. Character types are right justified in their fields. If the field width is not large enough to accommodate the character string then the field is filled with the first 'w' characters of the string.	print "(a10)", str
X	This is used for space output. This takes the form 'nX' where 'n' is the number of desired spaces.	print "(5x, a10)", str
/	Slash descriptor – used to insert blank lines. This takes the form '/' and forces the next data	print "(/,5x, a10)", str

	output to be on a new line.	

Following symbols are used with the format descriptors:

Symbol	Description
c	Column number
d	Number of digits to right of the decimal place for real input or output
m	Minimum number of digits to be displayed
n	Number of spaces to skip
r	Repeat count – the number of times to use a descriptor or group of descriptors
w	Field width – the number of characters to use for the input or output

Example 1

```
program printPi


   pi = 3.141592653589793238


   Print "(f6.3)", pi
   Print "(f10.7)", pi
   Print "(f20.15)", pi
   Print "(e16.4)", pi/100


end program printPi
```

When the above code is compiled and executed, it produces the following result:

```
3.142
3.1415927
3.141592741012573
```

```
0.3142E-01
```

Example 2

```
program printName
implicit none

   character (len=15) :: first_name
   print *,' Enter your first name.'
   print *,' Up to 20 characters, please'

   read *,first_name
   print "(1x,a)",first_name

end program printName
```

When the above code is compiled and executed, it produces the following result: (assume the user enters the name Zara)

```
Enter your first name.
Up to 20 characters, please
Zara
```

Example 3

```
program formattedPrint
implicit none

   real :: c = 1.2786456e-9, d = 0.1234567e3
   integer :: n = 300789, k = 45, i = 2
   character (len=15) :: str="Tutorials Point"

   print "(i6)", k
   print "(i6.3)", k
   print "(3i10)", n, k, i
   print "(i10,i3,i5)", n, k, i
   print "(a15)",str
   print "(f12.3)", d
   print "(e12.4)", c
   print '(/,3x,"n = ",i6, 3x, "d = ",f7.4)', n, d

end program formattedPrint
```

When the above code is compiled and executed, it produces the following result:

```
45
045
300789 45  2
300789 45  2
Tutorials Point
123.457
0.1279E-08

n = 300789 d = *******
```

The Format Statement

The format statement allows you to mix and match character, integer and real output in one statement. The following example demonstrates this:

```
program productDetails
implicit none

   character (len=15) :: name
   integer :: id
   real :: weight
   name = 'Ardupilot'
   id = 1
   weight = 0.08

   print *,' The product details are'

   print 100
   100 format (7x,'Name:', 7x, 'Id:', 1x, 'Weight:')


   print 200, name, id, weight
   200 format(1x, a, 2x, i3, 2x, f5.2)


end program productDetails
```

When the above code is compiled and executed, it produces the following result:

```
The product details are
Name:       Id:    Weight:
Ardupilot   1       0.08
```

18. FILE INPUT OUTPUT

Fortran allows you to read data from, and write data into files.

In the last chapter, you have seen how to read data from, and write data to the terminal. In this chapter you will study file input and output functionalities provided by Fortran.

You can read and write to one or more files. The OPEN, WRITE, READ and CLOSE statements allow you to achieve this.

Opening and Closing Files

Before using a file you must open the file. The **open** command is used to open files for reading or writing. The simplest form of the command is:

```
open (unit = number, file = "name").
```

However, the open statement may have a general form:

```
open (list-of-specifiers)
```

The following table describes the most commonly used specifiers:

Specifier	**Description**
[UNIT=] u	The unit number u could be any number in the range 9-99 and it indicates the file, you may choose any number but every open file in the program must have a unique number
IOSTAT= ios	It is the I/O status identifier and should be an integer variable. If the open statement is successful then the ios value returned is zero else a non-zero value.
ERR = err	It is a label to which the control jumps in case of any error.
FILE = fname	File name, a character string.
STATUS = sta	It shows the prior status of the file. A character string and can have one of the three values NEW, OLD or SCRATCH. A scratch file is created and deleted when closed or the program

	ends.
ACCESS = acc	It is the file access mode. Can have either of the two values, SEQUENTIAL or DIRECT. The default is SEQUENTIAL.
FORM= frm	It gives the formatting status of the file. Can have either of the two values FORMATTED or UNFORMATTED. The default is UNFORMATTED
RECL = rl	It specifies the length of each record in a direct access file.

After the file has been opened, it is accessed by read and write statements. Once done, it should be closed using the **close** statement.

The close statement has the following syntax:

```
close ([UNIT=]u[,IOSTAT=ios,ERR=err,STATUS=sta])
```

Please note that the parameters in brackets are optional.

Example

This example demonstrates opening a new file for writing some data into the file.

```
program outputdata
implicit none

   real, dimension(100) :: x, y
   real, dimension(100) :: p, q
   integer :: i

   ! data
   do i=1,100
      x(i) = i * 0.1
      y(i) = sin(x(i)) * (1-cos(x(i)/3.0))
   end do

   ! output data into a file
   open(1, file='data1.dat', status='new')
   do i=1,100
      write(1,*) x(i), y(i)
   end do

   close(1)

end program outputdata
```

When the above code is compiled and executed, it creates the file data1.dat and writes the x and y array values into it. And then closes the file.

Reading from and Writing into the File

The read and write statements respectively are used for reading from and writing into a file respectively.

They have the following syntax:

```
read ([UNIT=]u, [FMT=]fmt, IOSTAT=ios, ERR=err, END=s)
write([UNIT=]u, [FMT=]fmt, IOSTAT=ios, ERR=err, END=s)
```

Most of the specifiers have already been discussed in the above table.

The END=s specifier is a statement label where the program jumps, when it reaches end-of-file.

Example

This example demonstrates reading from and writing into a file.

In this program we read from the file, we created in the last example, data1.dat, and display it on screen.

```
program outputdata
implicit none

   real, dimension(100) :: x, y
   real, dimension(100) :: p, q
   integer :: i

   ! data
   do i=1,100
```

```
      x(i) = i * 0.1
      y(i) = sin(x(i)) * (1-cos(x(i)/3.0))
   end do

   ! output data into a file
   open(1, file='data1.dat', status='new')
   do i=1,100
      write(1,*) x(i), y(i)
   end do
   close(1)

   ! opening the file for reading
   open (2, file='data1.dat', status='old')

   do i=1,100
      read(2,*) p(i), q(i)
   end do

   close(2)

   do i=1,100
      write(*,*) p(i), q(i)
   end do

end program outputdata
```

When the above code is compiled and executed, it produces the following result:

```
0.100000001  5.54589933E-05
0.200000003  4.41325130E-04
0.300000012  1.47636665E-03
0.400000006  3.45637114E-03
0.500000000  6.64328877E-03
0.600000024  1.12552457E-02
0.699999988  1.74576249E-02
```

```
0.800000012  2.53552198E-02
0.900000036  3.49861123E-02
1.00000000   4.63171229E-02
1.10000002   5.92407547E-02
1.20000005   7.35742599E-02
1.30000007   8.90605897E-02
1.39999998   0.105371222
1.50000000   0.122110792
1.60000002   0.138823599
1.70000005   0.155002072
1.80000007   0.170096487
1.89999998   0.183526158
2.00000000   0.194692180
2.10000014   0.202990443
2.20000005   0.207826138
2.29999995   0.208628103
2.40000010   0.204863414
2.50000000   0.196052119
2.60000014   0.181780845
2.70000005   0.161716297
2.79999995   0.135617107
2.90000010   0.103344671
3.00000000   6.48725405E-02
3.10000014   2.02930309E-02
3.20000005  -3.01767997E-02
3.29999995  -8.61928314E-02
3.40000010  -0.147283033
3.50000000  -0.212848678
3.60000014  -0.282169819
3.70000005  -0.354410470
3.79999995  -0.428629100
3.90000010  -0.503789663
4.00000000  -0.578774154
```

```
4.09999990  -0.652400017
4.20000029  -0.723436713
4.30000019  -0.790623367
4.40000010  -0.852691114
4.50000000  -0.908382416
4.59999990  -0.956472993
4.70000029  -0.995793998
4.80000019  -1.02525222
4.90000010  -1.04385209
5.00000000  -1.05071592
5.09999990  -1.04510069
5.20000029  -1.02641726
5.30000019  -0.994243503
5.40000010  -0.948338211
5.50000000  -0.888650239
5.59999990  -0.815326691
5.70000029  -0.728716135
5.80000019  -0.629372001
5.90000010  -0.518047631
6.00000000  -0.395693362
6.09999990  -0.263447165
6.20000029  -0.122622721
6.30000019   2.53026206E-02
6.40000010   0.178709000
6.50000000   0.335851669
6.59999990   0.494883657
6.70000029   0.653881252
6.80000019   0.810866773
6.90000010   0.963840425
7.00000000   1.11080539
7.09999990   1.24979746
7.20000029   1.37891412
7.30000019   1.49633956
```

```
7.40000010   1.60037732
7.50000000   1.68947268
7.59999990   1.76223695
7.70000029   1.81747139
7.80000019   1.85418403
7.90000010   1.87160957
8.00000000   1.86922085
8.10000038   1.84674001
8.19999981   1.80414569
8.30000019   1.74167395
8.40000057   1.65982044
8.50000000   1.55933595
8.60000038   1.44121361
8.69999981   1.30668485
8.80000019   1.15719533
8.90000057   0.994394958
9.00000000   0.820112705
9.10000038   0.636327863
9.19999981   0.445154816
9.30000019   0.248800844
9.40000057   4.95488606E-02
9.50000000  -0.150278628
9.60000038  -0.348357052
9.69999981  -0.542378068
9.80000019  -0.730095863
9.90000057  -0.909344316
10.0000000  -1.07807255
```

19. PROCEDURES

A **procedure** is a group of statements that perform a well-defined task and can be invoked from your program. Information (or data) is passed to the calling program, to the procedure as arguments.

There are two types of procedures:

- Functions
- Subroutines

Function

A function is a procedure that returns a single quantity. A function should not modify its arguments.

The returned quantity is known as **function value**, and it is denoted by the function name.

Syntax:

Syntax for a function is as follows:

```
function name(arg1, arg2, ....)
   [declarations, including those for the arguments]
   [executable statements]
end function [name]
```

The following example demonstrates a function named area_of_circle. It calculates the area of a circle with radius r.

```
program calling_func

   real :: a
   a = area_of_circle(2.0)

   Print *, "The area of a circle with radius 2.0 is"
   Print *, a

end program calling_func
```

```


! this function computes the area of a circle with radius r
function area_of_circle (r)

! function result
implicit none

   ! dummy arguments
   real :: area_of_circle

   ! local variables
   real :: r
   real :: pi

   pi = 4 * atan (1.0)
   area_of_circle = pi * r**2

end function area_of_circle
```

When you compile and execute the above program, it produces the following result:

```
The area of a circle with radius 2.0 is
   12.5663710
```

Please note that:

- You must specify **implicit none** in both the main program as well as the procedure.
- The argument r in the called function is called **dummy argument**.

The result Option

If you want the returned value to be stored in some other name than the function name, you can use the **result** option.

You can specify the return variable name as:

```
function name(arg1, arg2, ....) result (return_var_name)
```

```
   [declarations, including those for the arguments]
   [executable statements]
end function [name]
```

Subroutine

A subroutine does not return a value, however it can modify its arguments.

Syntax

```
subroutine name(arg1, arg2, ....)
   [declarations, including those for the arguments]
   [executable statements]
end subroutine [name]
```

Calling a Subroutine

You need to invoke a subroutine using the **call** statement.

The following example demonstrates the definition and use of a subroutine swap, that changes the values of its arguments.

```
program calling_func
implicit none

   real :: a, b
   a = 2.0
   b = 3.0

   Print *, "Before calling swap"
   Print *, "a = ", a
   Print *, "b = ", b

   call swap(a, b)

   Print *, "After calling swap"
   Print *, "a = ", a
   Print *, "b = ", b
```

```

end program calling_func



subroutine swap(x, y)
implicit none

   real :: x, y, temp

   temp = x
   x = y
   y = temp

end subroutine swap
```

When you compile and execute the above program, it produces the following result:

```
Before calling swap
a = 2.00000000
b = 3.00000000
After calling swap
a = 3.00000000
b = 2.00000000
```

Specifying the Intent of the Arguments

The intent attribute allows you to specify the intention with which arguments are used in the procedure. The following table provides the values of the intent attribute:

Value	Used as	Explanation
in	intent(in)	Used as input values, not changed in the function
out	intent(out)	Used as output value, they are overwritten

inout	intent(inout)	Arguments are both used and overwritten

The following example demonstrates the concept:

```
program calling_func
implicit none

   real :: x, y, z, disc

   x= 1.0
   y = 5.0
   z = 2.0

   call intent_example(x, y, z, disc)

   Print *, "The value of the discriminant is"
   Print *, disc

end program calling_func



subroutine intent_example (a, b, c, d)
implicit none

   ! dummy arguments
   real, intent (in) :: a
   real, intent (in) :: b
   real, intent (in) :: c
   real, intent (out) :: d

   d = b * b - 4.0 * a * c

end subroutine intent_example
```

When you compile and execute the above program, it produces the following result:

```
The value of the discriminant is
   17.0000000
```

Recursive Procedures

Recursion occurs when a programming languages allows you to call a function inside the same function. It is called recursive call of the function.

When a procedure calls itself, directly or indirectly, is called a recursive procedure. You should declare this type of procedures by preceding the word **recursive** before its declaration.

When a function is used recursively, the **result** option has to be used.

Following is an example, which calculates factorial for a given number using a recursive procedure:

```
program calling_func
implicit none

   integer :: i, f
   i = 15

   Print *, "The value of factorial 15 is"
   f = myfactorial(15)
   Print *, f

end program calling_func

! computes the factorial of n (n!)
recursive function myfactorial (n) result (fac)
! function result
implicit none

   ! dummy arguments
   integer :: fac
   integer, intent (in) :: n
   select case (n)
      case (0:1)
         fac = 1
      case default
         fac = n * myfactorial (n-1)
   end select

end function myfactorial
```

Internal Procedures

When a procedure is contained within a program, it is called the internal procedure of the program. The syntax for containing an internal procedure is as follows:

```
program program_name
   implicit none
   ! type declaration statements
   ! executable statements
   . . .
   contains
   ! internal procedures
   . . .
end program program_name
```

The following example demonstrates the concept:

```
program mainprog
implicit none

   real :: a, b
   a = 2.0
   b = 3.0

   Print *, "Before calling swap"
   Print *, "a = ", a
   Print *, "b = ", b

   call swap(a, b)

   Print *, "After calling swap"
   Print *, "a = ", a
   Print *, "b = ", b

contains
   subroutine swap(x, y)
      real :: x, y, temp
      temp = x
      x = y
      y = temp
   end subroutine swap

end program mainprog
```

When you compile and execute the above program, it produces the following result:

```
Before calling swap
a = 2.00000000
b = 3.00000000
After calling swap
a = 3.00000000
b = 2.00000000
```

20. MODULES

A module is like a package where you can keep your functions and subroutines, in case you are writing a very big program, or your functions or subroutines can be used in more than one program.

Modules provide you a way of splitting your programs between multiple files.

Modules are used for:

- Packaging subprograms, data and interface blocks.
- Defining global data that can be used by more than one routine.
- Declaring variables that can be made available within any routines you choose.
- Importing a module entirely, for use, into another program or subroutine.

Syntax of a Module

A module consists of two parts:

- a specification part for statements declaration
- a contains part for subroutine and function definitions

The general form of a module is:

```
module name
   [statement declarations]
   [contains [subroutine and function definitions] ]
end module [name]
```

Using a Module into your Program

You can incorporate a module in a program or subroutine by the use statement:

```
use name
```

Please note that

- You can add as many modules as needed, each will be in separate files and compiled separately.
- A module can be used in various different programs.

- A module can be used many times in the same program.
- The variables declared in a module specification part, are global to the module.
- The variables declared in a module become global variables in any program or routine where the module is used.
- The use statement can appear in the main program, or any other subroutine or module which uses the routines or variables declared in a particular module.

Example

The following example demonstrates the concept:

```
module constants
implicit none

   real, parameter :: pi = 3.1415926536
   real, parameter :: e = 2.7182818285

contains
   subroutine show_consts()
      print*, "Pi = ", pi
      print*,  "e = ", e
   end subroutine show_consts

end module constants



program module_example
use constants
implicit none

   real :: x, ePowerx, area, radius
   x = 2.0
   radius = 7.0
   ePowerx = e ** x
   area = pi * radius**2

   call show_consts()


   print*, "e raised to the power of 2.0 = ", ePowerx
   print*, "Area of a circle with radius 7.0 = ", area


end program module_example
```

When you compile and execute the above program, it produces the following result:

```
Pi = 3.14159274
e =  2.71828175
e raised to the power of 2.0 = 7.38905573
Area of a circle with radius 7.0 = 153.938049
```

Accessibility of Variables and Subroutines in a Module

By default, all the variables and subroutines in a module is made available to the program that is using the module code, by the **use** statement.

However, you can control the accessibility of module code using the **private** and **public**attributes. When you declare some variable or subroutine as private, it is not available outside the module.

Example

The following example illustrates the concept:

In the previous example, we had two module variables, **e** and **pi.** Let us make them private and observe the output:

```
module constants
implicit none


   real, parameter,private :: pi = 3.1415926536
   real, parameter, private :: e = 2.7182818285


contains
   subroutine show_consts()
```

```
      print*, "Pi = ", pi
      print*, "e = ", e
   end subroutine show_consts

end module constants



program module_example
use constants
implicit none

   real :: x, ePowerx, area, radius
   x = 2.0
   radius = 7.0
   ePowerx = e ** x
   area = pi * radius**2

   call show_consts()

   print*, "e raised to the power of 2.0 = ", ePowerx
   print*, "Area of a circle with radius 7.0 = ", area

end program module_example
```

When you compile and execute the above program, it gives the following error message:

```
   ePowerx = e ** x
   1
Error: Symbol 'e' at (1) has no IMPLICIT type
main.f95:19.13:

   area = pi * radius**2
   1
Error: Symbol 'pi' at (1) has no IMPLICIT type
```

Since **e** and **pi,** both are declared private, the program module_example cannot access these variables anymore.

However, other module subroutines can access them:

```
module constants
implicit none

   real, parameter,private :: pi = 3.1415926536
   real, parameter, private :: e = 2.7182818285

contains
   subroutine show_consts()
      print*, "Pi = ", pi
      print*, "e = ", e
   end subroutine show_consts

   function ePowerx(x)result(ePx)
   implicit none
      real::x
      real::ePx
      ePx = e ** x
   end function ePowerx

   function areaCircle(r)result(a)
   implicit none
      real::r
      real::a
      a = pi * r**2
   end function areaCircle

end module constants



program module_example
```

```
use constants
implicit none

   call show_consts()

   Print*, "e raised to the power of 2.0 = ", ePowerx(2.0)
   print*, "Area of a circle with radius 7.0 = ", areaCircle(7.0)

end program module_example
```

When you compile and execute the above program, it produces the following result:

```
Pi = 3.14159274
e = 2.71828175
e raised to the power of 2.0 = 7.38905573
Area of a circle with radius 7.0 = 153.938049
```

21. INTRINSIC FUNCTIONS

Intrinsic functions are some common and important functions that are provided as a part of the Fortran language. We have already discussed some of these functions in the Arrays, Characters and String chapters.

Intrinsic functions can be categorised as:

- Numeric Functions
- Mathematical Functions
- Numeric Inquiry Functions
- Floating-Point Manipulation Functions
- Bit Manipulation Functions
- Character Functions
- Kind Functions
- Logical Functions
- Array Functions.

We have discussed the array functions in the Arrays chapter. In the following section we provide brief descriptions of all these functions from other categories.

In the function name column,

- A represents any type of numeric variable
- R represents a real or integer variable
- X and Y represent real variables
- Z represents complex variable
- W represents real or complex variable

Numeric Functions

Function	Description
ABS (A)	It returns the absolute value of A
AIMAG (Z)	It returns the imaginary part of a complex number

	Z
AINT (A [, KIND])	It truncates fractional part of A towards zero, returning a real, whole number.
ANINT (A [, KIND])	It returns a real value, the nearest integer or whole number.
CEILING (A [, KIND])	It returns the least integer greater than or equal to number A.
CMPLX (X [, Y, KIND])	It converts the real variables X and Y to a complex number X+iY; if Y is absent, 0 is used.
CONJG (Z)	It returns the complex conjugate of any complex number Z.
DBLE (A)	It converts A to a double precision real number.
DIM (X, Y)	It returns the positive difference of X and Y.
DPROD (X, Y)	It returns the double precision real product of X and Y.
FLOOR (A [, KIND])	It provides the greatest integer less than or equal to number A.
INT (A [, KIND])	It converts a number (real or integer) to integer, truncating the real part towards zero.
MAX (A1, A2 [, A3,...])	It returns the maximum value from the arguments, all being of same type.
MIN (A1, A2 [, A3,...])	It returns the minimum value from the arguments, all being of same type.
MOD (A, P)	It returns the remainder of A on division by P, both arguments being of the same type (A-INT(A/P)*P)

MODULO (A, P)	It returns A modulo P: (A-FLOOR(A/P)*P)
NINT (A [, KIND])	It returns the nearest integer of number A
REAL (A [, KIND])	It Converts to real type
SIGN (A, B)	It returns the absolute value of A multiplied by the sign of P. Basically it transfers the of sign of B to A.

Example

```
program numericFunctions
implicit none

   ! define constants
   ! define variables
   real :: a, b
   complex :: z

   ! values for a, b
   a = 15.2345
   b = -20.7689

   write(*,*) 'abs(a): ',abs(a),' abs(b): ',abs(b)
   write(*,*) 'aint(a): ',aint(a),' aint(b): ',aint(b)
   write(*,*) 'ceiling(a): ',ceiling(a),' ceiling(b): ',ceiling(b)
   write(*,*) 'floor(a): ',floor(a),' floor(b): ',floor(b)

   z = cmplx(a, b)
   write(*,*) 'z: ',z

end program numericFunctions
```

When you compile and execute the above program, it produces the following result:

```
abs(a): 15.2344999   abs(b): 20.7688999
aint(a): 15.0000000  aint(b): -20.0000000
ceiling(a): 16  ceiling(b): -20
floor(a): 15  floor(b): -21
z: (15.2344999, -20.7688999)
```

Mathematical Functions

Function	**Description**
ACOS (X)	It returns the inverse cosine in the range (0, π), in radians.
ASIN (X)	It returns the inverse sine in the range (-π/2, π/2), in radians.
ATAN (X)	It returns the inverse tangent in the range (-π/2, π/2), in radians.
ATAN2 (Y, X)	It returns the inverse tangent in the range (-π, π), in radians.
COS (X)	It returns the cosine of argument in radians.
COSH (X)	It returns the hyperbolic cosine of argument in radians.
EXP (X)	It returns the exponential value of X.
LOG (X)	It returns the natural logarithmic value of X.
LOG10 (X)	It returns the common logarithmic (base 10) value of X.
SIN (X)	It returns the sine of argument in radians.
SINH (X)	It returns the hyperbolic sine of argument in radians.
SQRT (X)	It returns square root of X.

TAN (X)	It returns the tangent of argument in radians.
TANH (X)	It returns the hyperbolic tangent of argument in radians.

Example

The following program computes the horizontal and vertical position x and y respectively of a projectile after a time, t:

Where, x = u t cos a and y = u t sin a - g t2 / 2

```
program projectileMotion
implicit none

   ! define constants
   real, parameter :: g = 9.8
   real, parameter :: pi = 3.1415927

   !define variables
   real :: a, t, u, x, y

   !values for a, t, and u
   a = 45.0
   t = 20.0
   u = 10.0

   ! convert angle to radians
   a = a * pi / 180.0
   x = u * cos(a) * t
   y = u * sin(a) * t - 0.5 * g * t * t

   write(*,*) 'x: ',x,'  y: ',y

end program projectileMotion
```

When you compile and execute the above program, it produces the following result:

```
x: 141.421356  y: -1818.57861
```

Numeric Inquiry Functions

These functions work with a certain model of integer and floating-point arithmetic. The functions return properties of numbers of the same kind as the variable X, which can be real and in some cases integer.

Function	Description
DIGITS (X)	It returns the number of significant digits of the model.
EPSILON (X)	It returns the number that is almost negligible compared to one. In other words, it returns the smallest value such that REAL(1.0, KIND(X)) + EPSILON(X) is not equal to REAL(1.0, KIND(X)).
HUGE (X)	It returns the largest number of the model
MAXEXPONENT (X)	It returns the maximum exponent of the model
MINEXPONENT (X)	It returns the minimum exponent of the model
PRECISION (X)	It returns the decimal precision
RADIX (X)	It returns the base of the model
RANGE (X)	It returns the decimal exponent range
TINY (X)	It returns the smallest positive number of the model

Floating-Point Manipulation Functions

Function	Description
EXPONENT (X)	It returns the exponent part of a model number
FRACTION (X)	It returns the fractional part of a number

NEAREST (X, S)	It returns the nearest different processor number in given direction
RRSPACING (X)	It returns the reciprocal of the relative spacing of model numbers near given number
SCALE (X, I)	It multiplies a real by its base to an integer power
SET_EXPONENT (X, I)	it returns the exponent part of a number
SPACING (X)	It returns the absolute spacing of model numbers near given number

Bit Manipulation Functions

Function	Description
BIT_SIZE (I)	It returns the number of bits of the model
BTEST (I, POS)	Bit testing
IAND (I, J)	Logical AND
IBCLR (I, POS)	Clear bit
IBITS (I, POS, LEN)	Bit extraction
IBSET (I, POS)	Set bit
IEOR (I, J)	Exclusive OR
IOR (I, J)	Inclusive OR
ISHFT (I, SHIFT)	Logical shift
ISHFTC (I, SHIFT [, SIZE])	Circular shift

NOT (I)	Logical complement

Character Functions

Function	Description
ACHAR (I)	It returns the Ith character in the ASCII collating sequence.
ADJUSTL (STRING)	It adjusts string left by removing any leading blanks and inserting trailing blanks
ADJUSTR (STRING)	It adjusts string right by removing trailing blanks and inserting leading blanks.
CHAR (I [, KIND])	It returns the Ith character in the machine specific collating sequence
IACHAR (C)	It returns the position of the character in the ASCII collating sequence.
ICHAR (C)	It returns the position of the character in the machine (processor) specific collating sequence.
INDEX (STRING, SUBSTRING [, BACK])	It returns the leftmost (rightmost if BACK is .TRUE.) starting position of SUBSTRING within STRING.
LEN (STRING)	It returns the length of a string.
LEN_TRIM (STRING)	It returns the length of a string without trailing blank characters.
LGE (STRING_A, STRING_B)	Lexically greater than or equal
LGT (STRING_A, STRING_B)	Lexically greater than

LLE (STRING_A, STRING_B)	Lexically less than or equal
LLT (STRING_A, STRING_B)	Lexically less than
REPEAT (STRING, NCOPIES)	Repeated concatenation
SCAN (STRING, SET [, BACK])	It returns the index of the leftmost (rightmost if BACK is .TRUE.) character of STRING that belong to SET, or 0 if none belong.
TRIM (STRING)	Removes trailing blank characters
VERIFY (STRING, SET [, BACK])	Verifies the set of characters in a string

Kind Functions

Function	Description
KIND (X)	It returns the kind type parameter value.
SELECTED_INT_KIND (R)	It returns kind of type parameter for specified exponent range.
SELECTED_REAL_KIND ([P, R])	Real kind type parameter value, given precision and range

Logical Function

Function	Description
LOGICAL (L [, KIND])	Convert between objects of type logical with different kind type parameters

22. NUMERIC PRECISION

We have already discussed that, in older versions of Fortran, there were two **real** types: the default real type and **double precision** type.

However, Fortran 90/95 provides more control over the precision of real and integer data types through the **kind** specifie.

The Kind Attribute

Different kind of numbers are stored differently inside the computer. The **kind** attribute allows you to specify how a number is stored internally. For example,

```
real, kind = 2 :: a, b, c
real, kind = 4 :: e, f, g
integer, kind = 2 :: i, j, k
integer, kind = 3 :: l, m, n
```

In the above declaration, the real variables e, f and g have more precision than the real variables a, b and c. The integer variables l, m and n, can store larger values and have more digits for storage than the integer variables i, j and k. Although this is machine dependent.

Example

```
program kindSpecifier
implicit none

   real(kind = 4) :: a, b, c
   real(kind = 8) :: e, f, g
   integer(kind = 2) :: i, j, k
   integer(kind = 4) :: l, m, n
   integer :: kind_a, kind_i, kind_e, kind_l

   kind_a = kind(a)
   kind_i = kind(i)
   kind_e = kind(e)
   kind_l = kind(l)

   print *,'default kind for real is', kind_a
   print *,'default kind for int is', kind_i
   print *,'extended kind for real is', kind_e
   print *,'default kind for int is', kind_l

end program kindSpecifier
```

When you compile and execute the above program it produces the following result:

```
default kind for real is 4
default kind for int is 2
extended kind for real is 8
default kind for int is 4
```

Inquiring the Size of Variables

There are a number of intrinsic functions that allows you to interrogate the size of numbers.

For example, the **bit_size(i)** intrinsic function specifies the number of bits used for storage. For real numbers, the **precision(x)** intrinsic function, returns the number of decimal digits of precision, while the **range(x)** intrinsic function returns the decimal range of the exponent.

Example

```
program getSize
implicit none

   real (kind = 4) :: a
   real (kind = 8) :: b
   integer (kind = 2) :: i
   integer (kind = 4) :: j

   print *,'precision of real(4) =', precision(a)
   print *,'precision of real(8) =', precision(b)

   print *,'range of real(4) =', range(a)
   print *,'range of real(8) =', range(b)


   print *,'maximum exponent of real(4) =' , maxexponent(a)
   print *,'maximum exponent of real(8) =' , maxexponent(b)

   print *,'minimum exponent of real(4) =' , minexponent(a)
   print *,'minimum exponent of real(8) =' , minexponent(b)

   print *,'bits in integer(2) =' , bit_size(i)
   print *,'bits in integer(4) =' , bit_size(j)

end program getSize
```

When you compile and execute the above program it produces the following result:

```
precision of real(4) = 6
precision of real(8) = 15
range of real(4) = 37
range of real(8) = 307
maximum exponent of real(4) = 128
maximum exponent of real(8) = 1024
minimum exponent of real(4) = -125
minimum exponent of real(8) = -1021
bits in integer(2) = 16
bits in integer(4) = 32
```

Obtaining the Kind Value

Fortran provides two more intrinsic functions to obtain the kind value for the required precision of integers and reals:

- selected_int_kind (r)
- selected_real_kind ([p, r])

The selected_real_kind function returns an integer that is the kind type parameter value necessary for a given decimal precision p and decimal exponent range r. The decimal precision is the number of significant digits, and the decimal exponent range specifies the smallest and largest representable number. The range is thus from 10-r to 10+r.

For example, selected_real_kind (p = 10, r = 99) returns the kind value needed for a precision of 10 decimal places, and a range of at least 10-99 to 10+99.

Example

```
program getKind
implicit none

   integer:: i
   i = selected_real_kind (p = 10, r = 99)
   print *,'selected_real_kind (p = 10, r = 99)', i

end program getKind
```

When you compile and execute the above program it produces the following result:

```
selected_real_kind (p = 10, r = 99) 8
```

23. PROGRAM LIBRARIES

There are various Fortran tools and libraries. Some are free and some are paid services.

Following are some free libraries:

- RANDLIB, random number and statistical distribution generators
- BLAS
- EISPACK
- GAMS–NIST Guide to Available Math Software
- Some statistical and other routines from NIST
- LAPACK
- LINPACK
- MINPACK
- MUDPACK
- NCAR Mathematical Library
- The Netlib collection of mathematical software, papers, and databases.
- ODEPACK
- ODERPACK, a set of routines for ranking and ordering.
- Expokit for computing matrix exponentials
- SLATEC
- SPECFUN
- STARPAC
- StatLib statistical library
- TOMS
- Sorting and merging strings

The following libraries are not free:

- The NAG Fortran numerical library
- The Visual Numerics IMSL library
- Numerical Recipes

24. PROGRAMMING STYLE

Programming style is all about following some rules while developing programs. These good practices impart values like readability, and unambiguity into your program.

A good program should have the following characteristics:

- Readability
- Proper logical structure
- Self-explanatory notes and comments

  For example, if you make a comment like the following, it will not be of much help:

  ```
  ! loop from 1 to 10
  do i=1,10
  ```

  However, if you are calculating binomial coefficient, and need this loop for nCr then a comment like this will be helpful:

  ```
  ! loop to calculate nCr
  do i=1,10
  ```

- Indented code blocks to make various levels of code clear.
- Self-checking codes to ensure there will be no numerical errors like division by zero, square root of a negative real number or logarithm of a negative real number.
- Including codes that ensure variables do not take illegal or out of range values, i.e., input validation.
- Not putting checks where it would be unnecessary and slows down the execution. For example:

  ```
  real :: x
  x = sin(y) + 1.0

  if (x >= 0.0) then
     z = sqrt(x)
  end if
  ```

- Clearly written code using appropriate algorithms.
- Splitting the long expressions using the continuation marker '&'.
- Making meaningful variable names.

25. DEBUGGING PROGRAM

A debugger tool is used to search for errors in the programs.

A debugger program steps through the code and allows you to examine the values in the variables and other data objects during execution of the program.

It loads the source code and you are supposed to run the program within the debugger. Debuggers debug a program by:

- Setting breakpoints,
- Stepping through the source code,
- Setting watch points.

Breakpoints specify where the program should stop, specifically after a critical line of code. Program executions after the variables are checked at a breakpoint.

Debugger programs also check the source code line by line.

Watch points are the points where the values of some variables are needed to be checked, particularly after a read or write operation.

The gdb Debugger

The gdb debugger, the GNU debugger comes with Linux operating system. For X windows system, gdb comes with a graphical interface and the program is named xxgdb.

Following table provides some commands in gdb:

Command	**Purpose**
break	Setting a breakpoint
run	Starts execution
cont	Continues execution
next	Executes only the next line of source code, without stepping into any function call
step	Execute the next line of source code by stepping into a function in

	case of a function call.

The dbx Debugger

There is another debugger, the dbx debugger, for Linux.

The following table provides some commands in dbx:

Command	**Purpose**
stop[var]	Sets a breakpoint when the value of variable var changes.
stop in [proc]	It stops execution when a procedure proc is entered
stop at [line]	It sets a breakpoint at a specified line.
run	Starts execution.
cont	Continues execution.
next	Executes only the next line of source code, without stepping into any function call.
step	Execute the next line of source code by stepping into a function in case of a function call.