1. R – Overview

R is a programming language and software environment for statistical analysis, graphics representation and reporting. R was created by Ross Ihaka and Robert Gentleman at the University of Auckland, New Zealand, and is currently developed by the R Development Core Team.

The core of R is an interpreted computer language which allows branching and looping as well as modular programming using functions. R allows integration with the procedures written in the C, C++, .Net, Python or FORTRAN languages for efficiency.

R is freely available under the GNU General Public License, and pre-compiled binary versions are provided for various operating systems like Linux, Windows and Mac.

R is free software distributed under a GNU-style copy left, and an official part of the GNU project called **GNU S**.

Evolution of R

R was initially written by **Ross Ihaka** and **Robert Gentleman** at the Department of Statistics of the University of Auckland in Auckland, New Zealand. R made its first appearance in 1993.

- A large group of individuals has contributed to R by sending code and bug reports.
-
- Since mid-1997 there has been a core group (the "R Core Team") who can modify the R source code archive.

Features of R

As stated earlier, R is a programming language and software environment for statistical analysis, graphics representation and reporting. The following are the important features of R:

- R is a well-developed, simple and effective programming language which includes conditionals, loops, user defined recursive functions and input and output facilities.
-
- R has an effective data handling and storage facility,
-
- R provides a suite of operators for calculations on arrays, lists, vectors and matrices.
-
- R provides a large, coherent and integrated collection of tools for data analysis.

-
- R provides graphical facilities for data analysis and display either directly at the computer or printing at the papers.

As a conclusion, R is world’s most widely used statistics programming language. It's the # 1 choice of data scientists and supported by a vibrant and talented community of contributors. R is taught in universities and deployed in mission critical business applications. This tutorial will teach you R programming along with suitable examples in simple and easy steps.

2. R – Environment Setup

Try it Option Online

You really do not need to set up your own environment to start learning R programming language. Reason is very simple, we already have set up R Programming environment online, so that you can compile and execute all the available examples online at the same time when you are doing your theory work. This gives you confidence in what you are reading and to check the result with different options. Feel free to modify any example and execute it online.

Try the following example using **Try it** option at the website available at the top right corner of the below sample code box:

```
# Print Hello World.
 print("Hello World")


# Add two numbers.
 print(23.9 + 11.6)
```

For most of the examples given in this tutorial, you will find **Try it** option at the website, so just make use of it and enjoy your learning.

Local Environment Setup

If you are still willing to set up your environment for R, you can follow the steps given below.

Windows Installation

You can download the Windows installer version of R from R-3.2.2 for Windows (32/64 bit) and save it in a local directory.

As it is a Windows installer (.exe) with a name "R-version-win.exe". You can just double click and run the installer accepting the default settings. If your Windows is 32-bit version, it installs the 32-bit version. But if your windows is 64-bit, then it installs both the 32-bit and 64-bit versions.

After installation you can locate the icon to run the Program in a directory structure "R\R-3.2.2\bin\i386\Rgui.exe" under the Windows Program Files. Clicking this icon brings up the R-GUI which is the R console to do R Programming.

Linux Installation

R is available as a binary for many versions of Linux at the location R Binaries.

The instruction to install Linux varies from flavor to flavor. These steps are mentioned under each type of Linux version in the mentioned link. However, if you are in a hurry, then you can use **yum** command to install R as follows:

```
$ yum install R
```

Above command will install core functionality of R programming along with standard packages, still you need additional package, then you can launch R prompt as follows:

```
$ R


R version 3.2.0 (2015-04-16) -- "Full of Ingredients"
 Copyright (C) 2015 The R Foundation for Statistical Computing
 Platform: x86_64-redhat-linux-gnu (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY. You
 are welcome to redistribute it under certain conditions.
 Type 'license()' or 'licence()' for distribution details.

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
 'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.


 >
```

Now you can use install command at R prompt to install the required package. For example, the following command will install **plotrix** package which is required for 3D charts.

```
>  install("plotrix")
```

R – Basic Syntax

As a convention, we will start learning R programming by writing a "Hello, World!" program. Depending on the needs, you can program either at R command prompt or you can use an R script file to write your program. Let's check both one by one.

R Command Prompt

Once you have R environment setup, then it’s easy to start your R command prompt by just typing the following command at your command prompt:

```
$ R
```

This will launch R interpreter and you will get a prompt > where you can start typing your program as follows:

```
>  myString <- "Hello, World!"
>  print ( myString)
[1] "Hello, World!"
```

Here first statement defines a string variable myString, where we assign a string "Hello, World!" and then next statement print() is being used to print the value stored in variable myString.

R Script File

Usually, you will do your programming by writing your programs in script files and then you execute those scripts at your command prompt with the help of R interpreter called **Rscript**. So let's start with writing following code in a text file called test.R as under:

```
# My first program in R Programming
 myString <- "Hello, World!"


print ( myString)
```

Save the above code in a file test.R and execute it at Linux command prompt as given below. Even if you are using Windows or other system, syntax will remain same.

```
$ Rscript test.R
```

When we run the above program, it produces the following result.

```
[1] "Hello, World!"
```

Comments

Comments are like helping text in your R program and they are ignored by the interpreter while executing your actual program. Single comment is written using # in the beginning of the statement as follows:

```
# My first program in R Programming
```

R does not support multi-line comments but you can perform a trick which is something as follows:

```
if(FALSE){
"This is a demo for multi-line comments and it should be put inside
    either a single of double quote"
 }

myString <- "Hello, World!"
 print ( myString)
```

Though above comments will be executed by R interpreter, they will not interfere with your actual program. You should put such comments inside, either single or double quote.

4. R – Data Types

Generally, while doing programming in any programming language, you need to use various variables to store various information. Variables are nothing but reserved memory locations to store values. This means that, when you create a variable you reserve some space in memory.

You may like to store information of various data types like character, wide character, integer, floating point, double floating point, Boolean etc. Based on the data type of a variable, the operating system allocates memory and decides what can be stored in the reserved memory.

In contrast to other programming languages like C and java in R, the variables are not declared as some data type. The variables are assigned with R-Objects and the data type of the R-object becomes the data type of the variable. There are many types of R-objects. The frequently used ones are:

- **Vectors**
- **Lists**
- **Matrices**
- **Arrays**
- **Factors**
- **Data Frames**

The simplest of these objects is the **vector object** and there are six data types of these atomic vectors, also termed as six classes of vectors. The other R-Objects are built upon the atomic vectors.

Data Type	Example	Verify

Logical	TRUE , FALSE	`v <- TRUE`
		`print(class(v))`
		it produces the following result:
		`[1] "logical"`

Numeric	12.3, 5, 999	
		```
		v <- 23.5
		print(class(v))
		```
		 it produces the following result:

		`[1] "numeric"`

Integer	2L, 34L, 0L	`v <- 2L`
		`print(class(v))`
		it produces the following result:
		`[1] "integer"`

Complex	3 + 2i	`v <- 2+5i`
		`print(class(v))`
		it produces the following result:
		`[1] "complex"`

Character	'a' , '"good", "TRUE", '23.4'	`v <- "TRUE"`
		`print(class(v))`
		it produces the following result:
		`[1] "character"`

Raw	"Hello" is stored as 48 65 6c 6c 6f	`v <- charToRaw("Hello")`
		`print(class(v))`
		it produces the following result:
		`[1] "raw"`

In R programming, the very basic data types are the R-objects called **vectors** which hold elements of different classes as shown above. Please note in R the number of classes is not confined to only the above six types. For example, we can use many atomic vectors and create an array whose class will become array.

Vectors

When you want to create vector with more than one element, you should use **c()** function which means to combine the elements into a vector.

```
# Create a vector.
apple <- c('red','green',"yellow")
 print(apple)

# Get the class of the vector.
 print(class(apple))
```

When we execute the above code, it produces the following result:

```
 [1] "red"    "green" "yellow"
 [1] "character"
```

Lists

A list is an R-object which can contain many different types of elements inside it like vectors, functions and even another list inside it.

```
# Create a list.
list1 <- list(c(2,5,3),21.3,sin)

# Print the list.
 print(list1)
```

When we execute the above code, it produces the following result:

```
[[1]]
[1] 2 5 3

[[2]]
[1] 21.3

[[3]]
function (x) .Primitive("sin")
```

Matrices

A matrix is a two-dimensional rectangular data set. It can be created using a vector input to the matrix function.

```
# Create a matrix.
M = matrix( c('a','a','b','c','b','a'), nrow=2,ncol=3,byrow = TRUE)
 print(M)
```

When we execute the above code, it produces the following result:

```
[,1] [,2] [,3]
[1,] "a" "a" "b"
[2,] "c" "b" "a"
```

Arrays

While matrices are confined to two dimensions, arrays can be of any number of dimensions. The array function takes a dim attribute which creates the required number of dimension. In the below example we create an array with two elements which are 3x3 matrices each.

```
# Create an array.
a <- array(c('green','yellow'),dim=c(3,3,2))
 print(a)
```

When we execute the above code, it produces the following result:

```
, , 1

     [,1]     [,2]     [,3]
[1,] "green"  "yellow" "green"
[2,] "yellow" "green"  "yellow"
[3,] "green"  "yellow" "green"

, , 2

     [,1]     [,2]     [,3]
[1,] "yellow" "green"  "yellow"
[2,] "green"  "yellow" "green"
```

```
[3,] "yellow" "green" "yellow"
```

Factors

Factors are the r-objects which are created using a vector. It stores the vector along with the distinct values of the elements in the vector as labels. The labels are always character irrespective of whether it is numeric or character or Boolean etc. in the input vector. They are useful in statistical modeling.

Factors are created using the **factor()** function.The **nlevels** functions gives the count of levels.

```
# Create a vector.
apple_colors <- c('green','green','yellow','red','red','red','green')


# Create a factor object. factor_apple
 <- factor(apple_colors)


# Print the factor.
 print(factor_apple)
 print(nlevels(factor_apple))
```

When we execute the above code, it produces the following result:

```
[1] green green yellow red      red    red    yellow green
Levels: green red yellow
# applying the nlevels function we can know the number of distinct values
[1] 3
```

Data Frames

Data frames are tabular data objects. Unlike a matrix in data frame each column can contain different modes of data. The first column can be numeric while the second column can be character and third column can be logical. It is a list of vectors of equal length.

Data Frames are created using the **data.frame()** function.

```
# Create the data frame.
BMI <-      data.frame(
                   gender = c("Male", "Male","Female"),
height = c(152, 171.5, 165),
weight = c(81,93, 78), Age =c(42,38,26)
                    )
print(BMI)
```

When we execute the above code, it produces the following result:

```
  gender height weight Age
1   Male  152.0     81  42
2   Male  171.5     93  38
3 Female  165.0     78  26
```

5. R – Variables

A variable provides us with named storage that our programs can manipulate. A variable in R can store an atomic vector, group of atomic vectors or a combination of many R-objects. A valid variable name consists of letters, numbers and the dot or underline characters. The variable name starts with a letter or the dot not followed by a number.

Variable Name	Validity	Reason
var_name2.	valid	Has letters, numbers, dot and underscore
var_name%	Invalid	Has the character '%'. Only dot(.) and underscore allowed.
2var_name	invalid	Starts with a number
.var_name , var.name	valid	Can start with a dot(.) but the dot(.)should not be followed by a number.
.2var_name	invalid	The starting dot is followed by a number making it invalid
_var_name	invalid	Starts with _ which is not valid

Variable Assignment

The variables can be assigned values using leftward, rightward and equal to operator. The values of the variables can be printed using **print()** or **cat()**function. The **cat()** function combines multiple items into a continuous print output.

```
# Assignment using equal operator.
 var.1 = c(0,1,2,3)


# Assignment using leftward operator.
 var.2 <- c("learn","R")
```

```
# Assignment using rightward operator.
 c(TRUE,1) -> var.3

print(var.1)
cat ("var.1 is ", var.1 ,"\n")
cat ("var.2 is ", var.2 ,"\n")
cat ("var.3 is ", var.3 ,"\n")
```

When we execute the above code, it produces the following result:

```
[1] 0 1 2 3
var.1 is  0 1 2 3
var.2 is  learn R
var.3 is  1 1
```

Note: The vector c(TRUE,1) has a mix of logical and numeric class. So logical class is coerced to numeric class making TRUE as 1.

Data Type of a Variable

In R, a variable itself is not declared of any data type, rather it gets the data type of the R - object assigned to it. So R is called a dynamically typed language, which means that we can change a variable's data type of the same variable again and again when using it in a program.

```
var_x <- "Hello"
cat("The class of var_x is ",class(var_x),"\n")

var_x <- 34.5
cat(" Now the class of var_x is ",class(var_x),"\n")

var_x <- 27L
cat("  Next the class of var_x becomes ",class(var_x),"\n")
```

When we execute the above code, it produces the following result:

```
 The class of var_x is character Now
   the class of var_x is numeric
Next the class of var_x becomes integer
```

Finding Variables

To know all the variables currently available in the workspace we use the **ls()** function. Also the ls() function can use patterns to match the variable names.

```
print(ls())
```

When we execute the above code, it produces the following result:

```
[1] "my var"     "my_new_var" "my_var"     "var.1"
[5] "var.2"      "var.3"      "var.name"   "var_name2."
[9] "var_x"      "varname"
```

Note: It is a sample output depending on what variables are declared in your environment.

The ls() function can use patterns to match the variable names.

```
# List the variables starting with the pattern "var".
 print(ls(pattern="var"))
```

When we execute the above code, it produces the following result:

```
[1] "my var"     "my_new_var" "my_var"     "var.1"
[5] "var.2"      "var.3"      "var.name"   "var_name2."
[9] "var_x"      "varname"
```

The variables starting with **dot(.)** are hidden, they can be listed using "all.names=TRUE" argument to ls() function.

```
print(ls(all.name=TRUE))
```

When we execute the above code, it produces the following result:

```
[1] ".cars"        ".Random.seed" ".var_name"    ".varname"     ".varname2"
[6] "my var"       "my_new_var"   "my_var"       "var.1"        "var.2"
[11]"var.3"        "var.name"     "var_name2."   "var_x"
```

Deleting Variables

Variables can be deleted by using the **rm()** function. Below we delete the variable var.3. On printing the value of the variable error is thrown.

```
rm(var.3)
 print(var.3)
```

When we execute the above code, it produces the following result:

```
[1] "var.3"
Error in print(var.3) : object 'var.3' not found
```

All the variables can be deleted by using the **rm()** and **ls()** function together.

```
rm(list=ls())
print(ls())
```

When we execute the above code, it produces the following result:

```
character(0)
```

6. R – Operators

An operator is a symbol that tells the compiler to perform specific mathematical or logical manipulations. R language is rich in built-in operators and provides following types of operators.

Types of Operators

We have the following types of operators in R programming:

- Arithmetic Operators
- Relational Operators
- Logical Operators
- Assignment Operators
- Miscellaneous Operators

Arithmetic Operators

Following table shows the arithmetic operators supported by R language. The operators act on each element of the vector.

Operator	Description	Example

+	Adds two vectors	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v+t)`
		it produces the following result:
		`[1] 10.0 8.5 10.0`

−	Subtracts second vector from the first	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v-t)`

		it produces the following result: `[1] -6.0 2.5 2.0`

*	Multiplies both vectors	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v*t)`
		it produces the following result:
		`[1] 16.0 16.5 24.0`

/	Divide the first vector with the second	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v/t)`
		When we execute the above code, it produces the following result:
		`[1] 0.250000 1.833333 1.500000`

%%	Give the remainder of the first vector with the second	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v%%t)`
		it produces the following result:
		`[1] 2.0 2.5 2.0`

%/%	The result of division of first vector with second (quotient)	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v%/%t)`
		it produces the following result:

		`[1] 0 1 1`

^	The first vector raised to the exponent of second vector	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v^t)`
		
		it produces the following result:
		
		`[1] 256.000 166.375 1296.000`

Relational Operators

Following table shows the relational operators supported by R language. Each element of the first vector is compared with the corresponding element of the second vector. The result of comparison is a Boolean value.

Operator	Description	Example

>	Checks if each element of the first vector is greater than the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v>t)`
		
		it produces the following result:
		
		`[1] FALSE TRUE FALSE FALSE`

<	Checks if each element of the first vector is less than the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v < t)`
		
		it produces the following result:
		
		`[1] TRUE FALSE TRUE FALSE`

==	Checks if each element of the first vector is equal to the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v==t)`
		it produces the following result:
		`[1] FALSE FALSE FALSE TRUE`

<=	Checks if each element of the first vector is less than or equal to the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v<=t)`
		it produces the following result:
		`[1] TRUE FALSE TRUE TRUE`

>=	Checks if each element of the first vector is greater than or equal to the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v>=t)`
		it produces the following result:
		`[1] FALSE TRUE FALSE TRUE`

!=	Checks if each element of the first vector is unequal to the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v!=t)`
		it produces the following result:
		`[1] TRUE TRUE TRUE FALSE`

Logical Operators

Following table shows the logical operators supported by R language. It is applicable only to vectors of type logical, numeric or complex. All numbers greater than 1 are considered as logical value TRUE.

Each element of the first vector is compared with the corresponding element of the second vector. The result of comparison is a Boolean value.

Operator	Description	Example

&	It is called Element-wise Logical AND operator. It combines each element of the first vector with the corresponding element of the second vector and gives a output TRUE if both the elements are TRUE.	`v <- c(3,1,TRUE,2+3i)`
		`t <- c(4,1,FALSE,2+3i)`
		`print(v&t)`
		it produces the following result:
		`[1] TRUE TRUE FALSE TRUE`

|	It is called Element-wise Logical OR operator. It combines each element of the first vector with the corresponding element of the second vector and gives a output TRUE if one the elements is TRUE.	`v <- c(3,0,TRUE,2+2i)`
		`t <- c(4,0,FALSE,2+3i)`
		`print(v|t)`
		it produces the following result:
		`[1] TRUE FALSE TRUE TRUE`

!	It is called Logical NOT operator. Takes each element of the vector and gives the opposite logical value.	`v <- c(3,0,TRUE,2+2i)`
		`print(!v)`
		it produces the following result:
		`[1] FALSE TRUE FALSE FALSE`

The logical operator && and || considers only the first element of the vectors and give a vector of single element as output.

Operator	Description	Example

&&	Called Logical AND operator. Takes first element of both the vectors and gives the TRUE only if both are TRUE.	`v <- c(3,0,TRUE,2+2i)`
		`t <- c(1,3,TRUE,2+3i)`
		`print(v&&t)`
		it produces the following result:
		`[1] TRUE`

||	Called Logical OR operator. Takes first element of both the vectors and gives the TRUE only if both are TRUE.	`v <- c(0,0,TRUE,2+2i)`
		`t <- c(0,3,TRUE,2+3i)`
		`print(v||t)`
		it produces the following result:
		`[1] FALSE`

Assignment Operators

These operators are used to assign values to vectors.

Operator	Description	Example

<- or **=** or **<<-**	Called Left Assignment	`v1 <- c(3,1,TRUE,2+3i)`
		`v2 <<- c(3,1,TRUE,2+3i)`
		`v3 = c(3,1,TRUE,2+3i)`
		`print(v1)`
		`print(v2)`
		`print(v3)`
		`it produces the following result:`
		`[1] 3+0i 1+0i 1+0i 2+3i`
		`[1] 3+0i 1+0i 1+0i 2+3i`
		`[1] 3+0i 1+0i 1+0i 2+3i`

-> or **->>**	Called Right Assignment	`c(3,1,TRUE,2+3i) -> v1`
		`c(3,1,TRUE,2+3i) ->> v2`
		`print(v1)`
		`print(v2)`
		`it produces the following result:`
		`[1] 3+0i 1+0i 1+0i 2+3i`
		`[1] 3+0i 1+0i 1+0i 2+3i`

Miscellaneous Operators

These operators are used to for specific purpose and not general mathematical or logical computation.

Operator	Description	Example

:	Colon operator. It creates the series of numbers in sequence for a vector.	
		```
		v <- 2:8
		print(v)
		```
		it produces the following result:`[1] 2 3 4 5 6 7 8`

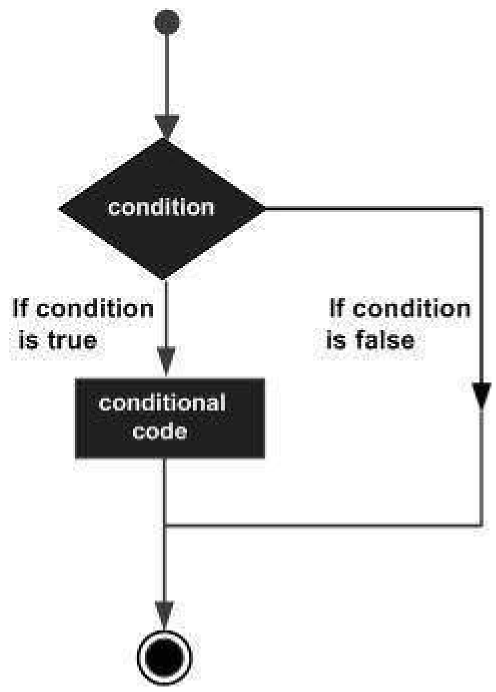
%in%	This operator is used to identify if an element belongs to a vector.	
		```
		v1 <- 8
		v2 <- 12
		t <- 1:10
		print(v1 %in% t)
		print(v2 %in% t)
		```
		it produces the following result:
		```
		[1] TRUE
		[1] FALSE
		```

%*%	This operator is used to multiply a matrix with its transpose.	
		```
		M = matrix( c(2,6,5,1,10,4), nrow=2,ncol=3,byrow = TRUE)
		t = M %*% t(M)
		print(t)
		```
		it produces the following result:
		```
		     [,1] [,2]
		[1,]   65   82
		 [2,]   82 117
		```

7. R – Decision making

Decision making structures require the programmer to 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:



R provides the following types of decision making statements. Click the following links to check their detail.

Statement	Description
if statement	An **if** statement consists of a Boolean expression followed by one or more statements.
if...else statement	An if statement can be followed by an optional else statement, which executes when the Boolean expression is false.

switch statement	A switch statement allows a variable to be tested for equality against a list of values.

R - If Statement

An **if** statement consists of a Boolean expression followed by one or more statements.

Syntax

The basic syntax for creating an **if** statement in R is:

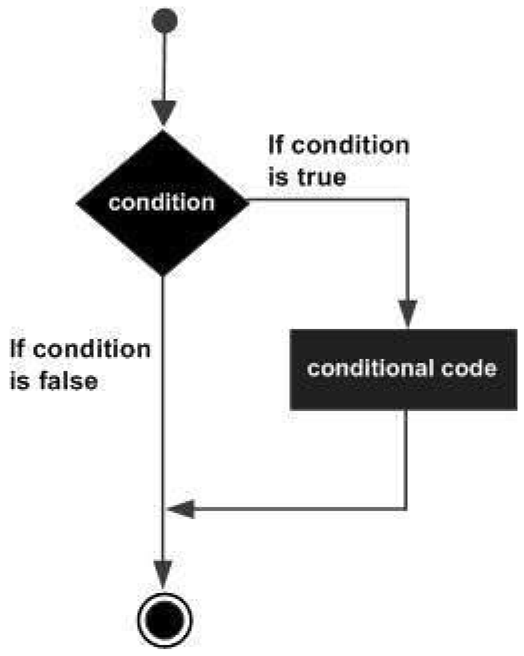
```
if(boolean_expression) {

// statement(s) will execute if the boolean expression is true.

 }
```

If the Boolean expression evaluates to be **true**, then the block of code inside the if statement will be executed. If Boolean expression evaluates to be **false**, then the first set of code after the end of the if statement (after the closing curly brace) will be executed.

Flow Diagram



Example

```
x <- 30L
```

```
if(is.integer(x)){ print("X
   is an Integer")
}
```

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

```
[1] "X is an Integer"
```

R – If...Else Statement

An **if** statement can be followed by an optional **else** statement which executes when the boolean expression is false.

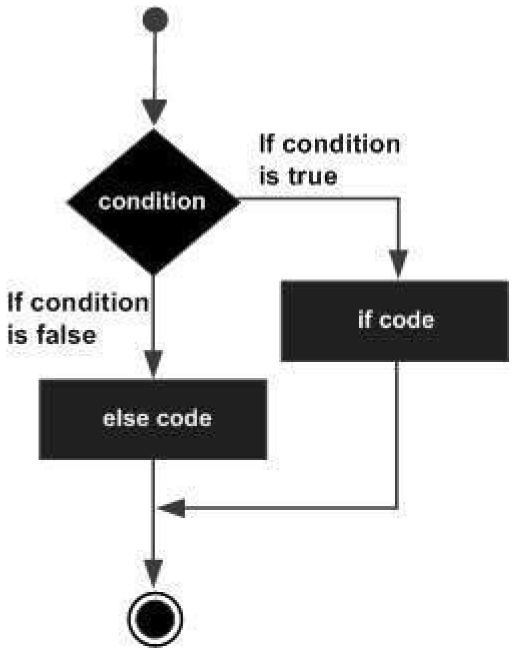
Syntax

The basic syntax for creating an **if...else** statement in R is:

```
if(boolean_expression) {
    // statement(s) will execute if the boolean expression is true.
} else {
   // statement(s) will execute if the boolean expression is false.
 }
```

If the Boolean expression evaluates to be **true**, then the **if block** of code will be executed, otherwise **else block** of code will be executed.

Flow Diagram



Example

```
x <- c("what","is","truth")
 if("Truth" %in% x){
print("Truth is found")
} else {
print("Truth is not found")
 }
```

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

```
[1] "Truth is not found"
```

Here "Truth" and "truth" are two different strings.

The if...else if...else Statement

An **if** statement can be followed by an optional **else if...else** statement, which is very useful to test various conditions using single if...else if statement.

When using **if**, **else if**, **else** statements there are few points to keep in mind.

- An **if** can have zero or one **else** and it must come after any **else if**'s.
- An **if** can have zero to many **else if**'s and they must come before the else.

- Once an **else if** succeeds, none of the remaining **else if**'s or **else**'s will be tested.

Syntax

The basic syntax for creating an **if...else if...else** statement in R is:

```
if(boolean_expression 1) {
// Executes when the boolean expression 1 is true.
}else if( boolean_expression 2) {
// Executes when the boolean expression 2 is true.
}else if( boolean_expression 3) {
// Executes when the boolean expression 3 is true.
}else {
// executes when none of the above condition is true.
 }
```

Example

```
x <- c("what","is","truth")
 if("Truth" %in% x){
print("Truth is found the first time")
} else if ("truth" %in% x) {
print("truth is found the second time")
} else {
print("No truth found")
 }
```

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

```
[1] "truth is found the second time"
```

R – Switch Statement

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

Syntax

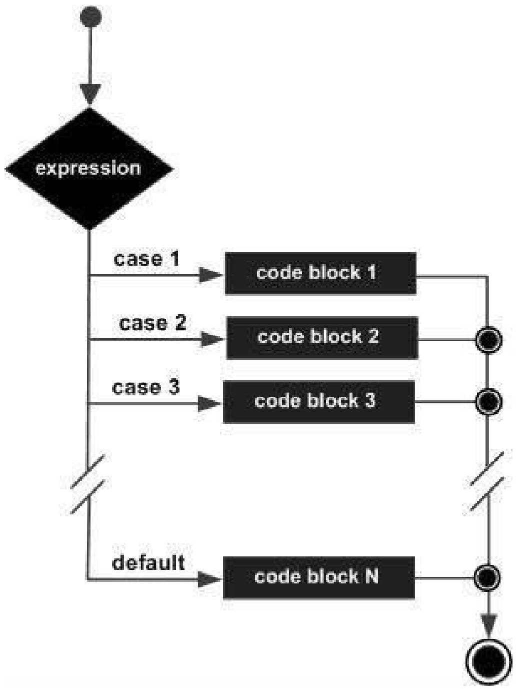
The basic syntax for creating a switch statement in R is :

```
switch(expression, case1, case2, case3 )
```

The following rules apply to a switch statement:

- If the value of expression is not a character string it is coerced to integer.
-
- You can have any number of case statements within a switch. Each case is followed by the value to be compared to and a colon.
-
- If the value of the integer is between 1 and nargs()-1 (The max number of arguments)then the corresponding element of case condition is evaluated and the result returned.
-
- If expression evaluates to a character string then that string is matched (exactly) to the names of the elements.
-
- If there is more than one match, the first matching element is returned.
-
- No Default argument is available.
-
- In the case of no match, if there is a unnamed element of ... its value is returned. (If there is more than one such argument an error is returned.)

Flow Diagram



Example

```
 x <- switch(
   3,
"first",
"second",
"third",
   "fourth"
 )
print(x)
```

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

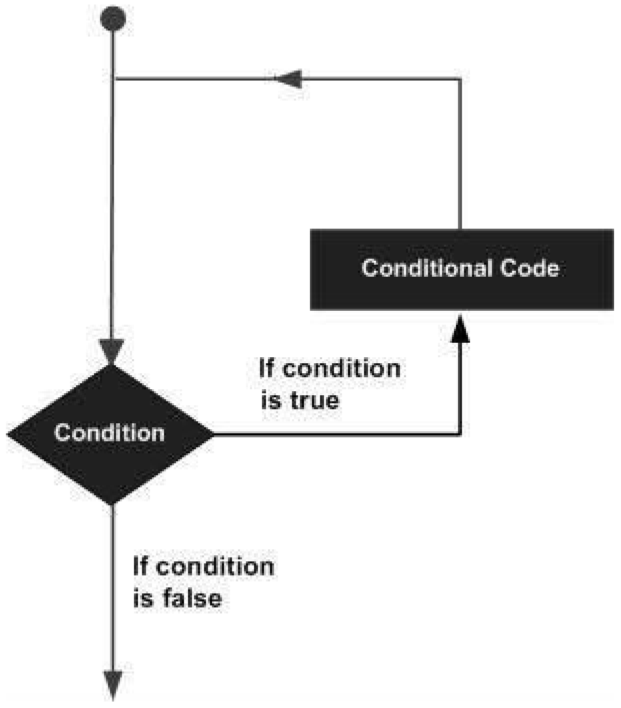
```
[1] "third"
```

8. R – 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 the following is the general form of a loop statement in most of the programming languages:



R programming language provides the following kinds of loop to handle looping requirements. Click the following links to check their detail.

Loop Type	Description
repeat loop	Executes a sequence of statements multiple times and abbreviates the code that manages the loop variable.
while loop	Repeats a statement or group of statements while a given condition is true. It tests the condition before executing the loop body.

for loop	Like a while statement, except that it tests the condition at the end of the loop body.

R - Repeat Loop

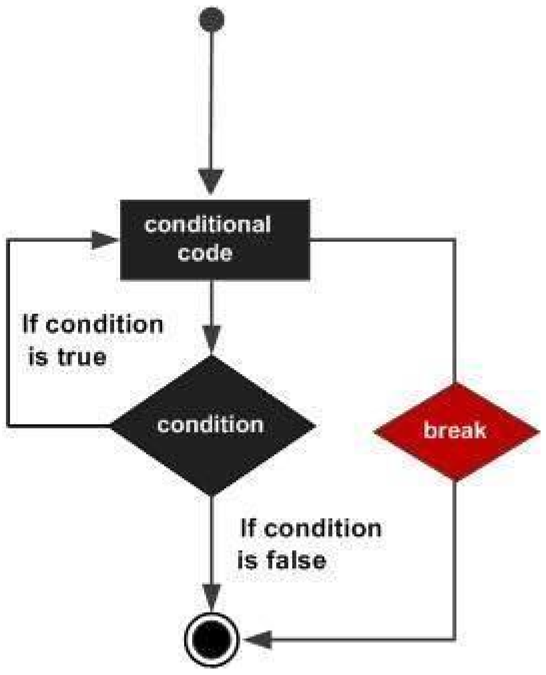
The Repeat loop executes the same code again and again until a stop condition is met.

Syntax

The basic syntax for creating a repeat loop in R is:

```
repeat {
commands if(condition){
break
    }
 }
```

Flow Diagram



Example

```
v <- c("Hello","loop")
```

```
cnt <- 2
 repeat{
print(v) cnt <-
    cnt+1 if(cnt
    > 5){
break
    }
 }
```

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

```
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
```

R - While Loop

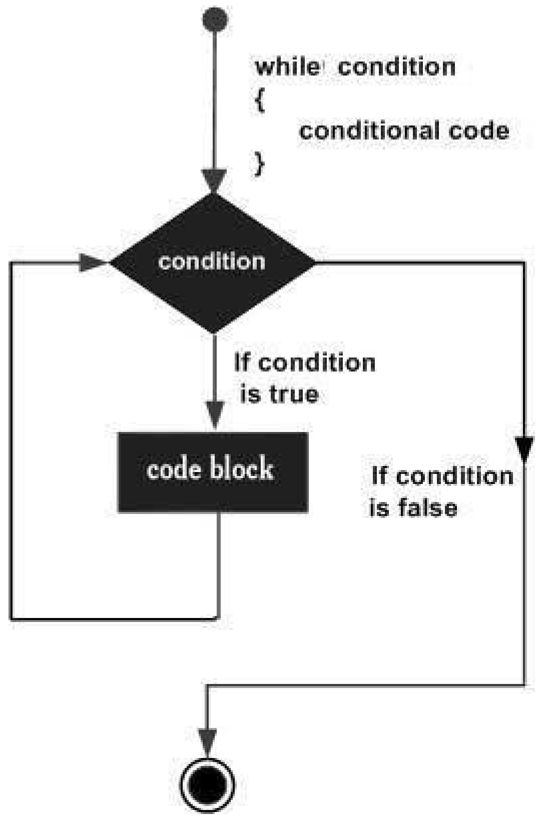
The While loop executes the same code again and again until a stop condition is met.

Syntax

The basic syntax for creating a while loop in R is :

```
while (test_expression) {
   statement
}
```

Flow Diagram



Here key point of the **while** loop is that the loop might not ever run. When the condition is tested and the result is false, the loop body will be skipped and the first statement after the while loop will be executed.

Example

```
v <- c("Hello","while loop")
 cnt <- 2
 while (cnt < 7){
    print(v)
cnt = cnt + 1
 }
```

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

```
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
```

```
[1] "Hello" "while loop"
```

R – For Loop

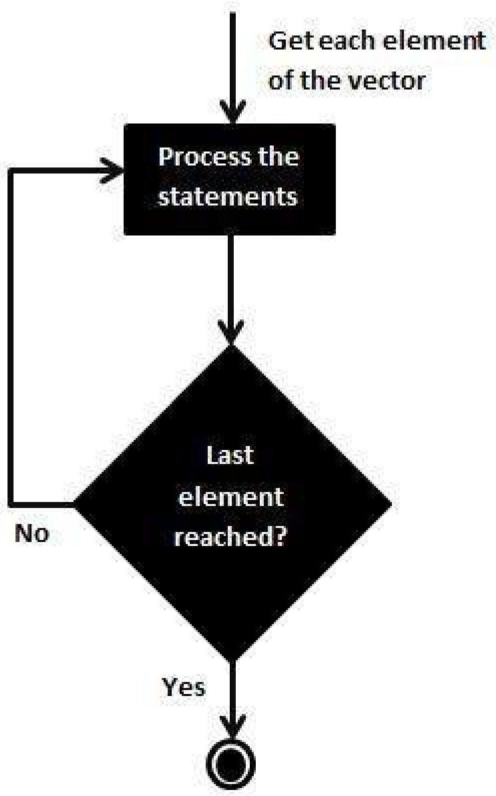
A for loop is a repetition control structure that allows you to efficiently write a loop that needs to execute a specific number of times.

Syntax

The basic syntax for creating a **for** loop statement in R is:

```
for (value in vector) {
   statements
}
```

Flow Diagram



R's for loops are particularly flexible in that they are not limited to integers, or even numbers in the input. We can pass character vectors, logical vectors, lists or expressions.

Example

```
v <- LETTERS[1:4]
for ( i in v) {
   print(i)
}
```

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

```
[1] "A"
[1] "B"
[1] "C"
[1] "D"
```

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.

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

Control Statement	Description
break statement	Terminates the loop statement and transfers execution to the statement immediately following the loop.
Next statement	The next statement simulates the behavior of R switch.

R – Break Statement

The break statement in R programming language has the following two usages:

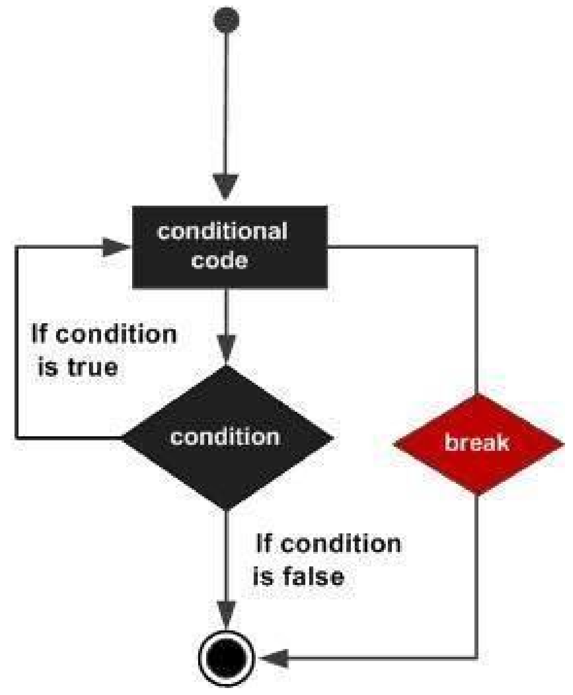
- When the break statement is encountered inside a loop, the loop is immediately terminated and program control resumes at the next statement following the loop.
-
- It can be used to terminate a case in the switch statement (covered in the next chapter).

Syntax

The basic syntax for creating a break statement in R is:

```
break
```

Flow Diagram



Example

```
v <- c("Hello","loop")
 cnt <- 2
repeat{
print(v) cnt <-
    cnt+1 if(cnt
    > 5){
break
    }
 }
```

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

```
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
```

R – Next Statement

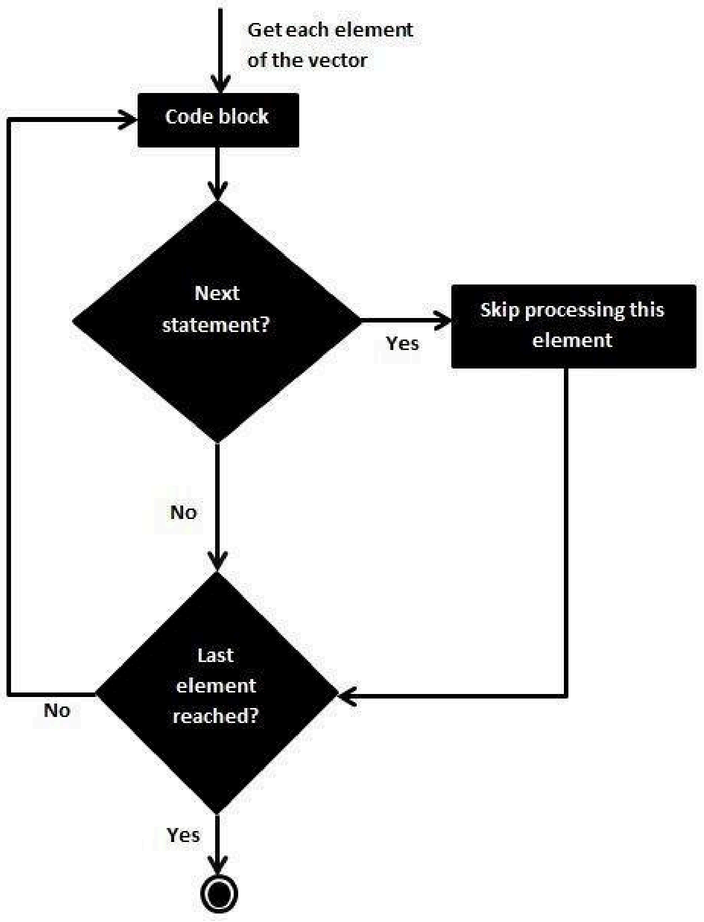
The **next** statement in R programming language is useful when we want to skip the current iteration of a loop without terminating it. On encountering next, the R parser skips further evaluation and starts next iteration of the loop.

Syntax

The basic syntax for creating a next statement in R is:

```
next
```

Flow Diagram



Example

```
v <- LETTERS[1:6]
for ( i in v){
if (i == "D"){
next
    }
print(i)
 }
```

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

```
[1] "A"
[1] "B"
```

```
[1] "C"
[1] "E"
[1] "F"
```

9. R – Function

A function is a set of statements organized together to perform a specific task. R has a large number of in-built functions and the user can create their own functions.

In R, a function is an object so the R interpreter is able to pass control to the function, along with arguments that may be necessary for the function to accomplish the actions.

The function in turn performs its task and returns control to the interpreter as well as any result which may be stored in other objects.

Function Definition

An R function is created by using the keyword **function**. The basic syntax of an R function definition is as follows:

```
function_name <- function(arg_1, arg_2, ...) {
    Function body
}
```

Function Components

The different parts of a function are:

- **Function Name:** This is the actual name of the function. It is stored in R environment as an object with this name.
-
- **Arguments:** An argument is a placeholder. When a function is invoked, you pass a value to the argument. Arguments are optional; that is, a function may contain no arguments. Also arguments can have default values.
-
- **Function Body:** The function body contains a collection of statements that defines what the function does.
-
- **Return Value:** The return value of a function is the last expression in the function body to be evaluated.

R has many **in-built** functions which can be directly called in the program without defining them first. We can also create and use our own functions referred as **user defined** functions.

Built-in Function

Simple examples of in-built functions are seq(), mean(), max(), sum(x)and paste(...) etc. They are directly called by user written programs. You can refer most widely used R functions.

```
# Create a sequence of numbers from 32 to 44.
 print(seq(32,44))

# Find mean of numbers from 25 to 82.
 print(mean(25:82))

# Find sum of numbers frm 41 to 68.
 print(sum(41:68))
```

When we execute the above code, it produces the following result:

```
[1] 32 33 34 35 36 37 38 39 40 41 42 43 44
[1] 53.5
[1] 1526
```

User-defined Function

We can create user-defined functions in R. They are specific to what a user wants and once created they can be used like the built-in functions. Below is an example of how a function is created and used.

```
# Create a function to print squares of numbers in sequence.
 new.function <- function(a) {
for(i in 1:a) {
b <- i^2 print(b)
             }
                     }
```

Calling a Function

```
# Create a function to print squares of numbers in sequence.
```

```
 new.function <- function(a) {
   for(i in 1:a) {
b <- i^2 print(b)
             }
                     }

# Call the function new.function supplying 6 as an argument.
 new.function(6)
```

When we execute the above code, it produces the following result:

```
[1] 1
[1] 4
[1] 9
[1] 16
[1] 25
[1] 36
```

Calling a Function without an Argument

```
# Create a function without an argument.
 new.function <- function() {
for(i in 1:5) { print(i^2)
             }
                     }

# Call the function without supplying an argument.
 new.function()
```

When we execute the above code, it produces the following result:

```
[1] 1
[1] 4
[1] 9
```

```
[1] 16

[1] 25
```

Calling a Function with Argument Values (by position and by name)

The arguments to a function call can be supplied in the same sequence as defined in the function or they can be supplied in a different sequence but assigned to the names of the arguments.

```
# Create a function with arguments.
 new.function <- function(a,b,c) {
result <- a*b+c
             print(result)
                            }


# Call the function by position of arguments.
 new.function(5,3,11)


# Call the function by names of the arguments.
 new.function(a=11,b=5,c=3)
```

When we execute the above code, it produces the following result:

```
[1] 26

[1] 58
```

Calling a Function with Default Argument

We can define the value of the arguments in the function definition and call the function without supplying any argument to get the default result. But we can also call such functions by supplying new values of the argument and get non default result.

```
# Create a function with arguments.
 new.function <- function(a = 3,b =6) {
result <- a*b print(result)
                                }
```

```
# Call the function without giving any argument.
 new.function()


# Call the function with giving new values of the argument.
 new.function(9,5)
```

When we execute the above code, it produces the following result:

```
[1] 18
[1] 45
```

Lazy Evaluation of Function

Arguments to functions are evaluated lazily, which means so they are evaluated only when needed by the function body.

```
# Create a function with arguments.
 new.function <- function(a, b) {
print(a^2) print(a)
         print(b)
                         }


# Evaluate the function without supplying one of the arguments.
 new.function(6)
```

When we execute the above code, it produces the following result:

```
[1] 36
[1] 6
Error in print(b) : argument "b" is missing, with no default
```

10. R – Strings

Any value written within a pair of single quote or double quotes in R is treated as a string. Internally R stores every string within double quotes, even when you create them with single quote.

Rules Applied in String Construction

- The quotes at the beginning and end of a string should be both double quotes or both single quote. They can not be mixed.
- Double quotes can be inserted into a string starting and ending with single quote.
-
- Single quote can be inserted into a string starting and ending with double quotes.
-
- Double quotes can not be inserted into a string starting and ending with double quotes.
-
- Single quote can not be inserted into a string starting and ending with single quote.

Examples of Valid Strings

Following examples clarify the rules about creating a string in R.

```
·  <- 'Start and end with single quote'
   print(a)

·  <- "Start and end with double quotes"
   print(b)

·  <- "single quote ' in between double quotes"
   print(c)

·  <- 'Double quotes " in between single quote'
   print(d)
```

When the above code is run we get the following output:

```
[1] "Start and end with single quote"
[1] "Start and end with double quotes"
```

```
[1] "single quote ' in between double quote"
[1] "Double quote \" in between single quote"
```

Examples of Invalid Strings

```
·  <- 'Mixed quotes"
   print(e)

·  <- 'Single quote ' inside single quote'
   print(f)

·  <- "Double quotes " inside double quotes"
   print(g)
```

When we run the script it fails giving below results.

```
...: unexpected INCOMPLETE_STRING

.... unexpected symbol
1: f <- 'Single quote ' inside

unexpected symbol
1: g <- "Double quotes " inside
```

String Manipulation

Concatenating Strings - paste() function

Many strings in R are combined using the **paste()** function. It can take any number of arguments to be combined together.

Syntax

The basic syntax for paste function is :

```
paste(..., sep = " ", collapse = NULL)
```

Following is the description of the parameters used:

- **...** represents any number of arguments to be combined.
-
- **sep** represents any separator between the arguments. It is optional.
-
- **collapse** is used to eliminate the space in between two strings. But not the space within two words of one string.

.

Example

```
'  <- "Hello"
'  <- 'How'
'  <- "are you? "

print(paste(a,b,c))

print(paste(a,b,c, sep = "-"))

print(paste(a,b,c, sep = "", collapse = ""))
```

When we execute the above code, it produces the following result:

```
[1] "Hello How are you? "
[1] "Hello-How-are you? "
[1] "HelloHoware you? "
```

Formatting numbers & strings - format() function

Numbers and strings can be formatted to a specific style using **format()**function.

Syntax

The basic syntax for format function is :

```
format(x, digits, nsmall,scientific,width,justify = c("left", "right", "centre",
 "none"))
```

Following is the description of the parameters used:

- **x** is the vector input.

-
- **digits** is the total number of digits displayed.
-
- **nsmall** is the minimum number of digits to the right of the decimal point.
-
- **scientific** is set to TRUE to display scientific notation.
-
- **width** indicates the minimum width to be displayed by padding blanks in the beginning.
-
- **justify** is the display of the string to left, right or center.

.

Example

```
# Total number of digits displayed. Last digit rounded off.
 result <- format(23.123456789, digits = 9)
print(result)

# Display numbers in scientific notation.
result <- format(c(6, 13.14521), scientific = TRUE)
 print(result)

# The minimum number of digits to the right of the decimal point.
 result <- format(23.47, nsmall = 5)
print(result)

# Format treats everything as a string.
 result <- format(6)
print(result)

# Numbers are padded with blank in the beginning for width.
 result <- format(13.7, width = 6)
print(result)

# Left justify strings.
```

```
result <- format("Hello",width = 8, justify = "l")
 print(result)

# Justfy string with center.
result <- format("Hello",width = 8, justify = "c")
 print(result)
```

When we execute the above code, it produces the following result:

```
[1] "23.1234568"
[1] "6.000000e+00" "1.314521e+01"
[1] "23.47000"
[1] "6"
[1] " 13.7"
[1] "Hello   "
[1] " Hello "
```

Counting number of characters in a string - ncahr() function

This function counts the number of characters including spaces in a string.

Syntax

The basic syntax for nchar() function is :

```
nchar(x)
```

Following is the description of the parameters used:

- **x** is the vector input.

Example

```
result <- nchar("Count the number of characters")
 print(result)
```

When we execute the above code, it produces the following result:

```
[1] 30
```

Changing the case - toupper() & tolower() functions

These functions change the case of characters of a string.

Syntax

The basic syntax for toupper() & tolower() function is :

```
toupper(x)
 tolower(x)
```

Following is the description of the parameters used:

- **x** is the vector input.

Example

```
# Changing to Upper case.
result <- toupper("Changing To Upper")
 print(result)

# Changing to lower case.
result <- tolower("Changing To Lower")
 print(result)
```

When we execute the above code, it produces the following result:

```
[1] "CHANGING TO UPPER"
[1] "changing to lower"
```

Extracting parts of a string - substring() function

This function extracts parts of a String.

Syntax

The basic syntax for substring() function is :

```
substring(x,first,last)
```

Following is the description of the parameters used:

- **x** is the character vector input.
- **first** is the position of the first character to be extracted.

- **last** is the position of the last character to be extracted.

Example

```
# Extract characters from 5th to 7th position.
 result <- substring("Extract", 5, 7)
 print(result)
```

When we execute the above code, it produces the following result:

```
[1] "act"
```

11. R – Vectors

Vectors are the most basic R data objects and there are six types of atomic vectors. They are logical, integer, double, complex, character and raw.

Vector Creation

Single Element Vector

Even when you write just one value in R, it becomes a vector of length 1 and belongs to one of the above vector types.

```
# Atomic vector of type character.
 print("abc");

# Atomic vector of type double.
 print(12.5)

# Atomic vector of type integer.
 print(63L)

# Atomic vector of type logical.
 print(TRUE)

# Atomic vector of type complex.
 print(2+3i)

# Atomic vector of type raw.
 print(charToRaw('hello'))
```

When we execute the above code, it produces the following result:

```
[1] "abc"
[1] 12.5
[1] 63
```

```
[1] TRUE
[1] 2+3i
[1] 68 65 6c 6c 6f
```

Multiple Elements Vector

Using colon operator with numeric data

```
# Creating a sequence from 5 to 13.
 v <- 5:13
print(v)

# Creating a sequence from 6.6 to 12.6.
 v <- 6.6:12.6
print(v)

# If the final element specified does not belong to the sequence then it is
 discarded.
v <- 3.8:11.4
print(v)
```

When we execute the above code, it produces the following result:

```
 [1]  5 6   7   8 9 10 11 12 13
 [1]  6.6  7.6  8.6  9.6 10.6 11.6 12.6
 [1]  3.8  4.8  5.8  6.8 7.8 8.8 9.8 10.8
```

Using sequence (Seq.) operator

```
# Create vector with elements from 5 to 9 incrementing by 0.4.
 print(seq(5, 9, by=0.4))
```

When we execute the above code, it produces the following result:

```
[1] 5.0 5.4 5.8 6.2 6.6 7.0 7.4 7.8 8.2 8.6 9.0
```

Using the c() function

The non-character values are coerced to character type if one of the elements is a character.

```
# The logical and numeric values are converted to characters.
 s <- c('apple','red',5,TRUE)
print(s)
```

When we execute the above code, it produces the following result:

```
[1] "apple" "red"   "5"    "TRUE"
```

Accessing Vector Elements

Elements of a Vector are accessed using indexing. The **[ ] brackets** are used for indexing. Indexing starts with position 1. Giving a negative value in the index drops that element from result. **TRUE**, **FALSE** or **0** and **1** can also be used for indexing.

```
# Accessing vector elements using position.
t <- c("Sun","Mon","Tue","Wed","Thurs","Fri","Sat")
u <- t[c(2,3,6)]
print(u)

# Accessing vector elements using logical indexing.
 v <- t[c(TRUE,FALSE,FALSE,FALSE,FALSE,TRUE,FALSE)]
print(v)

# Accessing vector elements using negative indexing.
 x <- t[c(-2,-5)]
print(x)

# Accessing vector elements using 0/1 indexing.
 y <- t[c(0,0,0,0,0,0,1)]
print(y)
```

When we execute the above code, it produces the following result:

```
 [1] "Mon" "Tue" "Fri"
 [1] "Sun" "Fri"
 [1] "Sun" "Tue" "Wed" "Fri" "Sat"
 [1] "Sun"
```

Vector Manipulation

Vector Arithmetic

Two vectors of same length can be added, subtracted, multiplied or divided giving the result as a vector output.

```
# Create two vectors.
 v1 <- c(3,8,4,5,0,11)
v2 <- c(4,11,0,8,1,2)

# Vector addition.
 add.result <- v1+v2
 print(add.result)

# Vector substraction.
 sub.result <- v1-v2
 print(sub.result)

# Vector multiplication.
 multi.result <- v1*v2
 print(multi.result)

# Vector division.
 divi.result <- v1/v2
 print(divi.result)
```

When we execute the above code, it produces the following result:

```
 [1]  7 19  4 13  1 13
 [1] -1 -3  4 -3 -1  9
 [1] 12 88  0 40  0 22

 [1] 0.7500000 0.7272727       Inf 0.6250000 0.0000000 5.5000000
```

Vector Element Recycling

If we apply arithmetic operations to two vectors of unequal length, then the elements of the shorter vector are recycled to complete the operations.

```
v1 <- c(3,8,4,5,0,11)
 v2 <- c(4,11)
# V2 becomes c(4,11,4,11,4,11)

add.result <- v1+v2
 print(add.result)

sub.result <- v1-v2
 print(sub.result)
```

When we execute the above code, it produces the following result:

```
[1] 7 19 8 16 4 22
[1] -1 -3 0 -6 -4 0
```

Vector Element Sorting

Elements in a vector can be sorted using the **sort()** function.

```
v <- c(3,8,4,5,0,11, -9, 304)

# Sort the elements of the vector.
 sort.result <- sort(v)
 print(sort.result)

# Sort the elements in the reverse order.
 revsort.result <- sort(v, decreasing = TRUE)
 print(revsort.result)
```

```
# Sorting character vectors.
v <- c("Red","Blue","yellow","violet")
 sort.result <- sort(v)
 print(sort.result)

# Sorting character vectors in reverse order.
 revsort.result <- sort(v, decreasing = TRUE)
 print(revsort.result)
```

When we execute the above code, it produces the following result:

```
 [1] -9 0      3        5   8 11 304
        4
                        4   3   0 -9
 [1] 304 11    8
 [1] "Blue"    "Red"    "violet" "yellow"
        5
 [1] "yellow" "violet" "Red"    "Blue"
```