Question 1

`R` was developed by statisticians working at

(i) Insightful

(ii) Bell Labs

(iii) The University of New South Wales

(iv) The University of Auckland

Question 2

The definition of free software consists of four freedoms (freedoms 0 through 3).

Which of the following is NOT one of the freedoms that are part of the definition?

(i) The freedom to study how the program works, and adapt it to your needs.

(ii) The freedom to improve the program, and release your improvements to the public, so that the whole community benefits.

(iii) The freedom to run the program, for any purpose.

(iv) The freedom to sell the software for any price.

Question 3

Useful `R` Commands

`class()` the class of an object

`mode()` the type or storage mode of an object.

`str()` display the internal structure of an R object

```
x <- c(2,3,5)
class(x)
mode(x)
str(x)
```

Question 3

In `R` the following are all **atomic data types** EXCEPT

(i) `logical`

(ii) `complex`

(iii) `list`

(iv) `integer`

```
u <- 4
v <- complex(3,4)
w <- 5L
x <- list(u,v,w)

class(u)
class(v)
class(w)
class(x)
str(u)
str(v)
str(w)
str(x)
```

Question 4

If I execute the expression `x <- 4` in `R` , what is the class of the object '`x`' as determined by the '`class()`' function?

(i) `vector`

(ii) `numeric`

(iii) `complex`

(iv) `real`

```
x <- 4
class(x)
```

```
##  Integers and Logical
y<- 4L
y
z <- TRUE
z
class(y)
class(z)
```

Built-In Data Sets

Several data sets , intended as learning tools, are automatically installed when `R` is installed. Many more are installed within packages to complement learning to use those packages. One of these is the famous Iris data set, which is used in many data mining exercises.

- `iris`
- `mtcars`
- `Nile`

To see what data sets are available, simply type `data()`. To load a data set, simply type in the name of the data set. Some data sets are very large. To just see the first few (or last) rows, we use the `head()` function or alternatively the `tail()` function. The default number of rows of these commands is 6. Other numbers can be specified.

```
> head(iris)
  Sepal.Length Sepal.Width Petal.Length Petal.Width Spe
1          5.1         3.5          1.4         0.2  se
2          4.9         3.0          1.4         0.2  se
3          4.7         3.2          1.3         0.2  se
4          4.6         3.1          1.5         0.2  se
5          5.0         3.6          1.4         0.2  se
6          5.4         3.9          1.7         0.4  se
```

```
>
> tail(iris,4)
    Sepal.Length Sepal.Width Petal.Length Petal.Width
147          6.3         2.5          5.0         1.9 v
148          6.5         3.0          5.2         2.0 v
149          6.2         3.4          5.4         2.3 v
150          5.9         3.0          5.1         1.8 v
```

In many situations, it is useful to call a particular data set using the `attach()` command. This will save having to specify the data sets over repeated operations. The file can then be detached using the `detach()` command.

Other Useful Commands

```
mode(x)
str(x)
dim(x)
length(x)
```

Try out these commands for some other objects, including inbuilt data sets **iris** and **Nile**.

```
iris
Nile
Y <- "R"
Z <- c(TRUE,FALSE,TRUE)
```

Question 5

What is the class of the object defined by the expression `x <- c(4, "a", TRUE)`?

(i) `mixed`

(i) `logical`

(i) `character`

(i) `integer`

```
x <- c(4, "a", TRUE)
class(x)
```

Question 6

If I have two vectors `x <- c(1,3, 5)` and `y <- c(3, 2, 10)`, what is produced by the expression `rbind(x, y)`?

(i) a vector of length 2

(ii) a 2 by 3 matrix

(iii) a vector of length 3

(iv) a 2 by 2 matrix

```
x <- c(1,3, 5)
y <- c(3, 2, 10)
rbind(x, y)
```

- Use the help file to find out what the commands `rbind()`, `cbind()` and `t()` do.
- The convention is to specify the number of rows, then number of columns.
- The tranpose operator "`t()`" is actually really useful for creating reports from data contained in data frames.

Question 7

A key property of vectors in `R` is that

(i) the length of a vector must be less than 32,768

(ii) elements of a vector all must be of the same class

(iii) elements of a vector can only be character or numeric

(iv) elements of a vector can be of different classes

Question 8

Suppose I have a list defined as `x <- list(2, "a", "b", TRUE)`.

What does `x[[2]]` give me?

(i) a list containing the number 2 and the letter "a".

(ii) a character vector with the elements "a" and "b".

(iii) a character vector containing the letter "a".

(iv) a list containing a character vector with the elements "a" and "b".

```
x <- list(2, "a", "b", TRUE)
x[[2]]
```

- Try out `dim()` and `class()` on x also.

Question 9

Suppose I have a vector `x <- 1:4` and a vector `y <- 2`. What is produced by the expression `x + y`?

(i) a numeric vector with elements 3, 4, 5, 6.

(ii) an integer vector with elements 3, 2, 3, 4.

(iii) a numeric vector with elements 3, 2, 3, 4.

(iv) an integer vector with elements 3, 2, 3, 6.

Question 10

Suppose I have a vector

```
x <- c(3, 5, 1, 10, 12, 6)
```

and I want to set all elements of this vector that are less than 6 to be equal to zero. What `R` code achieves this?

(i) `x[x > 0] <- 6`

(ii) `x[x < 6] <- 0`

(iii) `x[x > 6] <- 0`

(iv) `x[x == 6] <- 0`

This is called **Logical Indexing**. To get an idea of logical indexing, try out the following code snippets.

```
x <- c(3, 5, 1, 10, 12, 6)
x>0
x<6
X==6
```

The airquality data set

Some Useful Commands As well as some of the commands we have seen earlier, it is worth getting to know the following commands also.

1 `head()` and `tail()`

2 `names()`, `rownames()` and `colnames()`

3 `summary()`

4 `complete.cases()`

5 `dim()`, `nrow()` and `ncol()`

Use the `help` command to find out what each of these commands do.

```
help(complete.cases)
```

```
> head(airquality)
Ozone Solar.R   Wind Temp Month Day
1      41     190    7.4   67     5   1
2      36     118    8.0   72     5   2
3      12     149   12.6   74     5   3
....
```

Inspecting the data set

2a) Dimensions

2b) Column names (i.e. variables names)

2c) structure of data frame

Lets compute the dimensions of the data frame ***iris***, and also the length of the ***Nile*** data set.

```
dim(iris)
nrow(iris)
ncol(iris)
length(Nile)
```

Data frames often have specifically named rows and columns. Lets find out the names of the variables (columns) and cases (rows) for the data sets ***iris*** and ***mtcars***.

```
names(iris)
colnames(iris)
rownames(iris) # simply the case numbers.

names(mtcars)
```

```
rownames(mtcars)
colnames(mtcars)
```

The `summary()` command

The **`summary()`** command can be used to extract a short statistical summary (if applicable) from each column of the data frame. If there are missing values, the frequency of missing values will also be listed for each column.

```
> summary(iris)
  Sepal.Length    Sepal.Width     Petal.Length    Petal
 Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.
 1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu
 Median :5.800   Median :3.000   Median :4.350   Median
 Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean
 3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu
 Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.
```

Types of Data in Dataframes

What is the data type of each column in the iris data set? To find out, we use the `str()` command.

```
str(iris)
```

The output of this command is given below. There are four numeric variables, and one factor (i.e. categorical) variable.

```
'data.frame':   150 obs. of  5 variables:
 $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4
 $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9
 $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1
 $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0
 $ Species     : Factor w/ 3 levels "setosa","versicolo
>
```

The `head()` and `tail()` function

The head and tail functions can be used to access the first six and last six rows of a data frame. If a different number of rows is required, all you have to do is specify that number as an additional argument.

```
head(iris)     #First 6 rows
head(iris,2)   #First 2 rows

tail(iris)     #Last 6 rows
tail(iris,4)   #Last 4 rows
```

Accessing a particular row or set of rows

- Each value in a dataframe can be accessed directly by specifying the row and column i.e. `df[r,c]`.
- To access a particular row, simply specify the row number, while leaving the column number blank i.e. `df[r,]`
- To access a particular column, simple specify the column number, while leaving the row number blank i.e. `df[,c]`

```
iris[10,2]

iris[10,]

Formaldehyde[,2]
```

```
> iris[10,2]
[1] 3.1
> iris[10,]
   Sepal.Length Sepal.Width Petal.Length Petal.Width Sp
10          4.9         3.1          1.5         0.1  s
>
```

```
> Formaldehyde[,2]
[1] 0.086 0.269 0.446 0.538 0.626 0.782
```

Missing data

- Determining the number of missing data items
- Performing statistical operations removing missing data

As stated previously, the `summary()` command can be used to determine the number of missing data items in a data frame. The additional argument `na.rm=TRUE` can also be used with certain functions (see the help file)

```
> X <- c(4,6,3,12,NA,8)
> mean(X)
[1] NA
>
> summary(X)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
    3.0     4.0     6.0     6.6     8.0    12.0       1
>
> mean(X ,na.rm = TRUE)
[1] 6.6
```

Subsetting Data

Logical and Relational Operator

- AND - The logical operator is &
- OR - The logical operator is ||

Selection using the `subset()` Function

The `subset( )` function is the easiest way to select variables and observation.

Example 1

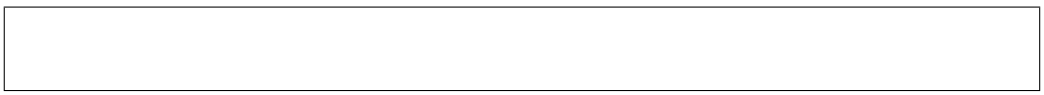
In the following example we will use the ***iris*** data set, we select all rows that have a value of sepal length of 6 or more, and determine how many observations there are, and then compute the mean of the petal lengths. (The answer is 5.263, from the summary output).

```
#call the subset iris.2

iris.2 = subset(iris,iris$Sepal.Length >= 6)

dim(iris.2)

summary(iris.2)
```



Example 2

There are three types of iris - setosa, versicoloir and virginica. Suppose we wish to compute the median of petal widths for the setosa irises only.

The equality operator is ==.

```
> iris.setosa =subset(iris,iris$Species=="setosa")
> summary(iris.setosa)
  Sepal.Length    Sepal.Width     Petal.Length    Petal
 Min.   :4.300   Min.   :2.300   Min.   :1.000   Min.
 1st Qu.:4.800   1st Qu.:3.200   1st Qu.:1.400   1st Qu
 Median :5.000   Median :3.400   Median :1.500   Median
 Mean   :5.006   Mean   :3.428   Mean   :1.462   Mean
 3rd Qu.:5.200   3rd Qu.:3.675   3rd Qu.:1.575   3rd Qu
 Max.   :5.800   Max.   :4.400   Max.   :1.900   Max.
       Species
 setosa    :50
 versicolor: 0
 virginica : 0
```

Example 3

In the following example we will use the ***iris*** data set, we select all rows that have a value of sepal length of 6 or more, but have sepal width is at least 2.5.

```
> iris.3 = subset(iris,(iris$Sepal.Length >= 6)&(iris$S
> summary(iris.3)
```

```
 Sepal.Length    Sepal.Width     Petal.Length    Petal
Min.   :6.000   Min.   :2.500   Min.   :4.000   Min.
1st Qu.:6.300   1st Qu.:2.800   1st Qu.:4.750   1st Qu
Median :6.500   Median :3.000   Median :5.300   Median
Mean   :6.641   Mean   :3.013   Mean   :5.313   Mean
3rd Qu.:6.900   3rd Qu.:3.200   3rd Qu.:5.750   3rd Qu
Max.   :7.900   Max.   :3.800   Max.   :6.900   Max.
      Species
setosa    : 0
versicolor:21
virginica :42
```

Question 11

In the dataset provided for this Quiz, what are the column names of the dataset?

(i) Ozone, Solar.R, Wind, Temp, Month, Day

(ii) Ozone, Solar.R, Wind

(iii) Month, Day, Temp, Wind

(iv) 1, 2, 3, 4, 5, 6

Sequences and Numerical Indexing

A sequence of integers can be created usingn the colon symbol. The sequence may either be *count-up* or *count-down*.
Importantly, the sequence will return all integers betwen the upper and lower bound, and including both the upper and lower bound (*Other languages can be different in this respect*)

```
0:5
1:6
-4:5
10:1
```

A contiguous group of rows from a a data frame may be extracted using the appropriate sequence of values as indices. Likewise for a contiguous group of columns

```
iris[1:6,]     # First Six Rows
iris[,3:4]     # Third and Fourth Columns
iris[1:40,2:3] # 40 Rows, Columns 2 and 3
```

0.1 Relational and Logical Operators

Relational operators allow for the comparison of values in vectors.

greater than	$>$
less than	$<$
equal to	$==$
less than or equal to	$<=$
greater than or equal to	$>=$
not equal to	$!=$

- Note the difference of the equality operator "==" with assignment operator "=".
- & and && indicate logical AND and | and || indicate logical OR.
- The shorter form performs element-wise comparisons in much the same way as arithmetic operators. The longer form is appropriate for programming control-flow and typically preferred in "if" clauses.
- We can use relational operators to subset vectors (as well as more complex data objects such as data frames, which we will meet later).
- We specify the relational condition in square brackets.

- We can construct compound relational conditions too, using logical operators

```
> vec=1:19
> vec[vec<5]
[1] 1 2 3 4
> vec[(vec<6)|(vec>16)]
[1]  1  2  3  4  5 17 18 19
```

Question 12

Extract the first 2 rows of the data frame and print them to the console. What does the output look like?

```
Ozone Solar.R Wind Temp Month Day
1    41     190  7.4   67     5   1
2    36     118  8.0   72     5   2
```

```
Ozone Solar.R Wind Temp Month Day
1     7      NA  6.9   74     5  11
2    35     274 10.3   82     7  17
```

```
Ozone Solar.R Wind Temp Month Day
1    18     224 13.8   67     9  17
2    NA     258  9.7   81     7  22
```

```
Ozone Solar.R Wind Temp Month Day
1     9      24 10.9   71     9  14
2    18     131  8.0   76     9  29
```

Question 13

How many observations (i.e. rows) are in this data frame?

- 129
- 153
- 160
- 45

Question 14

Extract the last 2 rows of the data frame and print them to the console. What does the output look like?

```
Ozone Solar.R Wind Temp Month Day
152    11      44  9.7   62     5  20
153   108     223  8.0   85     7  25
```

```
Ozone Solar.R Wind Temp Month Day
152    34     307 12.0   66     5  17
153    13      27 10.3   76     9  18
```

```
Ozone Solar.R Wind Temp Month Day
152    18     131  8.0   76     9  29
153    20     223 11.5   68     9  30
```

```
Ozone Solar.R Wind Temp Month Day
152    31     244 10.9   78     8  19
153    29     127  9.7   82     6   7
```

Question 15

What is the value of Ozone in the 47th row?

(i) 63

(ii) 34

(iii) 18

(iv) 21

Question 16

How many missing values (`NA`s) are in the *Ozone* column of this data frame?

(i) 37

(ii) 78

(iii) 43

(iv) 9

```
names(airquality)
attach(airquality)
is.na(Ozone)

!is.na(Ozone)

which(is.na(Ozone))

length(which(is.na(Ozone)))
detach(airquality)
```

Question 17

What is the mean of the Ozone column in this dataset? Exclude missing values (coded as NA) from this calculation.

(i) 42.1

(ii) 18.0

(iii) 53.2

(iv) 31.5

Question 18

Extract the subset of rows of the data frame where Ozone values are above 31 and Temp values are above 90.

What is the mean of `Solar.R` in this subset?

(i) 185.9

(ii) 212.8

(iii) 334.0

(iv) 205.0

```
attach(airquality)

Ozone>31
## TRUE for cases where Ozone > 31

Temp>90
## TRUE for cases where Temp >90

(Ozone>31)&(Temp>90)
## TRUE for both conditions

## Create a temporary subset (temp)

temp <-airquality[(Ozone>31)&(Temp>90),]

summary(temp)
```

Question 19

What is the mean of "Temp" when "Month" is equal to 6?

(i) 90.2

(ii) 85.6

(iii) 79.1

(iv) 75.3

Question 20

What was the maximum ozone value in the month of May (i.e. Month = 5)?

(i) 100

(ii) 115

(iii) 18

(iv) 97