

R Textbook Companion for
Statistics for Business and Economics
by Anderson, Sweeney, and Williams¹

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May 22, 2020

¹Funded by a grant from the National Mission on Education through ICT
- <http://spoken-tutorial.org/NMEICT-Intro>. This Textbook Companion and R
codes written in it can be downloaded from the "Textbook Companion Project"
section at the website - <https://r.fossee.in>.

Book Description

Title: Statistics for Business and Economics

Author: Anderson, Sweeney, and Williams

Publisher: Cengage Learning, USA

Edition: 11

Year: 2011

ISBN: 9780538471886

R numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means an R code whose theory is explained in Section 2.3 of the book.

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Chapter 2

Descriptive Statistics Tabular and Graphical Presentations

R code Exa 2.1a Summarizing Categorical Data Part 1

```
1                                     # Page no. :  
                                     33  
2  
3 # Frequency Distribution (Categorical Data)  
4  
5 # Dataset  
6  
7 soft_drink_names <- c("Coke Classic", "Diet Coke", "  
    Pepsi", "Diet Coke", "Coke Classic", "Coke Classic  
    ",  
8                               "Dr. Pepper", "Diet Coke", "  
                               Pepsi", "Pepsi", "Coke  
                               Classic", "Dr. Pepper",  
9                               "Sprite", "Coke Classic", "Diet  
                               Coke", "Coke Classic", "  
                               Coke Classic", "Sprite",  
10                              "Coke Classic", "Diet Coke", "  
                               Coke Classic", "Diet Coke",  
                               "Coke Classic", "Sprite",
```

```

11         "Pepsi", "Coke Classic", "Coke
           Classic", "Coke Classic", "
           Pepsi", "Coke Classic",
12         "Sprite", "Dr. Pepper", "Pepsi"
           , "Diet Coke", "Pepsi", "
           Coke Classic",
13         "Coke Classic", "Coke Classic",
           "Pepsi", "Dr. Pepper", "
           Coke Classic", "Diet Coke",
14         "Pepsi", "Pepsi", "Pepsi", "
           Pepsi", "Coke Classic", "Dr.
           Pepper", "Pepsi", "Sprite")
15
16 soft_drink_table <- data.frame(table(soft_drink_
           names))
17
18                                     # Page no. : 34
19
20 FD <- data.frame(Soft_drinks = soft_drink_table$soft
           _drink_names ,
21                 Frequency = soft_drink_table$Freq)
           # Frequency Distribution
22
23
24 RF <- FD$Frequency / sum(FD$Frequency)   # Relative
           Frequency
25
26 FD <- cbind(FD, Relative_frequency = RF)
27
28 PF <- FD$Relative_frequency * 100       # Percentage
           Frequency
29
30 FD <- cbind(FD, Percentage_frequency = PF)
31
32 View(FD)   # Viewing the Frequency Distribution
           Table
33
34 # Total values of Frequency Distribution

```

```

35
36 total_freq <- sum(FD$Frequency)
37
38 total_rel_freq <- sum(FD$Relative_frequency)
39
40 total_per_freq <- sum(FD$Percentage_frequency)
41
42 cat("Total value for frequency is", total_freq, "\n"
    )
43 cat("Total value for relative frequency is", total_
    rel_freq, "\n")
44 cat("Total value for percentage frequency is", total
    _per_freq)

```

R code Exa 2.1b Summarizing Categorical Data Part 2

```

1                                     # Page no. :
                                     35
2
3 # Bar Charts and Pie Charts
4
5 # Dataset
6
7 soft_drink_names <- c("Coke Classic", "Diet Coke", "
    Pepsi", "Diet Coke", "Coke Classic", "Coke Classic
    ",
8                               "Dr. Pepper", "Diet Coke", "
    Pepsi", "Pepsi", "Coke
    Classic", "Dr. Pepper",
9                               "Sprite", "Coke Classic", "
    Diet Coke", "Coke Classic",
    "Coke Classic", "Sprite",
10                              "Coke Classic", "Diet Coke", "
    Coke Classic", "Diet Coke",
    "Coke Classic", "Sprite",

```

```

11         "Pepsi", "Coke Classic", "Coke
           Classic", "Coke Classic",
           "Pepsi", "Coke Classic",
12         "Sprite", "Dr. Pepper", "Pepsi",
           ", "Diet Coke", "Pepsi", "
           Coke Classic",
13         "Coke Classic", "Coke Classic",
           ", "Pepsi", "Dr. Pepper", "
           Coke Classic", "Diet Coke",
14         "Pepsi", "Pepsi", "Pepsi", "
           Pepsi", "Coke Classic", "Dr
           . Pepper", "Pepsi", "Sprite
           ")

15
16 soft_drink_table <- data.frame(table(soft_drink_
           names))
17
18 # Install Library if not installed
19
20 # install.packages("ggplot2")
21
22 # Import Library
23
24 library(ggplot2)
25
26 # Bar Chart
27
28 ggplot(soft_drink_table, aes(soft_drink_names, Freq,
           fill = soft_drink_names))+geom_bar(stat = "
           identity")+
29 labs(title="Bar chart" , x = "Soft Drink", y = "
           Frequency")+ylim(0,20)
30
31 # Pie Chart
32
33 soft_drink_purchase_slices <- soft_drink_table$Freq
34 soft_drink_names_labels <- soft_drink_table$soft_
           drink_names

```

```

35 soft_drink_purchase_pct <- (soft_drink_table$Freq/
    sum(soft_drink_table$Freq)) * 100
36
37 soft_drink_names_labels <- paste(soft_drink_names_
    labels, soft_drink_purchase_pct)
38 soft_drink_names_labels <- paste(soft_drink_names_
    labels, "%", sep = "")
39
40 pie(soft_drink_purchase_slices, labels = soft_drink_
    names_labels,
41     col = rainbow(length(soft_drink_names_labels)),
42     main = "Pie Chart for Soft Drink Purchase")

```

R code Exa 2.2a Summarizing Quantitative Data

```

1                                     # Page no. :
                                     39-40
2
3 # Frequency Distribution (Quantitative Data)
4
5 audit_data <- c
    (12,15,20,22,14,14,15,27,21,18,19,18,22,33,16,18,17,23,28,13)
6
7 no_of_classes <- 5
8
9 width <- (max(audit_data) - min(audit_data)) / no_of
    _classes
10
11 width <- ceiling(width) # Rounding up of the value
12
13 breaks <- seq(10,34,by = width)
14
15 class_range <- cut(audit_data, breaks, right=T)
16

```

```

17 frequency <- table(class_range)
18
19 frequency_distribution <- data.frame(frequency)
20
21 frequency_distribution <- data.frame(class_range =
    frequency_distribution$class_range,
22                                     frequency =
    frequency_distribution$Freq)
23
24 # Note that :- Book answer will differ with my
    answer though number of classes and width of
25 # each class is same as in the book!!!
26
27                                     # Page no. :
                                        41
28
29 relative_frequency <- round(frequency_distribution$
    frequency / sum(frequency_distribution$frequency)
30                          ,2) # Rounding
                                of data to 2
                                digits
31
32 percentage_frequency <- relative_frequency * 100
33
34 audit_data_FD <- cbind(frequency_distribution,
35                        relative_frequency,
    percentage_frequency
    )
36
37 View(audit_data_FD)
38
39                                     # Page no. :
                                        41-42
40
41 # Dot Plot and Histogram
42

```



```

43 # Install Library if not installed
44
45 # install.packages("ggplot2")
46
47 # Import Library
48
49 library(ggplot2)
50
51 # Dot Plot
52
53 dotchart(audit_data, main = "Dot Plot for the Audit
      Time Data", xlab = "Audit Time (days)",
54           cex = 0.5) # cex is for scaling
55
56 # Note that: Book dot plot is different from my dot
      plot.
57
58 # Histogram
59
60 ggplot(audit_data_FD, aes(class_range, frequency,
      fill = class_range))+
61   geom_histogram(stat = "identity")+labs(title="
      Histogram for the Audit Time Data" ,
62                                           x = "Audit
      Time (
      days)",
      y = "
      Frequency
     ")+ylim
      (0,8)

```

R code Exa 2.3a Scatter Plot and Tradeline

1

Page no. :
57–58

```

2
3 # Dataset
4
5 week <- c(1,2,3,4,5,6,7,8,9,10)
6 x <- c(2,5,1,3,4,1,5,3,4,2)
7 y <- c(50,57,41,54,54,38,63,48,59,46)
8 data <- data.frame(week,x,y)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
18 # Scatter Plot
19
20 ggplot(data, aes(x,y)) + geom_point() + geom_smooth(
  method = "lm", se = F) +
21 labs(title = "Scatter Plot and Tradeline for the
  Stereo and Sound Equipment Store",
22
x
=
"
Number
of
Commercials
"
,
23
y
=

```

```

"
Sales
(
$
100
s
)
"
)

```

R code Exa 2.4a Cumulative Distributions

```

1                                     # Page no. :
                                     44
2
3 # Cumulative Distributions
4
5 audit_time <- c("Less than or equal to 14", "Less
   than or equal to 19", "Less than or equal to 24",
6               "Less than or equal to 29", "Less
   than or equal to 34")
7 frequency <- c(4,8,5,2,1) # Refer to table no. 2.5
   page no. 40
8 cumulative_freq <- cumsum(frequency)
9
10 DF <- data.frame(audit_time, frequency, cumulative_
   freq)
11
12 CRF <- DF$cumulative_freq / sum(DF$frequency) #
   Cumulative Relative Frequency
13
14 CPF <- CRF * 100 # Cumulative Percentage Frequency

```

```

15
16 DF <- cbind(DF, CRF, CPF)
17 View(DF)
18
19 breaks <- seq(9, 34, by = 5)
20 cumfreq0 <- c(0, DF$cumulative_freq)
21
22 DF2 <- data.frame(breaks, cumfreq0)
23
24 # Install Library if not installed
25
26 # install.packages("ggplot2")
27
28 # Import Library
29
30 library(ggplot2)
31
32 ggplot(DF2, aes(breaks, cumfreq0, group = 1)) + geom
  _point() + geom_line() +
33   xlim(c(0,35)) + labs(title = "Ogive For the Audit
    Time Data", x ="Audit Time (Days)",
34     y ="Cumulative Frequency")

```

R code Exa 2.5a Exploratory Data Analysis The Stem and Leaf Display

```

1                                     # Page no. :
                                     49
2
3 # Exploratory Data Analysis : The Stem – and – Leaf
  Display
4
5 data <- c(112, 72, 69, 97, 107, 73, 92, 76, 86, 73,
  126, 128, 118, 127, 124, 82, 104, 132, 134, 83,
6      92, 108, 96, 100, 92, 115, 76, 91, 102,
      81, 95, 141, 81, 80, 106, 84, 119, 113,

```

```

7           98, 75,
           68, 98, 115, 106, 95, 100, 85, 94, 106,
           119)
8
9  stem(data)
10
11                                     # Page no. :
                                     51
12
13 data2 <- c(1565, 1852, 1644, 1766, 1888, 1912, 2044,
            1812, 1790, 1679, 2008, 1852, 1967, 1954,
14            1733)
15 stem(data2)  # Answer is varing from the book

```

Chapter 3

Descriptive Statistics Numerical Measures

R code Exa 3.1a Measures of Location Mean Part 1

```
1                                     # Page no. :  
                                     87  
2  
3 # Mean  
4  
5 x <- c(46, 54, 42, 46, 32)  
6  
7 sample_mean <- mean(x)  
8  
9 cat("Sample mean for x is ", sample_mean)
```

R code Exa 3.1b Measures of Location Mean Part 2

```
1                                     # Page no. :  
                                     88  
2
```

```

3 # Dataset
4
5 graduate <- c(1,2,3,4,5,6,7,8,9,10,11,12)
6 salary <- c
      (3450,3550,3650,3480,3355,3310,3490,3730,3540,3925,3520,3480)
7
8
9 dataset <- data.frame(graduate, salary)
10
11 # Mean
12
13 mean_salary <- mean(dataset$salary)
14
15 cat("Mean monthly starting salary of 12 business
      school graduates is",mean_salary)

```

R code Exa 3.1c Measures of Location Median Part 1

```

1
2
3 # Median
4
5 x <- c(32, 42, 46, 46, 54)
6
7 median <- median(x)
8
9 cat("Median value for x is ", median)

```

R code Exa 3.1d Measures of Location Median Part 2

```

1                                     # Page no
                                     . : 89
2
3 salary <- c
  (3450,3550,3650,3480,3355,3310,3490,3730,3540,3925,3520,3480)
4
5 # Median
6
7 median <- median(salary)
8
9 cat("The median of salary is ", median)

```

R code Exa 3.1e Measures of Location Percentiles and Quartiles

```

1                                     # Page no.
                                     : 90–91
2
3 salary <- c
  (3450,3550,3650,3480,3355,3310,3490,3730,3540,3925,3520,3480)
4
5 # 85th and 50th Percentiles
6
7 solution <- quantile(salary, probs = c(0.85, 0.5))
8
9 cat(" Value for 85th and 50th percentile are ",
  solution[1], ", ", solution[2])
10
11 # Note that: 85th percentile value is different from
  the book
12
13
14 # 25th, 50th, 75th Percentiles (First , Second , Third
  Quartiles)

```



```

15
16 values <- quantile(salary, probs = c(0.25, 0.5,
    0.75))
17
18 cat("Value for first , second, third quartiles are ",
    values[1], ", ", values[2], ", ", values[3] )
19
20 # Note that: First and Second Quartile values are
    different from the book

```

R code Exa 3.2a Measures of Variability Range and IQR

```

1
                                                    # Page no. :
                                                    96-97
2
3 salary <- c
    (3450,3550,3650,3480,3355,3310,3490,3730,3540,3925,3520,3480)
4
5 # Range
6
7 range <- range(salary)
8 diff <- range[2] - range[1]
9
10 cat("Range is",diff)
11
12 # Inter-Quartile Range
13
14 IQR <- IQR(salary)
15
16 cat("IQR is ",IQR)
17
18 # Note that : IQR value of Book is different.

```

R code Exa 3.2b Measures of Variability Variance

```
1                                     # Page no. :  
                                     97-98  
2  
3 students <- c(46, 54, 42, 46, 32)  
4  
5 # Variance  
6  
7 variance <- var(students)  
8  
9 cat(" Variance of students is ",variance)
```

R code Exa 3.2c Measures of Variability Standard Deviation

```
1                                     # Page no. :  
                                     98-99  
2  
3 salary <- c  
    (3450,3550,3650,3480,3355,3310,3490,3730,3540,3925,3520,3480)  
4  
5 # Variance  
6  
7 variance <- var(salary)  
8  
9 # Standard Deviation  
10  
11 sd <- sd(salary)  
12  
13 cat(" Variance of salary is ",variance)  
14 cat(" Standard Deviation is ",sd)
```

R code Exa 3.3a Z Score

```
1                                     # Page  
                                     no. :  
                                     104  
2  
3 # Z-score  
4  
5 students <- c(46,54,42,46,32)  
6  
7 deviation <- students - mean(students)  
8  
9 sample_variance <- var(students)  
10  
11 dataset <- data.frame(students,deviation)  
12  
13 z <- c()  
14  
15 for(i in 1:length(dataset$students)){  
16   z[i] <- deviation[i]/sqrt(sample_variance)  
17 }  
18  
19 dataset <- cbind(dataset, zScore = z)  
20  
21 View(dataset)
```

R code Exa 3.4a Boxplot

```
1                                     # Page no.  
                                     : 110  
2
```

```

3 salary <- c
  (3450,3550,3650,3480,3355,3310,3490,3730,3540,3925,3520,3480)

4
5 # Install Library if not installed
6
7 #install.packages("ggplot2")
8
9 # Import Library
10
11 library(ggplot2)
12
13 # Boxplot
14
15 ggplot(data.frame(salary), aes(x = "", y = salary))
  + geom_boxplot(fill = "purple")+
16   ggtitle("Boxplot for Salary") + ylab("Salary")

```

R code Exa 3.5a Covariance and Correlation Coefficient

```

1                                     # Page no. :
                                     115-116 and 119
2
3 # Dataset
4
5 x <- c(2,5,1,3,4,1,5,3,4,2)
6 y <- c(50,57,41,54,54,38,63,48,59,46)
7
8 dataset <- data.frame(x,y)
9
10 # Coveriance
11
12 coveriance <- cov(dataset$x,dataset$y)
13
14 cat("Value of covariance is ",coveriance)

```

```

15
16 # Correlation Coefficient
17
18 correlation <- cor(dataset$x,dataset$y)
19
20 cat("Value of correlation coefficient is ",
      correlation)

```

R code Exa 3.5b Sample Correlation Coefficient

```

1                                     # Page no.
                                     : 121
2
3 # Data
4
5 x <- c(5,10,15)
6 y <- c(10,30,50)
7
8 # Sample Correlation Coefficient
9
10 corr <- cor(x, y)
11
12 cat("Sample correlation coefficient of x and y is ",
      corr)

```

R code Exa 3.6a Weighted Mean

```

1                                     # Page no. :
                                     124 – 125
2
3 # Data
4
5 purchase <- c(1,2,3,4,5)

```

```

6 cost <- c(3.00,3.40,2.80,2.90,3.25)
7 pound <- c(1200,500,2750,1000,800)
8
9 dataset <- data.frame(purchase, cost, pound)
10
11 # Weighted Mean
12
13 mean <- weighted.mean(dataset$cost, dataset$pound)
14
15 cat("Weighted mean for the dataset is", mean)

```

R code Exa 3.6b Grouped Data Mean and Sample Variance

```

1
# Page no.
: 126
- 127

2
3 # Data
4
5 audit <- c("10-14", "15-19", "20-24", "25-29", "30-34")
6 midpoint <- c(12,17,22,27,32)
7 frequency <- c(4,8,5,2,1)
8
9 dataset <- data.frame(audit, midpoint, frequency)
10
11 # Mean for Grouped Data
12
13 mean <- weighted.mean(dataset$midpoint, dataset$
frequency)
14
15 cat("Mean for grouped data is", mean)
16
17 # Sample Variance for Grouped Data
18
19 var <- sum(dataset$frequency*((dataset$midpoint -

```

```
    mean)**2)) / (sum(dataset$frequency) - 1)
20
21 # Note that : Grouped sample variance has no inbuild
    function
22
23 cat("Sample variance for grouped data is",var)
```

Chapter 4

Introduction to Probability

R code Exa 4.1a Combinations

```
1
2
3 # Combinations
4
5 # Eg. 1
6
7 N <- 5
8 n <- 2
9
10 combinations <- choose(n = N, k = n)
11
12 cat("The total combinations are", combinations)
13
14 # Eg. 2
15
16 N <- 53
17 n <- 6
18
19 combinations <- choose(n = N, k = n)
20
```

Page no. :
154


```
21 cat("The total combinations are",combinations)
```

R code Exa 4.1b Permutations

```
1                                     # Page no.
2                                     : 155
3 # Permutations
4
5 N <- 5
6 n <- 2
7
8 permutations <- choose(n = N, k = n)*factorial(n)
9
10 cat("The total permutations are",permutations)
```

R code Exa 4.1c Assigning Probabilities

```
1                                     # Page no. : 155
2                                     - 156
3 # Assigning Probabilities
4
5 x <- c(0,1,2,3,4)
6 y <- c(2,5,6,4,3)
7
8 DF <- data.frame(x,y)
9
10 y_sum <- sum(DF$y)
11
12 prob <- DF$y / y_sum
13
14 DF <- cbind(DF,prob)
```

15
16 View(DF)

R code Exa 4.1d Probabilities Assigning Example

```
1                                     # Page no. :  
                                     157 – 158  
2  
3 # Probabilities Assigning Example  
4  
5 x <- c(2,2,2,3,3,3,4,4,4)  
6 y <- c(6,7,8,6,7,8,6,7,8)  
7  
8 z = list()  
9  
10 for(i in 1:length(x))  
11 {  
12   z[i] <- list(c(x[i],y[i]))  
13 }  
14  
15 past_project <- c(6,6,2,4,8,2,2,4,6)  
16  
17 DF <- data.frame(x,y,I(z),past_project)  
18  
19 past_project_sum <- sum(DF$past_project)  
20  
21 p <- DF$past_project / past_project_sum  
22  
23 DF <- cbind(DF,p)  
24  
25 total_probability <- sum(DF$p)  
26  
27 cat("Total probability for the Sample Point is",  
28     total_probability)
```

R code Exa 4.2a Probability of an Event

```
1                                     # Page no. :  
                                     161  
2  
3 # Probability of an Event  
4  
5 # C denotes the event that is completed in 10 months  
  or less  
6  
7 C <- c(list(c(2,6)), list(c(2,7)), list(c(2,8)),  
        list(c(3,7)), list(c(3,8)), list(c(4,6)))  
8 prob <- c(0.15,0.15,0.05,0.10,0.20,0.05)  
9  
10 dataset <- data.frame(I(C),prob)  
11  
12 event <- sum(dataset$prob)  
13  
14 #  $P(C) = P(2,6) + P(2,7) + P(2,8) + P(3,7) + P(3,8)$   
  +  $P(4,6)$   
15  
16 cat("Probability of an event P(C) is",event)  
17  
18 # L denotes the event that is completed in less than  
  10 months  
19  
20 L <- c(list(c(2,6)), list(c(2,7)), list(c(3,7)))  
21 prob <- c(0.15,0.15,0.10)  
22  
23 dataset <- data.frame(I(L),prob)  
24  
25 #  $P(L) = P(2,6) + P(2,7) + P(3,7)$   
26
```

```

27 event2 <- sum(dataset$prob)
28
29 cat("Probability of an event P(L) is",event2)
30
31 # M denotes the event that is completed in more than
    10 months
32
33 M <- c(list(c(3,8)), list(c(4,7)), list(c(4,8)))
34 prob <- c(0.05,0.10,0.15)
35
36 dataset <- data.frame(I(M),prob)
37
38 # P(M) = P(3,8) + P(4,7) + P(4,8)
39
40 event3 <- sum(dataset$prob)
41
42 cat("Probability of an event P(L) is",event3)

```

R code Exa 4.3a Probability Computation using Complement

```

1
                                                    # Page no. :
                                                    165
2
3 # Probability Computation using Complement
4
5 p_comp_A <- 0.80
6
7 p_A <- 1 - p_comp_A
8
9 cat("Probability for A is",p_A)

```

R code Exa 4.3b Intersection and Union of Events

```

1                                     # Pahe no. : 167
2
3 # Intersection and Union of Events
4
5 a <- 5
6 n <- 50
7 c <- 6
8 d <- 2
9
10 p_L <- a / n
11
12 p_D <- c / n
13
14 p_L_and_D <- d / n
15
16
17 cat("Probability for L intersection D is",p_L_and_D)
18
19 p_L_or_D <- p_L + p_D - p_L_and_D
20
21 cat("Probability for L union D is",p_L_or_D)

```

R code Exa 4.3c Addition Law

```

1                                     # Page no. :
2                                     168
3 # Addition Law
4
5 p_S <- 0.30
6 p_W <- 0.20
7 p_S_and_W <- 0.12
8
9 p_S_or_W <- p_S + p_W - p_S_and_W
10

```

```
11 cat(" Probability after applying addition law is ",p_  
    S_or_W)
```

R code Exa 4.4a Conditional Probability

```
1                                     # Page no. :  
                                     171 – 174  
2  
3 # Conditional Probability  
4  
5 position <- c("Promoted", "Not Promoted")  
6 gender <- c("Men", "Women")  
7 number1 <- c(288, 36) # Promoted  
8 number2 <- c(672, 204) # Not Promoted  
9  
10 DF <- data.frame(position, gender, number1, number2)  
11  
12 table <- round(prop.table(DF[,3:4]), 2)  
13 table <- as.matrix(table)  
14 table  
15  
16 position <- c("Promoted", "Not Promoted")  
17 men <- c(table[1,1][[1]], table[1,2][[1]])  
18 women <- c(table[2,1][[1]], table[2,2][[1]])  
19  
20 DF2 <- data.frame(position, men, women)  
21 View(DF2)  
22  
23 columnSums <- apply(DF2[,2:3], 2, sum)  
24 rowSums <- apply(DF2[,2:3], 1, sum)  
25  
26 cat(" Total Probability For having Men is",  
    columnSums[1])  
27 cat(" Total Probability For having Women is",  
    columnSums[2])
```

```

28 cat("Total Probability For Promotion", rowSums[1])
29 cat("Total Probability For Not a Promotion", rowSums
    [2])
30
31 cond1 <- DF2$men[1] / columnSums[1]
32
33 cat("Conditional Probability for Men and getting
    Promoted given the Probability
34     of Total Men is", cond1)
35
36 cond2 <- DF2$women[1] / columnSums[2]
37
38 cat("Conditional Probability for Women and getting
    Promoted given the Probability
39     of Total Women is", cond2)

```

R code Exa 4.4b Multiplication Law

```

1
2
3 # Multiplication Law
4
5 #  $P(S | D) = 0.75$ 
6
7 x <- 0.75
8
9 # Event  $S = 0.84$ 
10
11 y <- 0.84
12
13 x_and_y <- x * y
14
15 cat("After applying multiplication law we get", x_
    and_y)

```

Page no. :
174 – 175

```

16
17 # Multiplication Law for Independent Events
18
19 A <- 0.80
20
21 B <- 0.80
22
23 A_and_B <- A * B
24
25 cat("After applying multiplication law for
      independent events A and B we get", A_and_B)

```

R code Exa 4.5a Bayes Theorem Tabular Approach

```

1                                     # Page no. : 182
2
3 # Tabular Approach for Bayes' Theorem
4
5 events <- c("A1", "A2")
6 prior_probabilities <- c(0.65, 0.35)
7
8 conditional_probabilities <- c(0.02, 0.05)
9
10 joint_probabilities <- prior_probabilities *
    conditional_probabilities
11
12 total_joint_probability <- sum(joint_probabilities)
13
14 posterior_probabilities <- joint_probabilities /
    total_joint_probability
15
16 DF <- data.frame(events, prior_probabilities,
    conditional_probabilities
17                  , joint_probabilities, posterior_
    probabilities)

```



```
18
19 View(DF)
20
21 cat("Total posterior probability is",sum(DF$
    posterior_probabilities))
```

Chapter 5

Discrete Probability Distribution

R code Exa 5.1a Discrete Probability Distribution Graph Expected value Variance and Standard Deviation

```
1                                     # Page no. : 198
                                     - 199
2
3 # Discrete Probability Distribution:
4
5 x <- c(0,1,2,3,4,5)
6 prob_of_x <- c(0.18,0.39,0.24,0.14,0.04,0.01)
7
8 dataset <- data.frame(x, prob_of_x)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
```

```

18 ggplot(dataset, aes(x = x, y = prob_of_x)) + geom_
    bar(stat = "identity", fill = "blue") + labs(
19   title = "Graphical representation of the
        Probability Distribution",
20   x = "Number of Automobiles", y = "Probability")
21
22                                     # Page no. : 203
23
24 # Expected value
25
26 exp_values <- dataset$x * dataset$prob_of_x
27
28 dataset <- data.frame(cbind(dataset, exp_values))
29
30 expected_value <- sum(dataset$exp_values)
31 cat("Expected value for the given problem is",
    expected_value)
32
33                                     # Page no. : 204 –
                                     205
34
35 # Variance and Standard Deviation
36
37 deviation_of_x <- (dataset$x - expected_value)
38
39 deviation_square <- (deviation_of_x) ** 2
40 variance <- sum(dataset$prob_of_x * deviation_square
    )
41 standard_deviation <- sqrt(variance)
42
43 cat("Variance is",variance)
44 cat("Standard Deviation is",standard_deviation)

```

R code Exa 5.2a Binomial Probability Distribution

```

1                                     # Page no. : 211
2
3 # Binomial Probability Distribution
4
5 no_of_trials <- 3
6 no_of_successes <- 2
7 BPD <- choose(n = no_of_trials, k = no_of_successes)
8
9 cat("Answer is",BPD)
10
11 no_of_successes <- 3
12 BPD <- choose(n = no_of_trials, k = no_of_successes)
13 cat("Answer is",BPD)

```

R code Exa 5.2b Binomial Probability Distribution Eg2

```

1                                     # Page no
                                     . :
                                     211
2
3 # Binomial Probability Distribution Eg-2
4
5 # Data
6 customer1 <- c("Purchase","Purchase","No Purchase")
7 customer2 <- c("Purchase","No Purchase","Purchase")
8 customer3 <- c("No Purchase","Purchase","Purchase")
9
10 customer <- data.frame(customer1,customer2,customer3
11                          )
12 len <- nrow(customer) # Trial
13
14 x <- 1 # For purchase
15 y <- 0 # For no purchase
16

```

```

17 p <- 0.30
18 q <- 1 - p
19 outcome <- c()
20
21 # Install Library if not installed
22
23 install.packages("Rlab")
24
25 # Import Library
26
27 library(Rlab) # For dbern
28
29 for(i in 1:len)
30 {
31   if(customer1[i] == "Purchase" && customer2[i] == "
      Purchase" && customer3[i] == "Purchase")
32   {
33     outcome[i] = dbern(x,p) * dbern(x,p) * dbern(x,p)
34   } else if(customer1[i] == "Purchase" && customer2[
      i] == "Purchase" && customer3[i] == "No
      Purchase")
35   {
36     outcome[i] = dbern(x,p) * dbern(x,p) * dbern(y,p)
37   } else if(customer1[i] == "Purchase" && customer2[
      i] == "No Purchase" && customer3[i] == "
      Purchase")
38   {
39     outcome[i] = dbern(x,p) * dbern(y,p) * dbern(x,p)
40   } else if(customer1[i] == "Purchase" && customer2[
      i] == "No Purchase" && customer3[i] == "No
      Purchase")
41   {
42     outcome[i] = dbern(x,p) * dbern(y,p) * dbern(y,p)
43   } else if(customer1[i] == "No Purchase" &&

```

```

        customer2[i] == "Purchase" && customer3[i] == "
        Purchase")
44   {
45   outcome[i] = dbern(y,p) * dbern(x,p) * dbern(x,p
        )
46   } else if(customer1[i] == "No Purchase" &&
        customer2[i] == "Purchase" && customer3[i] == "
        No Purchase")
47   {
48   outcome[i] = dbern(y,p) * dbern(x,p) * dbern(y,p
        )
49   } else if(customer1[i] == "No Purchase" &&
        customer2[i] == "No Purchase" && customer3[i]
        == "Purchase")
50   {
51   outcome[i] = dbern(y,p) * dbern(y,p) * dbern(x,p
        )
52   } else
53   {
54   outcome[i] = dbern(y,p) * dbern(y,p) * dbern(y,p
        )
55   }
56 }
57
58 customer <- cbind(customer,outcome)
59
60 View(customer)
61
62
63
64 # Binomial Probability Function
65
66 x <- c(0,1,2,3)
67 fun <- c()
68
69 for (i in 0:length(x)) {

```

Page no. :
212 -
213

```

70   fun[i] <- dbinom(x[i],len,p)
71 }
72
73 dataset <- data.frame(x, fun)
74 View(dataset)
75
76 # Install Library if not installed
77
78 # install.packages("ggplot2")
79
80 # Import Library
81
82 library(ggplot2)
83
84 ggplot(dataset, aes(x = x, y = fun)) + geom_bar(stat
      = "identity", fill = "blue") + labs(
85   title = "Graphical representation of the
      Probability Distribution",
86   x = "Number of Customers", y = "Probability")
87
88                                     # Page no. :
89                                     214 -
89                                     215
89
90 # Expected Value, Variance and Standard Deviation
    for Binomial Probability Distribution
91
92 expected_value <- len * p
93 variance <- len * p * q
94 standard_deviation <- sqrt(variance)
95
96 cat("Expected value is",expected_value)
97 cat("Variance is",variance)
98 cat("Standard deviation is",standard_deviation)

```

R code Exa 5.3a Poisson Probability Distribution

```
1                                     # Page no. :  
                                     218  
2  
3 # Poisson Probability Distribution  
4  
5 x = 5  
6 expected_value <- 10  
7 e <- 2.72 # Exponential value  
8  
9 PPD <- dpois(x, expected_value) # Poisson  
   Probability Distribution  
10  
11 cat("Answer is",PPD)
```

R code Exa 5.4a Hypergeometric Probability Distribution

```
1                                     # Page no. : 222  
                                     - 223  
2  
3 # Hypergeometric Probability Distribution  
4  
5 # Probability for 1 defective item  
6  
7 N <- 12  
8 n <- 3  
9 r <- 5  
10 x <- 1  
11  
12 HPD <- dhyper(x = x,m = r,n = N-r,k = n)  
13  
14 cat("Answer is",HPD)  
15  
16 # Probability for atleast one defective item
```



```

17
18 HPD <- dhyper(x = 0,m = r,n = N-r,k = n) #
    Probability for no defective item
19
20 cat("Answer is",1 - HPD) # Probability for at least
    one defective item
21
22 # Expected value , Variance and Standard Deviation
23
24 expected_value <- n * (r / N)
25 variance <- expected_value * (1 -(r/N)) * ((N-n)/(N
    -1))
26 standard_deviation <- sqrt(variance)
27
28 cat("Expected value",expected_value)
29 cat("Variance",variance)
30 cat("standard deviation",standard_deviation)

```

R code Exa 5.5a Expected Value and Variance

```

1
2
3 # Expected Value and Variance
4
5 x <- c(0,1,2,3,4,5)
6 prob_of_x <- c(0.18,0.39,0.24,0.14,0.04,0.01)
7 expected_value <- x * prob_of_x
8
9 DF <- data.frame(x, prob_of_x, expected_value)
10
11 expected_mean <- sum(DF$expected_value)
12
13 cat("Expected mean is",expected_mean)
14

```

```
15 deviation <- DF$x - expected_mean
16 sq_deviation <- deviation ** 2
17 expected_value2 <- DF$prob_of_x * sq_deviation
18
19 DF <- cbind(DF, deviation, sq_deviation, expected_
    value2)
20 View(DF)
21
22 expected_variance <- sum(DF$expected_value2)
23
24 cat("Expected variance is", expected_variance)
25
26 expected_SD <- sqrt(expected_variance)
27
28 cat("Expected SD is", expected_SD)
```

Chapter 6

Continuous Probability Distribution

R code Exa 6.1a Uniform Probability Distribution

```
1                                     # Page no. : 234 –  
                                     236  
2  
3 # Uniform Probability Distribution  
4  
5 a <- 120  
6 b <- 140  
7 fun_over_x <- 1/20  
8  
9 # Since uniform probability is symmetric we can  
   split it into left and right parts which  
10 # are symmetric in nature  
11  
12 c <- 130 # (120+140)/2 = 130  
13  
14 # Probability of uniform probability distribution  
   is the area of the figure (rectangle)  
15  
16 # Area for the left symmetric part of the figure
```

```

17
18 area <- punif(c,a,b)
19 area_full <- 2 * area
20
21 cat("Probability is",area_full)
22
23 # Expected value , Variance and standard Deviation
24
25 expected_value <- (a + b) / 2
26 variance <- (b - a) ** 2 / 12
27 standard_deviation <- sqrt(variance)
28
29 cat("Expected value is",expected_value)
30 cat("Variance is",variance)
31 cat("Standard deviation is",standard_deviation)

```

R code Exa 6.2a Normal Probability Distribution

```

1                                     # Page no. : 246
                                     - 247
2
3 # Normal Probability Distribution
4
5 mean <- 36500
6 sigma <- 5000
7 x <- 40000
8 probability <- pnorm(40000, mean=36500, sd=5000,
9                       lower.tail= F)
9
10 cat("The probability of x exceed 40000 is",
11     probability)
11
12                                     # Page no. : 247
13
14 probability <- 0.10

```

```

15 z_value <- round(qnorm(probability), 2) # Round it
    to 2 decimal place
16 x <- (sigma * z_value) + mean
17
18 cat("Value of x for not more than 10% of area is
    selected is",x)

```

R code Exa 6.3a Normal Approximation of Binomial Probabilities

```

1                                     # Page no. : 251 -
                                     252
2
3 # Normal Approximation of Binomial Probabilities
4
5 n <- 100
6 p <- 0.1
7 q <- 1 - p
8
9 mu <- n * p
10 sigma <- sqrt(mu * q)
11
12 # P(x = 12) ==> P(11.5 <= x <= 12.5)
13
14 x1 <- 12.5
15 x2 <- 11.5
16 z_value1 <- (x1 - mu) / sigma
17 z_value2 <- (x2 - mu) / sigma
18
19 area1 <- pnorm(z_value1)
20 area2 <- pnorm(z_value2)
21
22 diff <- area1 - area2
23
24 cat("The normal approximation to the probability of
    12 successes in 100 trials is ",diff)

```

```

25
26 # Probability for 13
27
28 x <- 13.5
29 z <- (x - mu) / sigma
30 ans <- pnorm(z)
31
32 cat("Answer is", ans)

```

R code Exa 6.4a Exponential Probability Distribution

```

1                                     # Page no. :
                                     255
2
3 # Exponential Probability Distribution
4
5 mu <- 15
6 x1 <- 6
7 x2 <- 18
8
9 # P(x <= 6)
10
11 EPD <- pexp(x1, 1/mu)
12
13 # P(x <= 18)
14
15 EPD2 <- pexp(x2, 1/mu)
16
17 diff <- EPD2 - EPD
18
19 cat("The probability that loading a truck will take
    between 6 and 18 minutes is ", diff)
20
21 SD <- mu
22 sigma <- SD ** 2

```

```
23  
24 cat("Variance is", sigma)
```

Chapter 7

Sampling and Sampling Distribution

R code Exa 7.1a Point Estimator

```
1                                     # Page no
                                     . :
                                     274
2
3 # Sample Mean and Sample Standard Deviation
4
5 annual_salary <- c
  (49094.30,53263.90,49643.50,49894.90,47621.60,55924.00,49092.30,5
6
  55109.70,45922.60,57268.40,55688.80,51564.70,5618
7
  51932.60,52973.00,45120.90,51753.00,54391.80,5016
8
  50979.40,55860.90,57309.10)
9
10 program <- c("Yes","Yes","Yes","Yes","No","Yes","Yes
  ","Yes","Yes","Yes","Yes","Yes","No","Yes","No","No","
  Yes",
11             "No","Yes","Yes","Yes","Yes","Yes","Yes","No","
```



```

                                No", "No", "No", "No", "Yes", "Yes", "No")
12
13 dataset <- data.frame(annual_salary, program)
14
15 sample_mean <- mean(dataset$annual_salary)
16 sample_sd <- sd(dataset$annual_salary)
17
18 cat("Sample mean of the data is", sample_mean)
19 cat("Sample standard deviation is", sample_sd)
20
21 # Note that : Book SD is different from our SD
22
23 # Sample Proportion
24
25 n <- nrow(dataset)
26 x <- 19
27
28 sample_proportion <- x / n
29
30 cat("Sample Proportion is", sample_proportion)

```

R code Exa 7.2a Sampling Distribution

```

1                                # Page no. 277
                                - 278
2
3 # Sampling Distribution
4
5 mean_annual_salary <- c("49500.00-49999.99", "
                        50000.00-50499.99", "50500.00-50999.99", "
                        51000.00-51499.99",
6                        "51500.00-51999.99", "
                        52000.00-52499.99", "
                        52500.00-52999.99", "
                        53000.00-53499.99",

```

```

7                                     "53500.00–53999.99")
8 frequency <- c(2,16,52,101,133,110,54,26,6)
9 relative_frequency <- c
  (.004,.032,.104,.202,.266,.220,.108,.052,.012)
10
11 DF <- data.frame(mean_annual_salary,frequency,
  relative_frequency)
12
13 library(ggplot2)
14
15 ggplot(DF,aes(mean_annual_salary,relative_frequency)
  ) +
16   geom_histogram(stat = "identity", fill = "purple")
  + labs(title = "Relative Frequency Histogram",
17         x = "Mean Salary",
          y = "frequency"
          )

```

R code Exa 7.3a Sampling Distribution of Sample Mean

```

1                                     # Page no. :
                                     281
2
3 # Sampling Distribution of xbar
4
5 sigma <- 4000
6 N <- 2500
7 n <- 30
8 x <- n / N
9
10 if(x > 0.05) # Condition to include finite
  population factor or not (< 5%)
11 {
12   standard_error <- sqrt((N-n)/(N-1)) * (sigma /
    sqrt(n))

```

```

13 } else{
14   standard_error <- sigma / sqrt(n)
15 }
16
17 cat("Standard deviation of sample mean is",standard_
    error)
18
19                                     # Page no. : 284
20
21 # To find probability that xbar is between 51300 and
    52300
22
23 xbar1 <- 52300
24 xbar2 <- 51300
25 mu <- 51800
26
27 z1 <- (xbar1 - mu) / standard_error
28 z2 <- (xbar2 - mu) / standard_error
29
30 p1 <- pnorm(z1, lower.tail = T)
31 p2 <- pnorm(z2, lower.tail = T)
32
33 diff <- p1 - p2
34
35 cat("Probability that xbar is between 51300 and
    52300 is", diff)

```

R code Exa 7.3b Relationship between Sample Size and Sampling Distribution of xbar

```

1                                     # Page no. :
    285 -
    286
2
3 # Relationship between Sample Size and Sampling

```

```

      Distribution of xbar
4
5 sigma <- 4000
6 n <- 100
7 population_mean <- 51800
8
9 standard_error <- sigma / sqrt(n)
10
11 xbar1 <- 52300
12 xbar2 <- 51300
13
14 z1 <- (xbar1 - population_mean) / standard_error
15 z2 <- (xbar2 - population_mean) / standard_error
16
17 p1 <- pnorm(z1, lower.tail = T)
18 p2 <- pnorm(z2, lower.tail = T)
19
20 diff <- p1 - p2
21
22 cat("Probability that xbar is between 51300 and
      52300 with increased sample size is", diff)

```

R code Exa 7.4a Sampling Distribution of Sample Proportion

```

1
2
3 # Sampling Distribution of pbar
4
5 population_proportion <- 0.60
6 n <- 30
7 N <- 2500
8
9 x <- n / N
10

```

Page no.
: 290

```

11 if(x > 0.05) # Condition to include finite
    population or not ( < 5%)
12 {
13     standard_deviation <- sqrt((N-n)(N-1)) * sqrt((
        population_proportion *
14                                     (1
                                     -
                                     population
                                     -
                                     proportion
                                     )
                                     )
                                     /
                                     n
                                     )
15 } else{
16     standard_deviation <- sqrt((population_proportion
        * (1 - population_proportion)) / n)
17 }
18
19 cat("Standard deviation for sample proportion is",
    standard_deviation)

```

R code Exa 7.4b Practical value of the Sampling Distribution of Sample Proportion

```

1                                     # Page no. : 291
2
3 # Practical value of the Sampling Distribution of
    pbar

```

```

4
5 population_proportion <- 0.60
6 standard_error <- 0.0894
7 sample_proportion <- 0.65
8
9 z_value <- (sample_proportion - population_
    proportion) / standard_error
10
11 prob1 <- pnorm(sample_proportion, population_
    proportion, standard_error, lower.tail =T)
12
13 sample_proportion2 <- 0.55
14
15 z_value <- (sample_proportion2 - population_
    proportion) / standard_error
16
17 prob2 <- pnorm(sample_proportion2, population_
    proportion, standard_error, lower.tail =T)
18
19 final_prob <- prob1 - prob2
20
21 cat("The final probability is",final_prob)

```

R code Exa 7.4c Practical value of the Sampling Distribution of Sample Proportion Eg2

```

1                                     # Page no. : 292 –
                                     293
2
3 # Practical value of the Sampling Distribution of
  pbar Eg-2
4
5 population_proportion <- 0.60
6 n <- 100
7

```

```

8 standard_error <- sqrt(population_proportion*(1 -
  population_proportion)/(n))
9
10 sample_proportion <- 0.65
11
12 z_value <- (sample_proportion - population_
  proportion) / standard_error
13
14 prob1 <- pnorm(sample_proportion, population_
  proportion, standard_error, lower.tail =T)
15
16 sample_proportion2 <- 0.55
17
18 z_value <- (sample_proportion2 - population_
  proportion) / standard_error
19
20 prob2 <- pnorm(sample_proportion2, population_
  proportion, standard_error, lower.tail =T)
21
22 final_prob <- prob1 - prob2
23
24 cat("The final probability is",final_prob)

```

Chapter 8

Interval Estimation

R code Exa 8.1a Population Mean Sigma Known

```
1                                     # Page no. :  
                                     310 – 314  
2 # Population Mean Sigma known  
3  
4 pop_sd <- 20  
5 sample_size <- 100  
6 sample_mean <- 82  
7  
8 standard_error <- pop_sd / sqrt(sample_size)  
9  
10 # 95% confidence interval  
11  
12 margin_of_error <- qnorm(0.975)*standard_error #  
    95% confidence interval --> 1 - 0.025 = 0.975  
13  
14 IE <- sample_mean + c(-margin_of_error, margin_of_  
    error)  
15  
16 cat("The margin of error is given by", margin_of_  
    error)  
17 cat("The 95% interval estimate is given by", IE)
```



```

18
19 # 90% confidence interval
20
21 margin_of_error <- qnorm(0.95)*standard_error #
    90% confidence interval --> 1 - 0.05 = 0.95
22
23 IE <- sample_mean + c(-margin_of_error, margin_of_
    error)
24
25 cat("The margin of error is given by", margin_of_
    error)
26 cat("The 90% interval estimate is given by", IE)
27
28 # 99% confidence interval
29
30 margin_of_error <- qnorm(0.995)*standard_error #
    99% confidence interval --> 1 - 0.005 = 0.995
31
32 IE <- sample_mean + c(-margin_of_error, margin_of_
    error)
33
34 cat("The margin of error is given by", margin_of_
    error)
35 cat("The 99% interval estimate is given by", IE)

```

R code Exa 8.2a Population Mean Sigma Unknown

```

1                                     # Page no. :
                                     319 - 320
2
3
4 # Population Mean Sigma Unknown
5
6 credit_card_balances <- c
    (9430,7535,4078,5604,5179,4416,10676,1627,10112,6567,13627,18719,

```

```

7                                10544,13659,7061,6245,13021,9719,2200,1074
8                                7917,11346,12806,4972,11356,7117,9465,1926
9                                6845,10493,615,13627,12557,6232,9691,11448
10                               12851,5337,8372,7445,11032,6525,5239,6195,
11
12 test <- t.test(cradit_card_balances)
13 IE1 <- test$conf.int[1]
14 IE2 <- test$conf.int[2]
15
16 cat("The 95% interval estimate is given by", IE1, "
    to", IE2)

```

R code Exa 8.2b Population Mean Sigma Unknown Eg2

```

1                                # Page no. :
                                321 - 322
2
3 # Population Mean Sigma Unknown Eg-2
4
5 data <- c
    (52,44,55,44,45,59,50,54,62,46,54,42,60,62,43,42,48,55,57,56)
6
7
8 hist(data, col = "blue", main = "Histogram of
    Training Times", xlab = "Traing Times (days)",
9     ylab = "Frequency")
10
11 test <- t.test(data)
12 IE1 <- test$conf.int[1]

```

```

13 IE2 <- test$conf.int[2]
14
15 cat("The 95% interval estimate is given by", IE1, "
    to", IE2)

```

R code Exa 8.3a Determining the Sample Size

```

1                                     # Page no. :
                                     326 - 327
2
3 # Determining the Sample Size
4
5 margin_of_error <- 2
6 z_value <- 1.96    # 95% Level of Confidence Interval
7
8 sample_standard_deviation <- 9.65
9
10 sample_size <- ((z_value)**2) * ((sample_standard_
    deviation)**2) / (margin_of_error)**2
11
12 cat("Sample size is", ceiling(sample_size))
13 # If Sample Size is not integer then we round up to
    next higher integer

```

R code Exa 8.4a Population Proportion

```

1                                     # Page no. :
                                     329
2
3 # Population Proportion
4
5 N <- 900
6 n <- 396

```

```

7
8 p <- n / N
9 q <- 1 - p
10
11 # Confidence Interval is 95%
12
13 z_value <- qnorm(0.975) # 95% confidence interval
    --> 1 - 0.025 = 0.975
14
15 margin_of_error <- z_value * sqrt((p*q)/N)
16 IE <- p + c(-margin_of_error, margin_of_error)
17
18 cat("The margin of error is given by", margin_of_
    error)
19 cat("The 95% interval estimate is given by", IE)

```

R code Exa 8.4b Determining the Sample Size

```

1 # Page no. : 330
2
3 # Determining the Sample Size
4
5 margin_of_error <- 0.025
6 z_value <- 1.96 # 95% Level of Confidence Interval
7
8 p <- 0.44
9 q <- 1 - p
10
11 sample_size <- ((z_value)**2 * p * q) / (margin_of_
    error)**2
12
13 cat("Sample size is", ceiling(sample_size))
14 # If Sample Size is not integer then we round up to
    next higher integer

```

```
15
16                                     # Page no. :
                                     331
17
18 margin_of_error <- 0.025
19 z_value <- 1.96    # 95% Level of Confidence Interval
20
21 p <- 0.50
22 q <- 1 - p
23
24 sample_size <- ((z_value)**2 * p * q) / (margin_of_
    error)**2
25
26 cat("Sample size is",ceiling(sample_size))
27 # If Sample Size is not integer then we round up to
    next higher integer
```

Chapter 9

Hypothesis Testing

R code Exa 9.1a Population Mean Sigma Known One Tailed Test

```
1                                     # Page no. :  
                                     359 – 360  
2  
3 # Population Mean Sigma Known One Tailed Test  
4  
5 sigma <- 0.18  
6 n <- 36  
7 xbar <- 2.92  
8 mu <- 3  
9  
10 z_value <- (xbar - mu) / (sigma / sqrt(n))  
11 z_value <- round(z_value,2)  
12  
13 alpha <- 0.01  
14  
15 # P Value Approach (Lower-Tail Test)  
16  
17 pval <- pnorm(z_value)  
18  
19 if(pval > alpha)  
20 {
```

```

21   cat("Since p-value ",pval ,"is greater than 0.01,
      therefore we will accept null hypothesis")
22 } else {
23   cat("Since p-value ",pval ,"is less than 0.01,
      therefore we will reject null hypothesis and
      accept
24       alternative hypothesis.")
25 }
26
27 # Critical Value Approach (Lower-Tail Test)
28
29 z_alpha <- qnorm(1 - (alpha)) # Area of 0.01 to
      the left (1 - 0.01 = 0.99)
30 critical_approch <- -z_alpha
31
32 if(z_value <= critical_approch)
33 {
34   cat("Since z-value", z_value ,"is less then or
      equal to", critical_approch , "therefore we
      reject
35       the null hypothesis and accept the alternative
      hypothesis.")
36 } else{
37   cat("Since z-value", z_value ,"is more than",
      critical_approch,"therefore we accept the null
      hypothesis.")
38 }

```

R code Exa 9.1b Population Mean Sigma Known Two Tailed Test

```

1
                                     # Page no. :
                                     362 -
                                     364
2
3 # Population Mean Sigma Known Two Tailed Test

```

```

4
5 sample_size <- 50
6 sample_mean <- 297.6
7 population_mean <- 295
8 significance_level <- 0.05      # alpha
9 population_sd <- 12
10
11                                     # Page no. :
                                     364
12
13 ## Critical value approach
14
15 z_value <- (sample_mean - population_mean) / (
    population_sd / sqrt(sample_size))
16
17 z_half_alpha <- qnorm(1 - (significance_level/2))
18 critical_value_1 <- -z_half_alpha
19 critical_value_2 <- z_half_alpha
20
21 if(z_value >= critical_value_2 || z_value <=
    critical_value_1)
22 {
23   cat("Since z-value", z_value ,"does not lie in the
    range", critical_value_1 ,"and", critical_
    value_2
24     ,"therefore we reject the null hypothesis and
    accept the alternative hypothesis.")
25 } else{
26   cat("Since z-value", z_value ,"lies in the range",
    critical_value_1 ,"and", critical_value_2
27     ,"therefore we accept the null hypothesis.")
28 }
29
30                                     # Page no. :
                                     363 - 364
31
32 ## P-value approach
33

```



```

34 area_under_curve <- 1 - pnorm(z_value)
35 pval <- 2 * area_under_curve # P-value
36 if(pval > 0.05)
37 {
38   cat("Since p-value ",pval ,"is greater than 0.05,
        therefore we will accept null hypothesis")
39 } else {
40   cat("Since p-value ",pval ,"is less than 0.05,
        therefore we will reject null hypothesis and
        accept
41       alternative hypothesis.")
42 }

```

R code Exa 9.1c Relationship between Interval Estimation and Hypothesis Testing

```

1                                     # Page no. :
                                     366 - 367
2
3 # Relationship between Interval Estimation and
  Hypothesis Testing
4
5 mu <- 295
6 alpha <- 0.05
7 n <- 50
8 xbar <- 297.6
9 sigma <- 12
10
11 z_value <- 1.96 # alpha = 0.05 so alpha/2 = 0.05/
    2 = 0.025 (z-value is for 0.025)
12
13 # 95% Confidence Interval
14
15 margin_of_error <- z_value * (sigma / sqrt(n))
16

```

```

17 IE <- xbar + c(-margin_of_error, margin_of_error) #
    Interval Estimate
18
19 cat("Interval estimate for 95% Confidence Interval
    is", IE)
20
21 if(mu >= IE[2] || mu <= IE[1])
22 {
23   cat("Null Hypothesis is rejected..")
24 } else{
25   cat("Null Hypothesis cannot be rejected..")
26 }

```

R code Exa 9.2a Population Mean Sigma Unknown One Tailed Test

```

1
# Page no. :
# 371 -
# 372
2
3 # Population Mean Sigma Unknown One Tailed Test
4
5 mu0 <- 7
6 alpha <- 0.05
7 xbar <- 7.25
8 s <- 1.052
9 n <- 60
10
11 t_value <- (xbar - mu0) / (s / sqrt(n))
12
13 df <- n - 1
14
15 # Upper Tail Test
16
17 pval <- pt(t_value, df = df, lower.tail = F) # Book
    answer is 0.354

```

```

18
19 if(pval > alpha)
20 {
21   cat("Since p-value ",pval ,"is greater than 0.05,
        therefore we will accept null hypothesis")
22 } else {
23   cat("Since p-value ",pval ,"is less than 0.05,
        therefore we will reject null hypothesis and
        accept
24     alternative hypothesis.")
25 }

```

R code Exa 9.2b Population Mean Sigma Unknown Two Tailed Test

```

1                                     # Page no. :
                                     372 - 373
2
3 # Population Mean Sigma Unknown Two Tailed Test
4
5 mu0 <- 40
6 alpha <- 0.05
7 xbar <- 37.4
8 s <- 11.79
9 n <- 25
10
11 t_value <- (xbar - mu0) / (s / sqrt(n))
12
13 df <- n - 1 # Degree of Freedom
14
15 # Two Tail Test
16 # P - value Approach
17
18 pval <- 2 *(1 - pt(t_value,df = df,lower.tail = F))
    # Book answer is 0.2822
19

```

```

20 if(pval > alpha)
21 {
22   cat("Since p-value ",pval ,"is greater than 0.05,
        therefore we will accept null hypothesis")
23 } else {
24   cat("Since p-value ",pval ,"is less than 0.05,
        therefore we will reject null hypothesis and
        accept
25       alternative hypothesis.")
26 }
27
28 # Critical Value Approach
29
30 t_half_alpha <- qt(1 - (alpha/2),df)
31 critical_value_1 <- -t_half_alpha
32 critical_value_2 <- t_half_alpha
33
34 if(t_value >= critical_value_2 || t_value <=
    critical_value_1)
35 {
36   cat("Since t-value", t_value ,"does not lie in the
        range", critical_value_1 ,"and", critical_
        value_2
37       ,"therefore we reject the null hypothesis and
        accept the alternative hypothesis.")
38 } else{
39   cat("Since t-value", t_value ,"lies in the range",
        critical_value_1 ,"and", critical_value_2
40       ,"therefore we accept the null hypothesis.")
41 }

```

R code Exa 9.3a Population Proportion

1

Page no. :
377 – 378

```

2
3 # Population Proportion
4
5 p0 <- 0.20
6 alpha <- 0.05
7 n <- 400
8 x <- 100
9
10 p_bar <- x / n
11
12 z_value <- (p_bar - p0) / sqrt((p0*(1 - p0)) / n)
13
14 # Upper Tail Test
15
16 # P-value Approach
17
18 pval <- pnorm(z_value, lower.tail = F)
19 if(pval > alpha)
20 {
21   cat("Since p-value ", pval, "is greater than 0.05,
22       therefore we will accept null hypothesis")
23 } else {
24   cat("Since p-value ", pval, "is less than 0.05,
25       therefore we will reject null hypothesis and
26       accept
27       alternative hypothesis.")
28 }
29
30 # Critical Value Approach
31
32 z_alpha <- qnorm(1 - alpha)
33 critical_value <- z_alpha
34
35 if(z_value >= critical_value)
36 {
37   cat("Since z-value", z_value, "is greater then or
38       equal to", critical_value, "therefore we
39       reject

```

```

35         the null hypothesis and accept the alternative
           hypothesis.")
36 } else{
37     cat("Since z-value", z_value ,"is less than",
         critical_value,"therefore we accept the null
         hypothesis.")
38 }

```

R code Exa 9.4a Calculating the Probability of Type Second Errors

```

1                                     # Page no. :
                                     382 – 383
2
3 # Calculating the Probability of Type Second Errors
4
5 mu0 <- 120
6 alpha <- 0.05
7 z_value <- 1.645
8 n <- 36
9 sigma <- 12
10
11 xbar <- mu0 - z_value * (sigma / sqrt(n))
12
13 mu <- 112
14 z <- (xbar - mu) / (sigma / sqrt(n))
15
16 # Upper Tail Test
17
18 beta_value <- pnorm(z, lower.tail = F)
19
20 cat("The type 2nd error is",beta_value)
21
22                                     # Page no. : 384
23
24 xbar <- 116.71

```

```

25 mu <- 115
26 sigma <- 12
27 n <- 36
28
29 z <- (xbar - mu) / (sigma / sqrt(n))
30
31 # Upper Tail Test
32
33 beta_value <- pnorm(z, lower.tail = F)
34
35 cat("The type 2nd error is",beta_value)

```

R code Exa 9.5a Determining the Sample Size

```

1
2
3 # Determining the Sample Size
4
5 alpha <- 0.05
6 beta <- 0.10
7 z_alpha <- 1.645
8 z_beta <- 1.28
9 mu0 <- 120
10 mua <- 115
11 sigma <- 12
12
13 n <- ((z_alpha + z_beta)**2) * (sigma)**2 / (mu0 -
      mua)**2 # Sample Size
14 n <- ceiling(n)
15 cat("Sampling Size is",n)

```

Page no. :
389

Chapter 10

Inference About Means and Proportions With Two Populations

R code Exa 10.1a Inference about the Difference between the two Population Means Sigma 1 and Sigma 2 known

```
1                                     # Page no. :  
                                     410  
2  
3 # Inference about the Difference between the two  
  Population Means Sigma 1 and Sigma 2 known  
4  
5 sigma1 <- 9  
6 sigma2 <- 10  
7 sample_size1 <- 36  
8 sample_size2 <- 49  
9 sample_mean1 <- 40  
10 sample_mean2 <- 35  
11  
12 point_estimate <- sample_mean1 - sample_mean2  
13  
14 z_value <- qnorm(0.975)    # alpha/2 = 0.05/2 = 0.025
```



```

      = 1- 0.025 = 0.975
15
16 standard_error <- sqrt((((sigma1)^2)/(sample_size1))
      + (((sigma2)^2)/(sample_size2)))
17
18 IE1 <- point_estimate + z_value*standard_error
19 IE2 <- point_estimate - z_value*standard_error
20
21 cat("The interval estimation for the given
      information at 95% confidence level is ",IE2 ,"to
      "
22      , IE1)

```

R code Exa 10.1b Hypothesis Tests About Difference between two Means

```

1                                     # Page no. : 410
                                     - 412
2
3 # Hypothesis Tests About Difference between two
  Means
4
5 sigma1 <- 10
6 sigma2 <- 10
7 alpha <- 0.05
8 n1 <- 30
9 n2 <- 40
10 xbar1 <- 82
11 xbar2 <- 78
12 D0 <- 0
13
14 z_value <- ((xbar1 - xbar2) - D0) / sqrt((((sigma1)**
      2/n1) + ((sigma2)**2/n2))
15
16 # P-value Approach
17

```

```

18 # Two Tail Test
19
20 pval <- 2 * pnorm(z_value, lower.tail = F)
21
22 if(pval <= alpha)
23 {
24   cat("Since P-Value",pval,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis")
25 } else {
26   cat("Since P-Value",pval,"is more than 0.05
        therefore we cannot reject Null Hypothesis")
27 }
28
29 # Critical Value Approach
30
31 z_half_alpha <- qnorm(0.975) # alpha/2 = 0.05/2 =
    0.025 = 1- 0.025 = 0.975
32 critical_value_1 <- -z_half_alpha
33 critical_value_2 <- z_half_alpha
34
35 if(z_value >= critical_value_2 || z_value <=
    critical_value_1)
36 {
37   cat("Since Z-value",z_value,"does not lie in the
        range",critical_value_1,"to",critical_value_2,
38       "therefore we can reject Null Hypothesis")
39 } else {
40   cat("Since Z-value",z_value,"lie in the range",
        critical_value_1,"to",critical_value_2,
41       "therefore we cannot reject Null Hypothesis")
42 }

```

R code Exa 10.2a Inference about the Difference between the two Population Means Sigma 1 and Sigma 2 Unknown

```

1                                     # Page no. :
                                     415 - 417
2
3 # Inference about the Difference between the two
  Population Means Sigma 1 and Sigma 2 Unknown
4
5 s1 <- 150
6 s2 <- 125
7 n1 <- 28
8 n2 <- 22
9 xbar1 <- 1025
10 xbar2 <- 910
11
12 point_estimate <- xbar1 - xbar2
13
14 numerator <- (((s1)**2 /n1) + ((s2)**2 /n2))**2)
15 denominator <- ((1 /(n1 -1)) * (((s1)**2 / n1)**2))
    + ((1 /(n2 -1)) * (((s2)**2 / n2)**2))
16
17 df <- numerator / denominator # Degree of Freedom
18
19 t_value <- qt(0.975,df) # alpha/2 = 0.05/2 = 0.025
    = 1- 0.025 = 0.975
20
21 standard_error <- sqrt((((s1)^2)/(n1)) + (((s2)^2)/(
    n2)))
22
23 IE1 <- point_estimate + t_value*standard_error
24 IE2 <- point_estimate - t_value*standard_error
25
26 cat("The interval estimation for the given
    information at 95% confidence level is ",IE2 ,
27     "to", IE1)

```

R code Exa 10.2b Hypothesis Tests About Difference between two Means

```

1                                     # Page no. :
                                     418 -
                                     419

2
3 # Hypothesis Tests About Difference between two
  Means
4
5 x <- c(300, 280, 344, 385, 372, 360, 288, 321, 376,
        290, 301, 283)
6 y <- c(274, 220, 308, 336, 198, 300, 315, 258, 318,
        310, 332, 263)
7
8 DF <- data.frame(x,y)
9
10 test <- t.test(DF$x, DF$y, paired = F, alternative =
    "greater")
11 test
12
13 # Upper Tail Test
14
15 if(test$p.value <= 0.05)    # 95% Confidence Level
16 {
17     cat("Since P-Value",test$p.value,"is less than or
        equal to 0.05 therefore we can reject
        Null Hypothesis")
18 } else {
19     cat("Since P-Value",test$p.value,"is more than
        0.05 therefore we cannot reject Null Hypothesis
        ")
20 }
21 }

```

R code Exa 10.3a Inference About the Difference Between Two Population Means Matched samples

```

1                                                    # Page no. :
                                                    424 – 425
2
3 # Inference About the Difference Between Two
  Population Means Matched samples
4
5 workers <- c(1,2,3,4,5,6)
6 method_1 <- c(6.0,5.0,7.0,6.2,6.0,6.4)
7 method_2 <- c(5.4,5.2,6.5,5.9,6.0,5.8)
8 diff <- method_1 - method_2
9
10 dataFrame <- data.frame(workers, method_1, method_2,
  diff)
11
12 test <- t.test(dataFrame$method_1, dataFrame$method_
  2, paired = T)
13 test
14
15 # Two Tail Test
16
17 if(test$p.value <= 0.05)
18 {
19   cat("Since P-Value",test$p.value,"is less than or
    equal to 0.05 therefore we can
20     reject Null Hypothesis")
21 } else {
22   cat("Since P-Value",test$p.value,"is more than
    0.05 therefore we cannot reject Null Hypothesis
    ")
23 }
24
25 # Interval Estimate
26
27 IE1 <- test$conf.int[1]
28 IE2 <- test$conf.int[2]
29
30 cat("The interval estimation for the given
  information at 95% confidence level is ",IE1 ,"to

```

```
31      ” ,  
      IE2)
```

R code Exa 10.4a Inference About the Difference Between Two Population Proportions

```
1                                     # Page no. :  
                                     431  
2  
3 # Inference About the Difference Between Two  
  Population Proportions  
4  
5 n1 <- 250  
6 n2 <- 300  
7 x1 <- 35  
8 x2 <- 27  
9 alpha <- 0.1  
10  
11 pbar1 <- x1 / n1  
12 pbar2 <- x2 / n2  
13  
14 qbar1 <- 1 - pbar1  
15 qbar2 <- 1 - pbar2  
16  
17 # Interval Estimation  
18  
19 diff_prop <- pbar1 - pbar2  
20  
21 z_half_alpha <- qnorm(0.95) # alpha / 2 = 0.1 /  
  2 = 0.05 = 0.95 (1 - 0.05)  
22  
23 margin_of_error <- z_half_alpha * sqrt((pbar1 *  
  qbar1)/n1 + (pbar2 * qbar2)/n2 )  
24  
25 IE1 <- diff_prop + margin_of_error
```

```

26 IE2 <- diff_prop - margin_of_error
27
28 cat("The interval estimation for the given
      information at 90% confidence level is ",IE2 ,"to
      ", IE1)

```

R code Exa 10.4b Hypothesis Tests About Difference between two Proportions

```

1                                     # Page no. :
                                     432 - 433
2
3 # Hypothesis Tests About Difference between two
  Proportions
4
5 pbar1 <- 0.14
6 pbar2 <- 0.09
7 n1 <- 250
8 n2 <- 300
9 alpha <- 0.10   # Significance Level
10
11 pbar <- ((n1 * pbar1) + (n2 * pbar2)) / (n1 + n2)
    # Pooled Estimator
12
13 z_value <- (pbar1 - pbar2) / sqrt((pbar*(1 - pbar))*
    ((1/n1)+(1/n2)))
14
15 # Two Tail Test
16
17 pval <- 2 * pnorm(z_value, lower.tail = F)
18
19 if(pval <= alpha)
20 {
21   cat("Since P-Value",pval,"is less than or equal to
        0.10 therefore we can reject Null Hypothesis")

```

```
22 } else {  
23   cat("Since P-Value",pval,"is more than 0.10  
    therefore we cannot reject Null Hypothesis")  
24 }
```

Chapter 11

Inferences About Population Variances

R code Exa 11.1a Inferences About Population Variance

```
1                                                    # Page no. :  
                                                    453  
2  
3 # Inferences About the Population Variance  
4  
5 n <- 20  
6 variance <- 0.0025  
7 df <- 19    # Degrees of Freedom  
8  
9 chisq_1 <- qchisq(0.975,df)  
10 chisq_2 <- qchisq(0.025,df)  
11  
12 # Interval Estimation  
13  
14 IE1 <- sqrt((df * variance) / chisq_1)  
15 IE2 <- sqrt((df * variance) / chisq_2)  
16  
17 cat("Interval Estimation at 95% confidence interval  
    for population standard deviation is",IE1,
```

R code Exa 11.1b Hypothesis Testing

```
1                                     # Page no. :
                                     455 - 456
2
3 # Hypothesis Testing
4
5 n <- 24
6 alpha <- 0.05    # Significance Level
7 sigma0_sq <- 4
8 variance <- 4.9
9
10 chisq_value <- ((n - 1) * variance) / sigma0_sq
11
12 df <- n - 1    # Degree of Freedom
13
14 # Upper Tail Test
15
16 # P-value Approach
17
18 pval <- pchisq(chisq_value, df, lower.tail = F)
19
20 if(pval <= alpha)
21 {
22   cat("Since pval",pval,"is less than or equal to
23       0.05 therefore we can reject Null Hypothesis")
24 } else{
25   cat("Since pval",pval,"is greater than 0.05
26       therefore we cannot reject Null Hypothesis")
27 }
28
29 # Critical Value Approach
```

```

29 chisqvalue <- qchisq(0.95,df)    # Chi-square value
    for 0.95 (1 - 0.05)
30
31 if(chisq_value >= chisqvalue)
32 {
33     cat("Since Chi-square value",chisq_value,"is
        greater than or equal to Chi-square value",
        chisqvalue,
34         "therefore we will reject Null Hypothesis")
35 } else {
36     cat("Since Chi-square value",chisq_value,"is less
        than Chi-square value",chisqvalue,
37         "therefore we cannot reject Null Hypothesis")
38 }
39
40
41
42
43 n <- 30
44 alpha <- 0.05    # Significance Level
45 sigma0_sq <- 100
46 variance <- 162
47
48 chisq_value <- ((n - 1) * variance) / sigma0_sq
49
50 df <- n - 1    # Degree of Freedom
51
52 # Two Tail Test
53
54 # P-value Approach
55
56 pval <- 2 * pchisq(chisq_value, df, lower.tail = F)
57
58 if(pval <= alpha)
59 {
60     cat("Since pval",pval,"is less than or equal to

```

Page no. :
456 -
457

```

        0.05 therefore we can reject Null Hypothesis")
61 } else{
62     cat("Since pval",pval,"is greater than 0.05
        therefore we cannot reject Null Hypothesis")
63 }

```

R code Exa 11.2a Inferences About Two Population Variances

```

1                                     # Page no. :
                                     462 – 464
2
3 # Inferences About Two Population Variances
4
5 alpha <- 0.10    # Significance Level
6 n1 <- 26
7 n2 <- 16
8 sv1 <- 48
9 sv2 <- 20
10
11 f_value <- (sv1) / (sv2)
12
13 df1 <- n1 - 1    # Degrees of Freedom 1
14 df2 <- n2 - 1    # Degrees of Freedom 2
15
16 # Two Tail Test
17
18 # P-value Approach
19
20 pval <- 2 * pf(f_value,df1,df2,lower.tail = F)
21
22 if(pval <= alpha)
23 {
24     cat("Since pval",pval,"is less than or equal to
        0.10 therefore we can reject Null Hypothesis")
25 } else{

```

```

26   cat("Since pval",pval,"is greater than 0.10
      therefore we cannot reject Null Hypothesis")
27 }
28
29 # Critical Value Approach
30
31 half_alpha <- alpha / 2
32 fval <- qf(0.95,df1,df2)   # half_alpha = 0.05   = 1
      - 0.05 = 0.95
33
34 if(f_value >= fval)
35 {
36   cat("Since F value",f_value,"is greater than or
      equal to F value",fval,
37       "therefore we will reject Null Hypothesis")
38 } else {
39   cat("Since F value",f_value,"is less than F value"
      ,fval,
40       "therefore we cannot reject Null Hypothesis")
41 }
42
43                                     # Page no. :
                                     464
44
45 alpha <- 0.05   # Significance Level
46 n1 <- 41
47 n2 <- 31
48 sv1 <- 120
49 sv2 <- 80
50
51 f_value <- (sv1) / (sv2)
52
53 df1 <- n1 - 1   # Degrees of Freedom 1
54 df2 <- n2 - 1   # Degrees of Freedom 2
55
56 # Upper Tail Test
57
58 # P-value Approach

```

```

59
60 pval <- pf(f_value,df1,df2,lower.tail = F)
61
62 if(pval <= alpha)
63 {
64   cat("Since pval",pval,"is less than or equal to
        0.10 therefore we can reject Null Hypothesis")
65 } else{
66   cat("Since pval",pval,"is greater than 0.10
        therefore we cannot reject Null Hypothesis")
67 }
68
69 # Critical Value Approach
70
71 fval <- qf(0.90,df1,df2)   # alpha = 0.05 = 1 - 2
    * 0.05 = 0.90
72
73 if(f_value >= fval)
74 {
75   cat("Since F value",f_value,"is greater than or
        equal to F value",fval,
76       "therefore we will reject Null Hypothesis")
77 } else {
78   cat("Since F value",f_value,"is less than F value"
        ,fval,
79       "therefore we cannot reject Null Hypothesis")
80 }

```

Chapter 12

Tests of Goodness of Fit and Independence

R code Exa 12.1a Goodness of Fit Test A Multinomial Population

```
1                                     # Page no. :  
                                     474 – 476  
2  
3 # Goodness of Fit Test A Multinomial Population  
4  
5 category <- c("Company A", "Company B", "Company C")  
6 prop <- c(0.30, 0.50, 0.20)  
7 freq1 <- c(48, 98, 54)  
8 freq2 <- c(60, 100, 40)  
9 diff <- freq1 - freq2  
10 sq_diff <- (diff)**2  
11 answer <- sq_diff / freq2  
12 DF <- data.frame(category, prop, freq1, freq2, diff,  
                    sq_diff, answer)  
13  
14 total_observe_freq <- sum(DF$freq1)  
15 chisq_value <- sum(DF$answer)  
16  
17 alpha <- 0.05
```

```

18 df <- nrow(DF) - 1    # Degrees of Freedom
19
20 # Upper Tail Test
21
22 # P-value Approach
23
24 pval <- pchisq(chisq_value,df,lower.tail = F)
25
26 if(pval <= alpha)
27 {
28   cat("Since pval",pval,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis")
29 } else{
30   cat("Since pval",pval,"is greater than 0.05
        therefore we cannot reject Null Hypothesis")
31 }
32
33 # Critical Value Approach
34
35 chisqValue <- qchisq(0.95,df)    # 1 - alpha = 1 -
        0.05 = 0.95
36
37 if(chisq_value >= chisqValue)
38 {
39   cat("Since Chi-square value",chisq_value,"is
        greater than or equal to Chi-square value",
        chisqValue,
40       "therefore we will reject Null Hypothesis")
41 } else {
42   cat("Since Chi-square value",chisq_value,"is less
        than Chi-square value",chisqValue,
43       "therefore we cannot reject Null Hypothesis")
44 }

```

R code Exa 12.2a Tests of Independence


```

1
# Page no. :
480 – 482

2
3 # Tests of Independence
4
5 gender <- c("Male", "Female")
6 light <- c(20,30)
7 regular <- c(40,30)
8 dark <- c(20,10)
9 total <- c(80,70)
10
11 DF <- data.frame(gender, light, regular, dark, total
12 )
13 test <- chisq.test(DF[,2:4])
14 test
15
16 # Upper Tail Test
17
18 if(test$p.value <= 0.05)
19 {
20   cat("Since pval",test$p.value,"is less than or
21     equal to 0.05 therefore we can reject
22     Null Hypothesis")
23 } else{
24   cat("Since pval",test$p.value,"is greater than
25     0.05 therefore we cannot reject Null
26     Hypothesis")
27 }

```

R code Exa 12.3a Goodness of Fit Test Poisson Distribution

```

1
# Page no. :
488 – 490

2

```

```

3 # Goodness of Fit Test Poisson Distribution
4
5 x <- c(0,1,2,3,4,5,6,7,8,9)
6 observed_freq <- c(2,8,10,12,18,22,22,16,12,6)
7 y <- x * observed_freq
8 e <- 2.72
9
10 mu <- sum(y) / sum(observed_freq)
11 fun_of_x <- round(((mu)**x) * (e)**(-mu) / factorial
    (x), 4) # Function of x
12
13 expected_freq <- round(sum(observed_freq)*fun_of_x,
    2)
14
15 diff <- observed_freq - expected_freq
16
17 sq_diff <- round((diff)**2,2)
18
19 answer <- round(sq_diff / expected_freq,2)
20
21 DF <- data.frame(x,observed_freq,expected_freq,diff,
    sq_diff,answer)
22
23 total_observe_freq <- sum(DF$observed_freq)
24 total_expexted_freq <- sum(DF$expected_freq)
25
26 chisq_value <- sum(DF$answer)
27
28 df <- nrow(DF) - 2 # Degrees of Freedom (k - p - 1
    where k = 10, p = 1)
29
30 alpha <- 0.05
31
32 # Upper Tail Test
33
34 # P-value Approach
35
36 pval <- pchisq(chisq_value,df,lower.tail = F)

```

```

37
38 if(pval <= alpha)
39 {
40   cat("Since pval",pval,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis")
41 } else{
42   cat("Since pval",pval,"is greater than 0.05
        therefore we cannot reject Null Hypothesis")
43 }
44
45 # In Book it is taken 9 categories but we consider
    10 so p-value may vary but answeris correct

```

R code Exa 12.3b Goodness of Fit Test Normal Distribution

```

1                                     # Page no. :
                                     491 – 494
2
3 # Goodness of Fit Test Normal Distribution
4
5 data <- c
    (71,66,61,65,54,93,60,86,70,70,73,73,55,63,56,62,76,54,82,79,76,68,
6
    61,61,64,65,62,90,69,76,79,77,54,64,74,65,65,61,56,63,80,5
7
8 xbar <- mean(data)
9 s <- sd(data)
10
11 cat("Value of mean is",xbar)
12 cat("Value of standard variance is",s)
13
14 percentage <- c(0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9)
15 z <- c()
16 test_score <- c()

```

```

17
18 for (i in 1:length(percentage)) {
19   z[i] <- round(qnorm(percentage[i]),2)
20   test_score[i] <- round(xbar + (z[i] * round(s,2)),
21     2)
22 }
23 DF <- data.frame(percentage, z, test_score)
24
25 interval <- c("Less than 55.10", "55.10 to 59.68", "
26   59.68 to 63.01", "63.01 to 65.82",
27   "65.82 to 68.42", "68.42 to 71.02", "
28   71.02 to 73.83", "73.83 to 77.16",
29   "77.16 to 81.74", "81.74 and over")
30
31 observed_freq <- c(5,5,9,6,2,5,2,5,5,6)
32 expected_freq <- c(5,5,5,5,5,5,5,5,5,5)
33
34 answer <- (sq_diff) / expected_freq
35
36 dataset <- data.frame(interval, observed_freq,
37   expected_freq, diff, sq_diff, answer)
38
39 chisq <- sum(dataset$answer)
40
41 alpha <- 0.10 # Significance Level
42
43 df <- nrow(dataset) - 3 # Degrees of Freedom (k -
44   p - 1 where k = 10, p = 2)
45
46 # Upper Tail Test
47
48 # P-value Approach
49
50 pval <- pchisq(chisq,df,lower.tail = F)
51

```

```
50 if(pval <= alpha)
51 {
52   cat("Since pval",pval,"is less than or equal to
      0.05 therefore we can reject Null Hypothesis")
53 } else{
54   cat("Since pval",pval,"is greater than 0.05
      therefore we cannot reject Null Hypothesis")
55 }
```

Chapter 13

Experimental Design and Analysis of Variance

R code Exa 13.1a Analysis of Variance and the Completely Randomized Design

```
1                                     # Page no. :  
                                     510 – 512  
2  
3 # Analysis of Variance and the Completely Randomized  
  Design  
4  
5 method_A <- c(58,64,55,66,67)  
6 method_B <- c(58,69,71,64,68)  
7 method_C <- c(48,57,59,47,49)  
8  
9 DF <- data.frame(method_A,method_B,method_C)  
10  
11 mean1 <- sum(DF$method_A) / nrow(DF) # Sample Mean  
    1  
12 mean2 <- sum(DF$method_B) / nrow(DF) # Sample Mean  
    2  
13 mean3 <- sum(DF$method_C) / nrow(DF) # Sample Mean  
    3
```

```

14
15 variance1 <- sum((DF$method_A - mean1)**2) / (nrow(
    DF)-1)    # Sample Variance 1
16 variance2 <- sum((DF$method_B - mean2)**2) / (nrow(
    DF)-1)    # Sample Variance 2
17 variance3 <- sum((DF$method_C - mean3)**2) / (nrow(
    DF)-1)    # Sample Variance 3
18
19 sd1 <- sqrt(variance1)    # Sample Standard Variance
    1
20 sd2 <- sqrt(variance2)    # Sample Standard Variance
    2
21 sd3 <- sqrt(variance3)    # Sample Standard Variance
    3
22
23 sample_mean <- (mean1 + mean2 + mean3) / 3    #
    Overall Sample Mean
24
25 variance <- ((mean1 - sample_mean)**2 + (mean2 -
    sample_mean)**2 + (mean3 - sample_mean)**2) /
    (3 - 1)
26 # Sample Varince for Overall Sample Mean (3 -->
    Methods)
27
28 sigma_sq <- nrow(DF) * variance    # Between-
    treatment Estimate of Sigma Square
29
30 estimate_sigma_sq <- (variance1 + variance2 +
    variance3) / 3    # Within-treatment Estimate of
    Sigma Square
31
32 ratio <- sigma_sq / estimate_sigma_sq
33
34 cat("Ratio of Between-treatment Estimate of Sigma
    Square by Within-treatment Estimate
35     of Sigma Square is",ratio)

```

R code Exa 13.2a Analysis of Variance and the Completely Randomized Design

```
1                                     # Page no. : 518
2
3 # Analysis of Variance and the Completely Randomized
  Design
4
5 method_A <- c(58,64,55,66,67)
6 method_B <- c(58,69,71,64,68)
7 method_C <- c(48,57,59,47,49)
8
9 DF <- data.frame(method_A,method_B,method_C)
10
11 k <- ncol(DF)    # Number of Treatments
12 n <- nrow(DF)    # Number of Observations for each
  Treatment
13 N <- n * k      # Total Observations
14
15 df_numerator <- k - 1    # Degrees of Freedom for
  Numerator
16 df_denominator <- N - k  # Degrees of Freedom for
  Denominator
17
18 alpha <- 0.05
19
20 x <- c(t(as.matrix(DF)))
21 f <- c("method_A", "method_B", "method_C")
22 tm <- gl(k, 1, n*k, factor(f))
23 result <- anova(lm(x ~ tm))    # Similar to aov(x ~
  tm)
24
25 result
26
```



```

27 # Upper Tail Test
28
29 # Critical Value Approach
30
31 fval <- qf(0.95,df_numerator, df_denominator) # 1
    - alpha = 1 - 0.05 = 0.95
32 fval <- round(fval, 2)
33
34 fvalue <- result$'F value'[1]
35
36 if(fvalue >= fval)
37 {
38   cat("Since F value",fvalue,"is greater than or
        equal to F value",fval,
39       "therefore we will reject Null Hypothesis")
40 } else {
41   cat("Since fvalue value",fvalue,"is less than
        fvalue value",fval,
42       "therefore we cannot reject Null Hypothesis")
43 }
44
45 # P-value Approach
46
47 pval <- pf(fvalue,df_numerator,df_denominator,lower.
    tail = F)
48
49 if(pval <= alpha)
50 {
51   cat("Since pval",pval,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis")
52 } else{
53   cat("Since pval",pval,"is greater than 0.05
        therefore we cannot reject Null Hypothesis")
54 }

```

R code Exa 13.3a Multiple Comparison Procedures Fishers LSD

```
1                                     # Page no. : 525
                                     - 526
2
3 # Multiple Comparison Procedures : Fisher's LSD
4
5 method_A <- c(58,64,55,66,67)
6 method_B <- c(58,69,71,64,68)
7 method_C <- c(48,57,59,47,49)
8
9 DF <- data.frame(method_A,method_B,method_C)
10
11 k <- ncol(DF)    # Number of Treatments
12 n <- nrow(DF)    # Number of Observations for each
                    Treatment
13 N <- n * k      # Total Observations
14
15 x <- c(t(as.matrix(DF)))
16 f <- c("method_A", "method_B", "method_C")
17 tm <- gl(k, 1, n*k, factor(f))
18 result <- anova(lm(x ~ tm))    # Similar to aov(x ~
                                tm)
19
20 # Approach - 1
21
22 # Fisher's LSD Procedure for Method A and Method B
23
24 t_value1 <- (mean(DF$method_A) - mean(DF$method_B))
                / sqrt(result$'Mean Sq'[2] * ((1 / n)
25
```

```

26
27 t_value1 <- round(t_value1, 2)
28
29 df <- N - k    # Degrees of Freedom
30
31 # Two Tail Test
32
33 # P-value Approach
34
35 alpha <- 0.05
36
37 pval <- 2 * pt(t_value1, df, lower.tail = T)
38
39 if(pval <= alpha)
40 {
41   cat("Since pval",pval,"is less than or equal to
      0.05 therefore we can reject Null Hypothesis")
42 } else{
43   cat("Since pval",pval,"is greater than 0.05
      therefore we cannot reject Null Hypothesis")
44 }
45
46 tval <- qt(0.975,df)    # alpha/2 = 0.05 / 2 =
      0.025 = (1 - 0.025) = 0.975
47 tval <- round(tval, 3)
48
49 LSD <- tval * sqrt(result$'Mean Sq'[2] * ((1 / n) +
      (1 / n)))
50 LSD <- round(LSD, 2)
51
52 # Approach - 2
53
54 # Fisher 's LSD Procedure for Method A and Method C
55
56 diff_A_C <- mean(DF$method_A) - mean(DF$method_C)

```

```

57
58 if(diff_A_C > LSD)
59 {
60   cat("Since the value of difference", diff_A_C,"is
        greater than LSD",LSD,"therefore we will reject
61     Null Hypothesis")
62 } else{
63   cat("Since the value of difference", diff_A_C,"is
        less than LSD",LSD,"therefore we cannot reject
64     Null Hypothesis")
65 }
66
67 # Fisher 's LSD Procedure for Method B and Method C
68
69 diff_B_C <- mean(DF$method_B)- mean(DF$method_C)
70
71 if(diff_B_C > LSD)
72 {
73   cat("Since the value of difference", diff_B_C,"is
        greater than LSD",LSD,"therefore we will reject
74     Null Hypothesis")
75 } else{
76   cat("Since the value of difference", diff_B_C,"is
        less than LSD",LSD,"therefore we cannot reject
77     Null Hypothesis")
78 }

```

R code Exa 13.4a Randomized Block Design

```

1
2
3 # Randomized Block Design
4
5 blocks <- c(" Controller 1", " Controller 2", "

```

Page no. :
534

```

        Controller 3", "Controller 4", "Controller 5", "
        Controller 6")
6  system_A <- c(15, 14, 10, 13, 16, 13)
7  system_B <- c(15, 14, 11, 12, 13, 13)
8  system_C <- c(18, 14, 15, 17, 16, 13)
9
10 DF <- data.frame(blocks, system_A, system_B, system_
    C)
11
12 k <- ncol(DF) - 1    # Number of Treatments (blocks
    is not the treatment)
13 b <- nrow(DF)    # Number of blocks
14 N <- k * b    # Total sample Size
15
16 x <- c(t(as.matrix(DF[, -1])))
17 f <- c("system_A", "system_B", "system_C")
18 tm <- gl(k, 1, N, factor(f))
19 blk <- gl(b, k, N)
20 result <- anova(lm(x ~ tm + blk))    # Similar to aov
    (x ~ tm)
21
22 result
23
24 f_value <- result$'F value'[1]
25
26 # Upper Tail Test
27
28 # P-value Approach
29
30 pval <- result$'Pr(>F) '[1]
31
32 if(pval <= 0.05)
33 {
34   cat("Since pval", pval, "is less than or equal to
    0.05 therefore we can reject Null Hypothesis")
35 } else{
36   cat("Since pval", pval, "is greater than 0.05
    therefore we cannot reject Null Hypothesis")

```

R code Exa 13.5a Factorial Design

```

1                                     # Page no. : 542
2
3 # Factorial Experiment
4
5 program <- c("Three-hour review", "Three-hour review
      ", "One-day program", "One-day program", "10-week
      course",
6           "10-week course")
7 business <- c(500, 580, 460, 540, 560, 600)
8 engineering <- c(540, 460, 560, 620, 600, 580)
9 arts_and_science <- c(480, 400, 420, 480, 480, 410)
10
11 DF <- data.frame(program, business, engineering,
      arts_and_science)
12
13 a <- 3 # Number of levels in Factor A (Unique
      Programs)
14 b <- 3 # Number of levels in Factor B (Columns
      Except program)
15 r <- 2 # Number of Replications (Each Program has
      2 Replications)
16 N <- a * b * r # Total Observations
17
18 x <- c(t(as.matrix(DF[, -1])))
19 f1 <- c("Three-hour review", "One-day program", "10-
      week course")
20 f2 <- c("business", "engineering", "arts and science
      ")
21 tm2 <- gl(a, 1, N, factor(f1))
22 tm1 <- gl(b, r * a, N, factor(f2))
23 result <- anova(lm(x ~ tm1 * tm2)) # Similar to

```

```

        aov(x ~ tm)
24
25 result
26
27 alpha <- 0.05
28
29 # Upper Tail Test
30
31 pval1 <- result$'Pr(>F) '[1]
32 pval2 <- result$'Pr(>F) '[2]
33 pval3 <- result$'Pr(>F) '[3]
34
35 if(pval1 <= alpha)
36 {
37     cat("Since pval",pval1,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis
38         for Undergraduation.")
39 } else{
40     cat("Since pval",pval1,"is greater than 0.05
        therefore we cannot reject Null Hypothesis
41         for Undergraduation.")
42 }
43
44 if(pval2 <= alpha)
45 {
46     cat("Since pval",pval2,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis
47         for programs.")
48 } else{
49     cat("Since pval",pval2,"is greater than 0.05
        therefore we cannot reject Null Hypothesis
50         for programs.")
51 }
52
53 if(pval3 <= alpha)
54 {
55     cat("Since pval",pval3,"is less than or equal to
        0.05 therefore we can reject Null Hypothesis

```

```
56         for interaction.)
57 } else{
58   cat("Since pval",pval3,"is greater than 0.05
        therefore we cannot reject Null Hypothesis
59       for interaction.")
60 }
```

Chapter 14

Simple Linear Regression

R code Exa 14.1a Least Squares Method

```
1                                     # Page no. : 565
                                     - 566
2
3 # Least Squares Method
4
5 restaurant <- c(1,2,3,4,5,6,7,8,9,10)
6 student_population <- c(2,6,8,8,12,16,20,20,22,26)
7 quartely_sales <- c
   (58,105,88,118,117,137,157,169,149,202)
8
9 DF <- data.frame(restaurant, student_population,
   quartely_sales)
10
11 # Install Library if not installed
12
13 # install.packages("ggplot2")
14
15 # Import Library
16
17 library(ggplot2)
18
```

```

19 ggplot(DF,aes(student_population, quartely_sales)) +
    geom_point() +
20   labs(title = "Scatter Plot between Student
      Population and Quartely Sales",x = "Student
21       Population (1000s)", y = "Quartely Sales ($
      1000s)")
22
23                                     # Page no. : 567 –
                                     569
24
25 regressor <- lm(quartely_sales ~ student_population,
      data = DF)
26 res <- summary(regressor)
27
28 res
29
30 b1 <- res$coefficients[[2]]
31
32 b0 <- res$coefficients[[1]]
33
34 cat("Estimated Regression Equation is y_cap =",b0,"+
      ",b1,"x")
35
36 ggplot(DF,aes(student_population, quartely_sales)) +
    geom_point() +
37   geom_smooth(method='lm', se = F) + labs(title = "
      Scatter Plot between Student Population
38 and Quartely Sales",x = "Student Population (1000s)"
      , y = "Quartely Sales ($1000s)")

```

R code Exa 14.2a Coefficient of Determination

```

1                                     # Page no. :
                                     576 –
                                     580

```

```

2
3 # Coefficient of Determination
4
5 restaurant <- c(1,2,3,4,5,6,7,8,9,10)
6 student_population <- c(2,6,8,8,12,16,20,20,22,26)
7 quartely_sales <- c
    (58,105,88,118,117,137,157,169,149,202)
8
9 DF <- data.frame(restaurant, student_population,
    quartely_sales)
10
11 regressor <- lm(quartely_sales ~ student_population,
    data = DF)
12 res <- summary(regressor)
13
14 table <- anova(regressor)
15
16 SSE <- table$'Sum Sq'[2] # Sum of Squares due to
    Error
17
18 cat("Value of SSE is",SSE)
19
20 SSR <- table$'Sum Sq'[1] # Sum of Squares due to
    Regression
21
22 cat("Value of SSR is",SSR)
23
24 SST <- SSE + SSR # Total Sum of Squares
25
26 cat("Value of SST is",SST)
27
28 r_sq <- res$r.squared # Coefficient of
    Determination
29
30 corrcoeff <- sqrt(r_sq) # Correlation Coefficient
31
32 cat("Value of Coefficient of Determination is",r_sq)
33 cat("Value of correlation Coefficient is",corrcoeff)

```

R code Exa 14.3a Test of Significance

```
1                                     # Page no. :  
                                     485 – 489  
2  
3 # Test of Significance  
4  
5 restaurant <- c(1,2,3,4,5,6,7,8,9,10)  
6 student_population <- c(2,6,8,8,12,16,20,20,22,26)  
7 quartely_sales <- c  
    (58,105,88,118,117,137,157,169,149,202)  
8  
9 DF <- data.frame(restaurant, student_population,  
    quartely_sales)  
10  
11 regressor <- lm(quartely_sales ~ student_population,  
    data = DF)  
12 res <- summary(regressor)  
13  
14 standard_error_MSE <- res$sigma  
15  
16 cat("Value of square root of MSE is",standard_error_  
    MSE)  
17  
18 b1 <- res$coefficients[2]  
19  
20 tval <- res$coefficients[6]  
21  
22  
23 # T Test  
24  
25 # Two Tail Test  
26  
27 # P-value Approach
```

```

28
29 pval <- round(res$coefficients[8],3)
30
31 if(pval >= 0.01)
32 {
33   cat("Since pval",pval,"is greater than or equal to
        0.01 therefore we cannot reject the Null
        Hypothesis")
34 } else{
35   cat("Since pval",pval,"is less than 0.01 therefore
        we can reject the Null Hypothesis")
36
37 }
38
39 # F Test
40
41 test <- anova(regressor)
42
43 fval <- test$'F value'
44
45 pval <- round(test$'Pr(>F)')[1],3) # P value is
    extremely small ie negligible to 0
46
47 if(pval >= 0.01)
48 {
49   cat("Since pval",pval,"is greater than or equal to
        0.01 therefore we cannot reject the Null
        Hypothesis")
50 } else{
51   cat("Since pval",pval,"is less than 0.01 therefore
        we can reject the Null Hypothesis")
52
53 }
54
55 # Confidence Interval
56
57 confidence <- confint(regressor, "student_population
    ", level = 0.99)

```

```

58 IE1 <- confidence[1]
59 IE2 <- confidence[2]
60
61 cat("The 99 % confidence interval is ",IE1, "to",
      IE2)

```

R code Exa 14.4a Using the Estimated Regression Equation for Estimation and Prediction

```

1                                     # Page no. : 595 –
                                     597
2
3 # Using the Estimated Regression Equation for
  Estimation and Prediction
4
5 restaurant <- c(1,2,3,4,5,6,7,8,9,10)
6 student_population <- c(2,6,8,8,12,16,20,20,22,26)
7 quartely_sales <- c
  (58,105,88,118,117,137,157,169,149,202)
8
9 DF <- data.frame(restaurant, student_population,
  quartely_sales)
10
11 regressor <- lm(quartely_sales ~ student_population,
  data = DF)
12 res <- summary(regressor)
13
14 pred <- predict(regressor, data.frame(student_
  population=10), interval="confidence")
15
16 PE <- pred[1]
17 IE1 <- pred[2]
18 IE2 <- pred[3]
19
20 cat("Point estimate is ", PE)

```

```

21 cat(" Confidence Interval is ",IE1, "to", IE2)
22
23 pred2 <- predict(regressor, data.frame(student_
      population=10), interval="predict")
24
25 IE1 <- pred2[2]
26 IE2 <- pred2[3]
27
28 cat(" Prediction Confidence Interval is ",IE1, "to",
      IE2)

```

R code Exa 14.5a Residual Analysis Validating Model Assumptions

```

1                                     # Page no. : 605
                                     - 609
2
3 # Residual Analysis : Validating Model Assumptions
4
5 x <- c(2,6,8,8,12,16,20,20,22,26)   # Student
      Population
6 y <- c(58,105,88,118,117,137,157,169,149,202) #
      Sales
7
8 estimated_sales <- 60 + (5 * x)     # Regression
      Equation = 60 + 5 x
9
10 residuals <- y - estimated_sales
11
12 DF <- data.frame(x, y, estimated_sales, residuals)
13
14 # Install Library if not installed
15
16 # install.packages("ggplot2")
17
18 # Import Library

```

```

19
20 library(ggplot2)
21
22 ggplot(DF,aes(x, residuals)) + geom_point() + geom_
    hline(yintercept = 0, linetype=2) +
23 labs(title = "Residual Plot", x = "X", y = "Residual
    ")
24
25 ggplot(DF,aes(estimated_sales, residuals)) + geom_
    point() + geom_hline(yintercept = 0,
26     linetype=2) + labs(title = "Plot between
        Estimated Sales and Residuals", x =
27     "Estimated Sales", y =
        "Residual")

```

R code Exa 14.5b Standardized Residuals

```

1                                     # Page no. : 610 –
                                     612
2
3 # Standardized Residuals
4
5 i <- c(1,2,3,4,5,6,7,8,9,10)
6 x <- c(2,6,8,8,12,16,20,20,22,26)   # Student
    Population
7 n <- 10
8 s <- 13.829   # Standard error
9 y <- c(58,105,88,118,117,137,157,169,149,202)   #
    Sales
10
11 estimated_sales <- 60 + (5 * x)   # Regression
    Equation = 60 + 5 x
12
13 x_deviation <- x - mean(x)
14

```



```

15 x_deviation_sq <- (x_deviation)**2
16
17 z <- round(x_deviation_sq / sum(x_deviation_sq),4)
18
19 h <- round((1 / n) + z, 4)
20
21 s_i <- round(s * sqrt(1 -h), 4) # Standard
    Deviation for Residual i
22
23 residuals <- y - estimated_sales
24
25 standard_residuals <- round((residuals) / (s_i), 4)
26
27 DF <- data.frame(x, y, estimated_sales, x_deviation,
    x_deviation_sq, z, h, s_i, residuals, standard_
    residuals)
28
29 # Install Library if not installed
30
31 # install.packages("ggplot2")
32
33 # Import Library
34
35 library(ggplot2)
36
37 ggplot(DF,aes(x, standard_residuals)) + geom_point()
    + geom_hline(yintercept = 0, linetype=2) +
38   labs(title = "Scatter Plot between x and
    Standard Residuals", x = "X",
39     y = "Standard Residuals")
40
41 normal_scores <- round(qqnorm(1:10)$x, 2)
42 standard_residuals <- sort(standard_residuals,
    decreasing = F)
43
44 table <- data.frame(normal_scores, standard_
    residuals)
45

```

```

46 ggplot(table,aes(normal_scores, standard_residuals))
    + geom_point() +
47   geom_smooth(method = "lm", se = F) +
48 labs(title = "Scatter Plot between Normal Scores and
    Standard Residuals", x = "Normal Scores",
49       y = "Standard Residuals")

```

R code Exa 14.6a Detecting Outliers

```

1                                     # Page no. : 615
2
3 # Detecting Outliers
4
5 x <- c(1,1,2,3,3,3,4,4,5,6)
6 y <- c(45,55,50,75,40,45,30,35,25,15)
7
8 DF <- data.frame(x,y)
9
10 ggplot(DF,aes(x, y)) + geom_point()+ geom_smooth(
    method = "lm", se = F) +
11 labs(title = "Scatter Plot between x and Y Showing
    Outlier", x = "X", y = "Y")

```

R code Exa 14.6b Detecting Influential Observations

```

1                                     # Page no. :
                                     617 – 618
2
3 # Detecting Influential Observations
4
5 x <- c(10, 10, 15, 20, 20, 25, 70)
6 y <- c(135, 130, 120, 115, 120, 110, 100)
7

```

```

8 DF <- data.frame(x, y)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
18 ggplot(DF, aes(x, y)) + geom_point() + labs(title =
19     "Scatter Plot between x and y", x = "X",
20     y = "Y")
21
22 point <- x[7] # From Scatter Plot
23
24 h <- (1 / nrow(DF)) + (((point - mean(DF$x))**2) / (
25     sum((DF$x - mean(DF$x))**2)))
26
27 cat("Leverage at point 7 is", h)

```

Chapter 15

Multiple Regression

R code Exa 15.1a Least Squares Method

```
1                                     # Page no. :  
                                     646 – 647  
2  
3 # Least Squares Method  
4  
5 driving_assignment <- c(1,2,3,4,5,6,7,8,9,10)  
6 x <- c(100,50,100,100,50,80,75,65,90,90) # Miles  
   Traveled  
7 y <- c(9.3,4.8,8.9,6.5,4.2,6.2,7.4,6.0,7.6,6.1) #  
   Travel Time (hours)  
8  
9 DF <- data.frame(driving_assignment, x ,y)  
10  
11 # Install Library if not installed  
12  
13 # install.packages("ggpolt2")  
14  
15 # Import Library  
16  
17 library(ggplot2)  
18
```

```

19 ggplot(DF,aes(x, y)) + geom_point() +labs(title = "
    Scatter Plot between Miles Traveled
20    and Travel Time", x = "Miles Traveled", y = "
    Travel Time in Hours")
21
22                                     # Page no. : 647
                                     - 648
23
24 model <- lm(y ~ x, data = DF)
25 summ <- summary(model)
26 summ
27
28 b0 <- model$coefficients[1]
29 b1 <- model$coefficients[2]
30
31 cat("Linear Regression Equation is y_cap =",b0,"+",
    b1,"x1")
32
33 # F Test
34
35 fval <- summ$fstatistic[1]
36
37 # Upper Tail Test
38
39 # P-value Approach
40
41 alpha <- 0.05
42
43 pval <- summ$coefficients[8] # P-value
44
45 if(pval >= alpha)
46 {
47     cat("Since pval",pval,"is greater than or equal to
        0.01 therefore we cannot reject the Null
        Hypothesis")
48 } else{
49     cat("Since pval",pval,"is less than 0.05 therefore
        we can reject the Null Hypothesis")

```

```
50
51 }
```

R code Exa 15.2a Two Independent Variables

```
1                                     # Page no. : 648
                                     #   649
2
3 # Two Independent Variables
4
5 driving_assignment <- c(1,2,3,4,5,6,7,8,9,10)
6 x1 <- c(100,50,100,100,50,80,75,65,90,90) # Miles
   Traveled
7 x2 <- c(4,3,4,2,2,2,3,4,3,2) # Number of
   Deliveries
8 y <- c(9.3,4.8,8.9,6.5,4.2,6.2,7.4,6.0,7.6,6.1) #
   Travel Time (hours)
9
10 DF <- data.frame(driving_assignment, x1, x2, y)
11
12 model <- lm(y ~ x1 + x2, data = DF)
13 summary(model)
14
15 b0 <- model$coefficients[1]
16 b1 <- model$coefficients[2]
17 b2 <- model$coefficients[3]
18
19 cat("Multiple Regression Equation is y_cap =",b0,"+"
     ,b1,"x1 +" ,b2,"x2")
```

R code Exa 15.3a Multiple Coefficient of Determination

```

1                                     # Page no. :
                                     654 - 655
2
3 # Multiple Coefficient of Determination
4
5 driving_assignment <- c(1,2,3,4,5,6,7,8,9,10)
6 x1 <- c(100,50,100,100,50,80,75,65,90,90)    # Miles
   Traveled
7 x2 <- c(4,3,4,2,2,2,3,4,3,2)    # Number of
   Deliveries
8 y <- c(9.3,4.8,8.9,6.5,4.2,6.2,7.4,6.0,7.6,6.1)    #
   Travel Time (hours)
9
10 DF <- data.frame(driving_assignment, x1, x2, y)
11
12 model <- lm(y ~ x1 + x2, data = DF)
13 summ <- summary(model)
14
15 mean_y <- mean(DF$y)    # Mean of Travel time
16
17 predicted_travel_time <- round(predict(model), 2)
18
19 DF <- cbind(DF, predicted_travel_time)
20
21 SSR <- sum((DF$predicted_travel_time - mean_y)**2)
   # Sum of Squares due to Regression
22
23 cat("Value of SSR is", SSR)
24
25 SSE <- sum((DF$y - DF$predicted_travel_time)**2)    #
   Sum of Squares due to Error
26
27 cat("Value of SSE", SSE)
28
29 SST <- SSR + SSE    # Total Sum of Squares
30
31 cat("Value of SST", SST)
32

```

```

33 r_sq <- summ$r.squared # Multiple Coefficient of
    Determination
34
35 cat("Value of Multiple Coefficient of Determination
    is", r_sq)
36
37 adj_r_sq <- summ$adj.r.squared # Adjusted Multiple
    Coefficient of Determination
38
39 cat("Value of Adjusted Multiple Coefficient of
    Determination is", adj_r_sq)

```

R code Exa 15.4a Testing of significance

```

1                                     # Page no. :
                                     660 – 662
2
3 # Testing for Significance
4
5 driving_assignment <- c(1,2,3,4,5,6,7,8,9,10)
6 x1 <- c(100,50,100,100,50,80,75,65,90,90) # Miles
    Traveled
7 x2 <- c(4,3,4,2,2,2,3,4,3,2) # Number of
    Deliveries
8 y <- c(9.3,4.8,8.9,6.5,4.2,6.2,7.4,6.0,7.6,6.1) #
    Travel Time (hours)
9
10 DF <- data.frame(driving_assignment, x1, x2, y)
11
12 model <- lm(y ~ x1 + x2, data = DF)
13 summ <- summary(model)
14
15 SSR <- 21.6252 # Sum of Squares due to Regression
16
17 SSE <- 2.2952 # Sum of Squares due to Error

```



```

18
19 n <- nrow(DF)    # Total Observations
20
21 p <- 2    # Number of Independent Variables
22
23 MSR <- SSR / p    # Mean Square due to Regression
24
25 cat("Value of MSR is",MSR)
26
27 MSE <- SSE / (n - p - 1)    # Mean Square due to
    Error
28
29 # F Test
30
31 fval <- summ$fstatistic[1]
32
33 alpha <- 0.01
34
35 # Upper Tail Test
36
37 # P-value Approach
38
39 pval <- summ$coefficients[11]
40
41 if(pval >= alpha)
42 {
43     cat("Since pval",pval,"is greater than or equal to
        0.01 therefore we cannot reject the Null
        Hypothesis")
44 } else{
45     cat("Since pval",pval,"is less than 0.01 therefore
        we can reject the Null Hypothesis")
46
47 }
48
49 s <- summ$sigma    # Standard Error of the Estimate
50
51 cat("Value of Standard Error of the Estimate is",s)

```

```

52
53 coeff <- as.data.frame(summ$coefficients)
54
55 b1 <- coeff$Estimate[2]
56 b2 <- coeff$Estimate[3]
57
58 s1 <- coeff$`Std. Error`[2]    # Standard Error of
    the x1 (Miles Traveled)
59 s2 <- coeff$`Std. Error`[3]    # Standard Error of
    the x2 (Number of Deliveries)
60
61 df <- n - p - 1    # Degrees of Freedom
62
63 # T Test
64
65 tval1 <- round(b1 / s1, 3)
66 tval2 <- round(b2 / s2, 3)
67
68 # Upper Tail Test
69
70 # P-value Approach
71
72 pval1 <- round(pt(tval1, df, lower.tail = F),5)
73 pval2 <- round(pt(tval2, df, lower.tail = F),5)
74
75
76 if(pval1 >= alpha && pval2 >= alpha)
77 {
78   cat("Since pval1",pval1,"and pval2",pval2,"is
        greater than or equal to 0.01 therefore we
        cannot reject the
79     Null Hypothesis")
80 } else{
81   cat("Since pval1",pval1,"and pval2",pval2,"is less
        than 0.01 therefore we can reject the Null
        Hypothesis")
82
83 }

```

R code Exa 15.5a Categorical Independent Variables

```
1                                     # Page no. :  
                                     668 – 671  
2  
3 # Categorical Independent Variables  
4  
5 service <- c(1:10)  
6 month <- c(2,6,8,3,2,7,9,8,4,6)  
7 repair <- c("electrical","mechanical","electrical","  
            "mechanical","electrical","electrical",  
8            "mechanical","mechanical","electrical","  
            electrical")  
9 time <- c(2.9, 3.0, 4.8, 1.8, 2.9, 4.9, 4.2, 4.8,  
          4.4, 4.5)  
10  
11 DF <- data.frame(service, month, repair, time)  
12  
13 # With one Independent variable  
14  
15 regressor <- lm(time ~ month, data = DF)  
16 res <- summary(regressor)  
17  
18 res  
19  
20 b0 <- res$coefficients[1]  
21 b1 <- res$coefficients[2]  
22  
23 cat("Equation is y = ", b0 ,"+",b1,"x1")  
24  
25 # With Categorical Variable  
26  
27 DF$repair <- factor(DF$repair,  
28                     levels = c('electrical', 'mechanical'))
```

```

                                mechanical'),
29                             labels = c(1, 0))
30
31 regressor <- lm(time ~ month + repair, data = DF)
32 res <- summary(regressor)
33
34 res
35
36 b0 <- res$coefficients[1]
37 b1 <- res$coefficients[2]
38 b2 <- res$coefficients[3]
39
40 # For Electrical Repair
41
42 bterm <- b0 + b2 * 1
43
44 cat("Equation for electrical is y = ", bterm, "+",
      b1, "x1" )
45
46 # For Mechanical Repair
47
48 bterm2 <- b0 + b2 * 0
49
50 cat("Equation for mechanical is y = ", bterm2, "+",
      b1, "x1" )

```

R code Exa 15.6a Residual Analysis

```

1
2
3 # Residual Analysis
4
5 miles <- c(100, 50, 100, 100, 50, 80, 75, 65, 90,
             90)

```

Page no. :
676 – 679

```

6 deliveries <- c(4, 3, 4, 2, 2, 2, 3, 4, 3, 2)
7 time <- c(9.3, 4.8, 8.9, 6.5, 4.2, 6.2, 7.4, 6.0,
8           7.6, 6.1)
9 DF <- data.frame(miles, deliveries, time)
10
11 regressor <- lm(time ~ miles + deliveries, data = DF
12                )
13 res <- summary(regressor)
14 predict <- predict(regressor)
15 residuals <- DF$time - predict
16 std_residuals <- rstandard(regressor)
17
18 DF <- cbind(DF, predict, residuals, std_residuals)
19
20 View(DF)
21
22 # Install Library if not installed
23
24 # install.packages("ggplot2")
25
26 # Import Library
27
28 library(ggplot2)
29
30 ggplot(DF, aes(predict, std_residuals)) + geom_point
31   () + geom_hline(yintercept = 0,
32     linetype=2) + labs(title = "Plot between
33       predicted values and standardizes residuals
34       ", x =
35         "Prediction", y
36         = "
37         Standardization
38         Residual")
39
40
41 leverage <- hatvalues(regressor)

```

```

36 cook_dist <- cooks.distance(regressor)
37
38 DF <- cbind(DF, leverage, cook_dist)
39
40 View(DF)

```

R code Exa 15.6b Influential Observations

```

1                                     # Page no. :
                                     679 – 680
2
3 # Influential Observations
4
5 x <- c(1, 1, 2, 3, 4, 4, 5, 15)
6 y <- c(18, 21, 22, 21, 23, 24, 26, 39)
7
8 DF <- data.frame(x, y)
9
10 regressor <- lm(y ~ x, data = DF)
11 res <- summary(regressor)
12
13 lev <- hatvalues(regressor)
14 DF <- cbind(DF, lev)
15
16 View(DF)
17
18
19 # Install Library if not installed
20
21 # install.packages("ggplot2")
22
23 # Import Library
24
25 library(ggplot2)
26

```

```

27 ggplot(DF,aes(x, y)) + geom_point() + geom_smooth(
    method = "lm", se = F) +
28   labs(title = "Plot between x and y", x = "X", y =
    "Y")
29
30
31 cat("Equation is y = ",res$coefficients[1],"+",res$
    coefficients[2], "x1")
32
33
34 # Removing Influential Observation
35
36 x <- c(1, 1, 2, 3, 4, 4, 5)
37 y <- c(18, 21, 22, 21, 23, 24, 26)
38
39 DF <- data.frame(x, y)
40
41 regressor <- lm(y ~ x, data = DF)
42 res <- summary(regressor)
43
44 cat("Equation is y = ",res$coefficients[1],"+",res$
    coefficients[2], "x1")

```

R code Exa 15.7a Logistic Regression

```

1
2
3 # Logistic Regression
4
5 customer <- c(1,2,3,4,5,6,7,8,9,10)
6 spending <- c
    (2.291,3.215,2.135,3.924,2.528,2.473,2.384,7.076,1.182,3.345)
7
8
9 card <- c(1,1,1,0,1,0,0,0,1,0)

```

```
8 coupon <- c(0,0,0,0,0,1,0,0,1,0)
9
10 DF <- data.frame(customer, spending, card, coupon)
11
12 regressor <- glm(coupon ~ spending + card, data = DF
13 )
14 summary(regressor)
15 # Book answer is different
```

Chapter 16

Regression Analysis Model Building

R code Exa 16.1a General Linear Model

```
1                                     # Page no. : 714
                                     # 717
2
3 # General Linear Model
4
5 x <- c(41,106,76,10,22,12,85,111,40,51,9,12,6,56,19)
      # Months Employed
6 y <- c
      (275,296,317,376,162,150,367,308,189,235,83,112,67,325,189)
      # Scales Sold
7
8 DF <- data.frame(x,y)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
```

```

16 library(ggplot2)
17
18 ggplot(DF, aes(x,y)) + geom_point() + labs(title = "
    Scatter Plot between Months
19     Employed and Scales sold", x = "Months Employed",
    y = "Scales Sold")
20
21 model <- lm(y ~ x, data = DF)
22 summary(model)
23
24 b1 <- model$coefficients[1]
25 b2 <- model$coefficients[2]
26
27 cat("Regression Equation is sales =",b1,"+",b2,"
    months")
28 # Book Answer is sales = 111 + 2.38 months    (Data
    is wrongly used in book)
29
30 predicted_scales_sold <- predict(model)
31
32 DF <- cbind(DF, predicted_scales_sold)
33
34 # Standard Residuals
35
36 standard_residuals <- rstandard(model)
37
38 DF <- cbind(DF, standard_residuals)
39
40 ggplot(DF,aes(predicted_scales_sold, standard_
    residuals)) + geom_point() +
41     geom_hline(yintercept = 0, linetype=2) +
42     labs(title = "Scatter Plot between Predicted scales
    sold and Standard Residuals",
43         x = "Predicted scales sold", y = "Standard
    Residuals")
44
45                                     # Page no. :
                                     716 - 717

```

```

46
47 x2 <- x**2
48
49 DF2 <- data.frame(x,x2,y)
50
51 model2 <- lm(y ~ x + x2, data = DF2)
52 summary(model2)
53
54 b1 <- model2$coefficients[1]
55 b2 <- model2$coefficients[2]
56 b3 <- model2$coefficients[3]
57
58 cat("Regression Equation is sales =",b1,"+",b2,"
      months", "+",b3,"monthsq")
59 # Book Answer is sales = 45.3 + 6.34 months - 0.0345
      monthsq (Data is wrongly used in book)
60
61 predicted_scales_sold2 <- predict(model2)
62
63 DF2 <- cbind(DF2, predicted_scales_sold2)
64
65 # Standard Residuals
66
67 standard_residuals2 <- rstandard(model2)
68
69 DF2 <- cbind(DF2, standard_residuals2)
70
71 ggplot(DF2,aes(predicted_scales_sold2, standard_
      residuals2)) + geom_point() +
72   geom_hline(yintercept = 0, linetype=2) +
73   labs(title = "Scatter Plot between Predicted
      scales sold and Standard Residuals",
74         x = "Predicted scales sold", y = "Standard
      Residuals")

```

R code Exa 16.1b Interaction

```
1                                     # Page no. : 718
                                     - 721
2
3 # Interaction
4
5 price <- c(2.00, 2.50, 3.00, 2.00, 2.50, 3.00, 2.00,
6           2.50, 3.00, 2.00, 2.50, 3.00,
7           2.00, 2.50, 3.00, 2.00, 2.50, 3.00, 2.00,
8           2.50, 3.00, 2.00, 2.50, 3.00)
9 advertising <- c(50, 50, 50, 50, 50, 50, 50, 50, 50,
10                50, 50, 50, 100, 100, 100, 100, 100,
11                100, 100, 100, 100, 100, 100, 100)
12 sales <- c(478, 373, 335, 473, 358, 329, 456, 360,
13            322, 437, 365, 342, 810, 653, 345, 832, 641,
14            372, 800, 620, 390, 790, 670, 393)
15
16 DF <- data.frame(price, advertising, sales)
17
18 # Install Library if not install
19
20 # install.packages("dplyr")
21
22 # Import Library
23
24 library(dplyr)
25
26 DF %>% group_by(price, advertising) %>% summarize(
27   Average=mean(sales))
28
29 model <- lm(sales ~ price + advertising + (price *
30             advertising), data = DF)
31
32 res <- summary(model)
33
34 b0 <- res$coefficients[1]
35 b1 <- res$coefficients[2]
36 b2 <- res$coefficients[3]
```

```

30 b3 <- res$coefficients[4]
31
32 cat("Equation is sales = ", b0, "+", b1, "Price +",
      b2, "AdvExp +", b3, "PriAdv")

```

R code Exa 16.1c Transformations Involving the Dependent Variables

```

1                                     # Page no. : 721
                                     # 724
2
3 # Transformations Involving the Dependent Variables
4
5 x <- c
   (2289,2113,2180,2448,2026,2702,2657,2106,3226,3213,3607,2888)
   # Weight
6 y <- c
   (28.7,29.2,34.2,27.9,33.3,26.4,23.9,30.5,18.1,19.5,14.3,20.9)
   # Miles Per Gallon
7
8 DF <- data.frame(x,y)
9
10 # Install Library if not install
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
18 ggplot(DF, aes(x,y)) + geom_point() + labs(title = "
   Scatter Plot between Weight and Miles
19                                     Per
                                     Gallon
                                     ", x =
                                     ")

```

```
Weight
", y =
"
Miles
Per
Gallon
")
```

```
20
21 model <- lm(y ~ x, data = DF)
22 summary(model)
23
24 b1 <- model$coefficients[1]
25 b2 <- model$coefficients[2]
26
27 cat("Regression Equation is sales =",b1,"+",b2,"
    months")
28
29 # Prediction
30
31 predicted_miles_per_gallon <- predict(model)
32
33 DF <- cbind(DF, predicted_miles_per_gallon)
34
35 # Standard Residuals
36
37 standard_residuals <- rstandard(model)
38
39 DF <- cbind(DF, standard_residuals)
40
41
42 ggplot(DF,aes(predicted_miles_per_gallon, standard_
    residuals)) + geom_point() +
43   geom_hline(yintercept = 0, linetype=2) +
44   labs(title = "Scatter Plot between Predicted Miles
    per Gallon and Standard Residuals",
45     x = "Predicted Miles per Gallon", y = "
    Standard Residuals")
46
```

```

47 # Log Transformation
48
49 #log_x <- log(x)
50 log_y <- log(y)
51
52 DF2 <- data.frame(x, log_y)
53
54 options(scipen = 999) # To display not in
    scientific notation
55 model <- lm(log_y ~ x, data = DF2)
56 summary(model)
57
58 b1 <- model$coefficients[1]
59 b2 <- model$coefficients[2]
60
61 cat("Regression Equation is sales =",b1,"+",b2,"
    months")
62
63 # Prediction
64
65 predicted_miles_per_gallon <- predict(model)
66
67 DF2 <- cbind(DF2, predicted_miles_per_gallon)
68
69 # Standard Residuals
70
71 standard_residuals <- rstandard(model)
72
73 DF2 <- cbind(DF2, standard_residuals)
74
75
76 ggplot(DF2,aes(predicted_miles_per_gallon, standard_
    residuals)) + geom_point() +
77   geom_hline(yintercept = 0, linetype=2) + labs(
    title = "Scatter Plot between Log
78 Transformation of Predicted Miles per Gallon and
    Standard Residuals",
79   x = "Predicted Miles per Gallon", y = "

```

R code Exa 16.2a Analysis of a Large Problem

```
1                                     # Page no. : 736
                                     - 738
2
3 # Analysis of a Large Problem
4
5 Sales <- c(3669.88, 3473.95, 2295.10, 4675.56,
6           6125.96, 2134.94, 5031.66, 3367.45, 6519.45,
7           4876.37, 2468.27, 2533.31, 2408.11,
8           2337.38, 4586.95, 2729.24, 3289.40,
9           2800.78,
10          3264.20, 3453.62, 1741.45, 2035.75,
11          1578.00, 4167.44, 2799.97)
12 Time <- c(43.10, 108.13, 13.82, 186.18, 161.79,
13           8.94, 365.04, 220.32, 127.64, 105.69, 57.72,
14           23.58,
15           13.82, 13.82, 86.99, 165.85, 116.26,
16           42.28, 52.84, 165.04, 10.57, 13.82,
17           8.13, 58.44,
18           21.14)
19 Poten <- c(74065.1, 58117.3, 21118.5, 68521.3,
20            57805.1, 37806.9, 50935.3, 35602.1, 46176.8,
21            42053.2,
22            36829.7, 33612.7, 21412.8, 20416.9,
23            36272.0, 23093.3, 26878.6, 39572.0,
24            51866.1, 58749.8,
25            23990.8, 25694.9, 23736.3, 34314.3,
26            22809.5)
27 AdvExp <- c(4582.9, 5539.8, 2950.4, 2243.1, 7747.1,
28            402.4, 3140.6, 2086.2, 8846.2, 5673.1, 2761.8,
29            1991.8, 1971.5, 1737.4, 10694.2, 8618.6,
30            7747.9, 4565.8, 6022.7, 3721.1,
```



```

      861.0, 3571.5,
16      2845.5, 5060.1, 3552.0)
17 Share <- c(2.51, 5.51, 10.91, 8.27, 9.15, 0.15,
      8.54, 7.07, 12.54, 8.85, 5.38, 5.43, 8.48, 7.80,
18      10.34, 5.15, 6.64, 5.45, 6.31, 6.35,
      7.37, 8.39, 5.15, 12.88, 9.14)
19 Change <- c(0.34, 0.15, -0.72, 0.17, 0.50, 0.15,
      0.55, -0.49, 1.24, 0.31, 0.37, -0.65, 0.64, 1.01,
20      0.11, 0.04, 0.68, 0.66, -0.10, -0.03,
      -1.63, -0.43, 0.04, 0.22, -0.74)
21 Accounts <- c(74.86, 107.32, 96.75, 195.12, 180.44,
      104.88, 256.10, 126.83, 203.25, 119.51, 116.26,
22      142.28, 89.43, 84.55, 119.51, 80.49,
      136.58, 78.86, 136.58, 138.21,
      75.61, 102.44,
23      76.42, 136.58, 88.62)
24 Work <- c(15.05, 19.97, 17.34, 13.40, 17.64, 16.22,
      18.80, 19.86, 17.42, 21.41, 16.32, 14.51,
25      19.35, 20.02, 15.26, 15.87, 7.81, 16.00,
      17.44, 17.98, 20.99, 21.66, 21.46,
      24.78,
26      24.96)
27 Rating <- c(4.9, 5.1, 2.9, 3.4, 4.6, 4.5, 4.6, 2.3,
      4.9, 2.8, 3.1, 4.2, 4.3, 4.2, 5.5, 3.6, 3.4,
28      4.2, 3.6, 3.1, 1.6, 3.4, 2.7, 2.8, 3.9)
29
30 DF <- data.frame(Sales, Time, Poten, AdvExp, Share,
      Change, Accounts, Work, Rating)
31 View(DF)
32
33 library(corrplot)
34
35 matrix <- round(cor(DF), 3)
36 matrix
37
38 regressor <- lm(Sales ~ Time + Poten + AdvExp +
      Share + Change + Accounts + Work + Rating,
39      data = DF)

```

```

40 summary(regressor)
41
42 cat("Equation is Sales = ",regressor$coefficients
    [1],"+",regressor$coefficients[2],"Time +",
43     regressor$coefficients[3],"Poten +",regressor$
    coefficients[4],"AdvExp +",regressor$
    coefficients[5],
44     "Share +",regressor$coefficients[6],"Change +",
    regressor$coefficients[7],"Accounts +",
45     regressor$coefficients[8],"Work +",regressor$
    coefficients[8],"Rating")
46
47 # Book Answer is different
48
49 regressor2 <- lm(Sales ~ Poten + AdvExp + Share,
    data = DF)
50 summary(regressor2)
51
52 cat("Equation is Sales = ",regressor2$coefficients
    [1],"+",regressor2$coefficients[3],"Poten +",
53     regressor2$coefficients[4],"AdvExp +",regressor2
    $coefficients[5],
54     "Share")
55
56 # Book Answer is different

```

R code Exa 16.3a Multiple Regression Approach to Experimental Design

```

1                                     # Page no. : 745 –
                                     747
2
3 # Multiple Regression Approach to Experimental
  Design
4
5 A <- c(58,64,55,66,67)

```

```

6 B <- c(58,69,71,64,68)
7 C <- c(48,57,59,47,49)
8
9 DF <- data.frame(A,B,C)
10
11 newA <- c(1,1,1,1,1,0,0,0,0,0,0,0,0,0,0)
12 newB <- c(0,0,0,0,0,1,1,1,1,1,0,0,0,0,0)
13 y <- c(58,64,55,66,67,58,69,71,64,68,48,57,59,47,49)
14
15 DF2 <- data.frame(newA, newB, y)
16
17 regressor <- lm(y ~ newA + newB, data = DF2)
18 summary(regressor)
19
20 cat("Equation is y = ",regressor$coefficients[1],"+",
      ,regressor$coefficients[2], "A +",
21      regressor$coefficients[3], "B")

```

Chapter 17

Index Numbers

R code Exa 17.1a Price Relatives

```
1                                     # Page no. : 765
2
3 # Price Relatives
4
5 year <- c
      (1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002
6
7 price_per_gallon <- c(1.30,
      1.10,1.09,1.07,1.08,1.11,1.22,1.20,1.03,1.14,1.48,1.42,1.34,1.56,
8
9 DF <- data.frame(year,price_per_gallon)
10
11 base_year <- 1990
12 base_year_price <- DF$price_per_gallon[DF$year ==
      base_year]
13
14 price_relative <- round(((DF$price_per_gallon) / (
      base_year_price)) * 100, 2)
15
```

```

16 DF <- cbind(DF, price_relative)
17
18 View(DF)

```

R code Exa 17.2a Aggregate Price Indexes

```

1                                     # Page no. :
                                     766
2
3 # Aggregate Price Indexes
4
5 item <- c("Gallon of gasoline","Quart of oil","Tire"
6           ,"Insurance policy")
7 year_1990 <- c(1.30,2.10,130.00,820.00)
8 year_2008 <- c(3.25,8.00,140.00,1030.00)
9 quantity <- c(1000,15,2,1)
10
11 DF <- data.frame(item,year_1990,year_2008,quantity)
12
13 base_year <- 1990
14
15 sum_of_1990_items <- sum(DF$year_1990)
16
17 sum_of_2008_items <- sum(DF$year_2008)
18
19 aggregate_index_2008 <- (sum_of_2008_items / sum_of_
20   1990_items) * 100
21
22 cat("The unweighted aggregate index for year 2008 is
23   ",aggregate_index_2008)
24
25 sum_of_1990_items <- sum(DF$year_1990 * DF$quantity)
26 # Weighted Sum
27
28

```

```

25 sum_of_2008_items <- sum(DF$year_2008 * DF$quantity)
    # Weighted Sum
26
27 aggregate_index_2008 <- (sum_of_2008_items / sum_of_
    1990_items) * 100
28
29 cat("The weighted aggregate index for year 2008 is",
    aggregate_index_2008)

```

R code Exa 17.3a Computing an Aggregate Price Index from Price Relatives

```

1                                     # Page no. : 769
                                     - 770
2
3 # Computing an Aggregate Price Index from Price
  Relatives
4
5 item <- c("Gallon of gasoline","Quart of oil","Tire"
    ,"Insurance policy")
6 year_1990 <- c(1.30,2.10,130.00,820.00)
7 year_2008 <- c(3.25,8.00,140.00,1030.00)
8 quantity <- c(1000,15,2,1)
9
10 DF <- data.frame(item,year_1990,year_2008,quantity)
11
12 base_year <- 1990
13
14 price_relative <- (DF$year_2008 / DF$year_1990) *
    100
15
16 weight <- DF$year_1990 * DF$quantity
17
18 weight_price_relative <- price_relative * weight
19

```

```

20 DF <- cbind(DF, price_relative, weight, weight_price
    _relative)
21
22 aggregate_2008 <- sum(DF$weight_price_relative) /
    sum(DF$weight)
23
24 cat("Aggregate Price Index for year 2008 is",
    aggregate_2008)

```

R code Exa 17.4a Deflating a Series by Price Indexes

```

1                                     # Page no. :
                                     774
2
3 # Deflating a Series by Price Indexes
4
5 year <- c(2004,2005,2006,2007,2008)
6 hourly_wage <- c(15.69,16.12,16.76,17.45,18.07)
7 CPI <- c(188.9,195.3,201.6,207.3,215.3)
8
9 DF <- data.frame(year, hourly_wage, CPI)
10
11 # Install Library if not installed
12
13 # install.packages("ggplot2")
14
15 # Import Library
16
17 library(ggplot2)
18
19 ggplot(DF, aes(year, hourly_wage)) + geom_line() +
    geom_point() +
20   labs(title = "Year V/S Hourly Wage Graph", x = "
    Year", y = "Hourly Wage")
21

```

```
22
23 deflated_hourly_wage <- (DF$hourly_wage / DF$CPI) *
    100
24
25 DF <- cbind(DF, deflated_hourly_wage)
26
27 ggplot(DF, aes(year, deflated_hourly_wage)) + geom_
    line() + geom_point() +
28   ylim(c(7.75,9.0)) +
29   labs(title = "Year V/S Real Hourly Wage Graph", x
    = "Year", y = "Real Hourly Wage")
```

Chapter 18

Time Series Analysis and Forecasting

R code Exa 18.1a Time Series Patterns

```
1                                     # Page no. : 786
                                     - 787
2
3 # Time Series Patterns
4
5 week <- c(1,2,3,4,5,6,7,8,9,10,11,12)
6 sales <- c(17,21,19,23,18,16,20,18,22,20,15,22)
7
8 DF <- data.frame(week,sales)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
18 ggplot(DF,aes(week,sales)) + geom_line() + geom_
```

```

19     point() + ylim(c(0,25)) + labs(title =
        "Week V/S Sales Time Series
        Plot", x = "Weeks", y = "
        Sales")

```

R code Exa 18.1b Time Series Patterns Eg2

```

1                                     # Page no. : 787
                                     - 788
2
3 # Time Series Patterns Eg-2
4
5 week <- c
    (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22)
6 sales <- c
    (17,21,19,23,18,16,20,18,22,20,15,22,31,34,31,33,28,32,30,29,34,30)
7
8 DF <- data.frame(week,sales)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
18 ggplot(DF,aes(week,sales)) + geom_line() + geom_
    point() + ylim(c(0,40)) +
19 labs(title = "Week V/S Sales Time Series Plot", x =
    "Weeks", y = "Sales")

```

R code Exa 18.1c Time Series Patterns Eg3

```
1                                     # Page no. :  
                                     788 – 789  
2  
3 # Time Series Patterns Eg-3  
4  
5 year <- c(1,2,3,4,5,6,7,8,9,10)  
6 sales <- c  
    (21.6,22.9,25.5,21.9,23.9,27.5,31.5,29.7,28.6,31.4)  
7  
8 DF <- data.frame(year,sales)  
9  
10 # Install Library if not installed  
11  
12 # install.packages("ggplot2")  
13  
14 # Import Library  
15  
16 library(ggplot2)  
17  
18 ggplot(DF,aes(year,sales)) + geom_line() + geom_  
    point() + ylim(c(20,34)) +  
19 labs(title = "Years V/S Sales Time Series Plot", x  
    = "Years", y = "Sales")
```

R code Exa 18.1d Time Series Patterns Eg4

```
1                                     # Page no. : 789  
                                     – 790  
2
```

```

3 # Time Series Patterns Eg-4
4
5 year <- c(1,2,3,4,5,6,7,8,9,10)
6 revenue <- c
      (23.1,21.3,27.4,34.6,33.8,43.2,59.5,64.4,74.2,99.3)

7
8 DF <- data.frame(year,revenue)
9
10 # Install Library if not installed
11
12 # install.packages("ggplot2")
13
14 # Import Library
15
16 library(ggplot2)
17
18 ggplot(DF,aes(year,revenue)) + geom_line() + geom_
      point() + ylim(c(0,120)) +
19   labs(title = "Years V/S Revenue Time Series Plot",
        x = "Years", y = "Revenue")

```

R code Exa 18.1e Time Series Patterns Eg5

```

1
2                                     # Page no. : 790
3                                     - 791
4
5 # Time Series Patterns Eg-5
6
7 year_quart <- c("Y1 Q1", "Y1 Q2", "Y1 Q3", "Y1 Q4",
      "Y2 Q1", "Y2 Q2", "Y2 Q3", "Y2 Q4", "Y3 Q1",
      "Y3 Q2", "Y3 Q3", "Y3 Q4", "Y4 Q1",
      "Y4 Q2", "Y4 Q3", "Y4 Q4", "Y5 Q1",
      "Y5 Q2",
      "Y5 Q3", "Y5 Q4") # Years and

```

```

                                Quarters
8  sales <- c(125, 153, 106, 88, 118, 161, 133, 102,
              138, 144, 113, 80, 109, 137, 125, 109, 130, 165,
9              128, 96)
10
11 DF <- data.frame(year_quart, sales)
12
13 # Install Library if not installed
14
15 # install.packages("ggplot2")
16
17 # Import Library
18
19 library(ggplot2)
20
21 ggplot(DF,aes(year_quart,sales, group = 1)) + geom_
    line() + geom_point() + ylim(c(0,180)) +
22   labs(title = "Years/quarter V/S Sales Time Series
    Plot", x = "Year/Quarter", y = "Sales")

```

R code Exa 18.1f Time Series Patterns Eg6

```

1                                                    # Page no. :
                                                    791 – 792
2
3 # Time Series Patterns Eg-6
4
5 year_quart <- c("Y1 Q1", "Y1 Q2", "Y1 Q3", "Y1 Q4",
                  "Y2 Q1", "Y2 Q2", "Y2 Q3", "Y2 Q4", "Y3 Q1",
6                  "Y3 Q2", "Y3 Q3", "Y3 Q4", "Y4 Q1",
                  "Y4 Q2", "Y4 Q3", "Y4 Q4")
7
8 sales <- c(4.8, 4.1, 6.0, 6.5, 5.8, 5.2, 6.8, 7.4,
            6.0, 5.6, 7.5, 7.8, 6.3, 5.9, 8.0, 8.4)
9

```

```

10 DF <- data.frame(year_quart, sales)
11
12 # Install Library if not installed
13
14 # install.packages("ggplot2")
15
16 # Import Library
17
18 library(ggplot2)
19
20 ggplot(DF,aes(year_quart,sales, group = 1)) + geom_
    line() + geom_point() + ylim(c(0.0,9.0)) +
21   labs(title = "Years/quarter V/S Sales Time Series
        Plot", x = "Year/Quarter", y = "Sales")

```

R code Exa 18.2a Forecast Accuracy

```

1                                     # Page no. :
                                     793 – 795
2
3 # Forecast Accuracy
4
5 week <- c(1,2,3,4,5,6,7,8,9,10,11,12)
6 sales <- c(17,21,19,23,18,16,20,18,22,20,15,22)
7 forecast <- c(NA,17,21,19,23,18,16,20,18,22,20,15)
8
9 DF <- data.frame(week,sales,forecast)
10
11 forecast_error <- DF$sales - DF$forecast
12
13 absolute_forecast_error <- abs(forecast_error)
14
15 square_absolute_forecast_error <- absolute_forecast_
    error**2
16

```

```

17 percent_error <- round((forecast_error / DF$sales) *
    100, 2)
18
19 absolute_percent_error <- abs(percent_error)
20
21 DF <- cbind(DF,forecast_error,absolute_forecast_error
    ,square_absolute_forecast_error,
22             percent_error,absolute_percent_error)
23
24 View(DF)
25
26 total_forecast_error <- sum(DF$forecast_error, na.rm =
    T)
27
28 total_absolute_forecast_error <- sum(DF$absolute_
    forecast_error, na.rm = T)
29
30 total_sq_abs_error <- sum(DF$square_absolute_forecast
    _error, na.rm = T)
31
32 total_percent_error <- sum(DF$percent_error, na.rm =
    T)
33
34 total_absolute_percent_error <- sum(DF$absolute_
    percent_error, na.rm = T)
35
36 # Native Value
37
38 MAE <- round(total_absolute_forecast_error / (nrow(DF
    )-1), 2) # Not including 1st row
39 # Mean Absolute Error
40
41 MSE <- round(total_sq_abs_error / (nrow(DF)-1), 2)
    # Not including 1st row
42 # Mean Square Error
43
44 MAPE <- round(total_absolute_percent_error / (nrow(
    DF)-1), 2) # Not including 1st row

```

```

45 # Mean Absolute Percent Error
46
47 cat(" Value of MAE is",MAE)
48 cat(" Value of MSE is",MSE)
49 cat(" Value of MAPE is",MAPE)
50
51 # Average of Past Values
52
53 forecast2 <- c(NA
               ,17.00,19.00,19.00,20.00,19.60,19.00,19.14,19.00,19.33,19.40,19.00)
54
55 DF2 <- data.frame(week,sales,forecast2)
56
57 forecast_error2 <- DF2$sales - DF2$forecast2
58
59 absolute_forecast_error2 <- abs(forecast_error2)
60
61 square_absolute_forecast_error2 <- absolute_forecast_
    error2**2
62
63 percent_error2 <- round((forecast_error2 / DF2$sales)
    * 100, 2)
64
65 absolute_percent_error2 <- abs(percent_error2)
66
67 DF2 <- cbind(DF2,forecast_error2,absolute_forecast_
    error2,square_absolute_forecast_error2,
68             percent_error2,absolute_percent_error2)
69
70 View(DF2)
71
72 total_forecast_error2 <- sum(DF2$forecast_error2, na.
    rm = T)
73
74 total_absolute_forecast_error2 <- sum(DF2$absolute_
    forecast_error2, na.rm = T)
75

```



```

76 total_sq_abs_error2 <- sum(DF2$square_absolute_
    forecast_error2, na.rm = T)
77
78 total_percent_error2 <- sum(DF2$percent_error2, na.
    rm = T)
79
80 total_absolute_percent_error2 <- sum(DF2$absolute_
    percent_error2, na.rm = T)
81
82 MAE2 <- round(total_absolute_forecast_error2 / (nrow(
    DF2)-1), 2) # Not including 1st row
83 # Mean Absolute Error
84
85 MSE2 <- round(total_sq_abs_error2 / (nrow(DF2)-1),
    2) # Not including 1st row
86 # Mean Square Error
87
88 MAPE2 <- round(total_absolute_percent_error2 / (nrow
    (DF2)-1), 2) # Not including 1st row
89 # Mean Absolute Percent Error
90
91 cat("Value of MAE is",MAE2)
92 cat("Value of MSE is",MSE2)
93 cat("Value of MAPE is",MAPE2)

```

R code Exa 18.3a Moving Averages

```

1                                     # Page no. : 798
                                     - 799
2
3 # Moving Averages
4
5 week <- c(1,2,3,4,5,6,7,8,9,10,11,12)
6 sales <- c(17,21,19,23,18,16,20,18,22,20,15,22)
7 forecast <- c(NA,NA,NA,19,21,20,19,18,18,20,20,19)

```

```

8
9 DF <- data.frame(week,sales,forecast)
10
11 forecast_error <- DF$sales - DF$forecast
12
13 absolute_forecast_error <- abs(forecast_error)
14
15 square_absolute_forecast_error <- absolute_forecast_
    error**2
16
17 percent_error <- round((forecast_error / DF$sales) *
    100, 2)
18
19 absolute_percent_error <- abs(percent_error)
20
21 DF <- cbind(DF,forecast_error,absolute_forecast_error
    ,square_absolute_forecast_error,
22             percent_error,absolute_percent_error)
23
24 View(DF)
25
26 # Install Library if not installed
27
28 # install.packages("ggplot2")
29
30 # Import Library
31
32 library(ggplot2)
33
34 ggplot(DF,aes(week)) + geom_line(aes(y = forecast),
    color = "red")+
35   geom_line(aes(y = sales), color = "blue") + geom_
    point(aes(y = forecast)) +
36   geom_point(aes(y = sales))+
37   ylim(c(0,25)) +
38   labs(title = "Week V/S Sales Time Series Plot", x
    = "Week", y = "Sales")

```

R code Exa 18.3b Exponential Smoothing

```
1                                     # Page no. : 802
                                     - 803
2
3 # Exponential Smoothing
4
5 week <- c(1,2,3,4,5,6,7,8,9,10,11,12)
6 sales <- c(17,21,19,23,18,16,20,18,22,20,15,22)
7 forecast <- c(NA,17.00,17.80, 18.04, 19.03, 18.83,
8               18.26, 18.61, 18.49, 19.19, 19.35, 18.48)
9 forecast_error <- sales - forecast
10 forecast_error_sq <- (forecast_error)**2
11
12 DF <- data.frame(week, sales, forecast, forecast_error
13                 , forecast_error_sq)
14
15 View(DF)
16
17 # Install Library if not installed
18
19 # install.packages("ggplot2")
20
21 # Import Library
22
23 library(ggplot2)
24
25 ggplot(DF,aes(week)) + geom_line(aes(y = forecast),
26                                   color = "red")+
27   geom_line(aes(y = sales), color = "blue") + geom_
28     point(aes(y = forecast)) +
29     geom_point(aes(y = sales))+
30     ylim(c(0,25)) +
31     labs(title = "Week V/S Sales Time Series Plot", x
```

```
= "Week", y = "Sales")
```

R code Exa 18.4a Trend Projection

```
1                                     # Page no. :  
                                     807 – 808  
2  
3 # Trend Projection  
4  
5 year <- c(1,2,3,4,5,6,7,8,9,10)  
6 sales <- c  
    (21.6,22.9,25.5,21.9,23.9,27.5,31.5,29.7,28.6,31.4)  
  
7  
8 DF <- data.frame(year,sales)  
9  
10 # Install Library if not installed  
11  
12 # install.packages("ggplot2")  
13  
14 # Import Library  
15  
16 library(ggplot2)  
17  
18 ggplot(DF,aes(year,sales)) + geom_line() + geom_  
    point() + ylim(c(20,34)) +  
19 labs(title = "Years V/S Sales Time Series Plot", x  
    = "Years", y = "Sales")  
20  
21 ggplot(DF,aes(year,sales)) + geom_line() + geom_  
    point() + ylim(c(20,34)) +  
22 geom_smooth(method = "lm", se = F) +  
23 labs(title = "Years V/S Sales Time Series and  
    Linear Function Plot", x = "Years", y = "Sales")
```

R code Exa 18.4b Trend Projection Part2

```
1                                     # Page no. : 809 –
                                     812
2
3 # Trend Projection Part-2
4
5 year <- c(1,2,3,4,5,6,7,8,9,10)
6 sales <- c
      (21.6,22.9,25.5,21.9,23.9,27.5,31.5,29.7,28.6,31.4)
7 forecast <- c
      (21.5,22.6,23.7,24.8,25.9,27.0,28.1,29.2,30.3,31.4)
8
9 DF <- data.frame(year,sales,forecast)
10
11 regressor <- lm(sales ~ year, data = DF)
12
13 cat("Linear Trend Equation is T =",regressor$
      coefficients[1],"+",regressor$coefficients[2], "t"
      )
14
15 res <- anova(regressor)
16
17 cat("MSE is ",res$'Sum Sq'[2]/10)
18
19 cat("MSE is ",res$'Mean Sq'[2])
20
21 regressor
22 res
23
24 # Install Library if not installed
25
```

```

26 # install.packages("ggplot2")
27
28 # Import Library
29
30 library(ggplot2)
31
32 ggplot(DF,aes(year,sales)) + geom_line() + geom_
    point() + ylim(c(20,34)) +
33   geom_smooth(method = "lm", se = F) +
34   labs(title = "Years V/S Sales Time Series Plot", x
        = "Years", y = "Sales")

```

R code Exa 18.4c Nonlinear Trend Regression

```

1                                     # Page no. : 814 –
                                     816
2
3 # Nonlinear Trend Regression
4
5 year <- c(1,2,3,4,5,6,7,8,9,10)
6 revenue <- c
    (23.1,21.3,27.4,34.6,33.8,43.2,59.5,64.4,74.2,99.3)
7
8 year_sq <- year**2
9
10 DF <- data.frame(year,revenue,year_sq)
11
12 # Install Library if not installed
13
14 # install.packages("gpplot2")
15
16 # Import Library
17
18 library(ggplot2)
19

```

```

19 ggplot(DF,aes(year,revenue)) + geom_line() + geom_
    point() + ylim(c(0,120)) +
20   labs(title = "Years V/S Revenue Time Series Plot",
        x = "Year", y = "Revenue")
21
22 regressor <- lm(revenue ~ year + year_sq, data = DF)
23 summary(regressor)
24 anova(regressor)
25
26 ggplot(DF,aes(year,revenue)) + geom_line() + geom_
    point() + ylim(c(0,120)) + geom_smooth(method =
27
    "
    lm
    "
    ,
    se
    =
    F
    )
    +

28   labs(title = "Years V/S Revenue Time Series Plot",
        x = "Year", y = "Revenue")

```

R code Exa 18.5a Seasonality Without Trend

```

1                                     # Page no. : 821
                                     - 822
2
3 # Seasonality Without Trend
4

```

```

5 year_quart <- c("Y1 Q1", "Y1 Q2", "Y1 Q3", "Y1 Q4",
  "Y2 Q1", "Y2 Q2", "Y2 Q3", "Y2 Q4", "Y3 Q1",
6      "Y3 Q2", "Y3 Q3", "Y3 Q4", "Y4 Q1",
      "Y4 Q2", "Y4 Q3", "Y4 Q4", "Y5 Q1",
      "Y5 Q2",
7      "Y5 Q3", "Y5 Q4") # Years and
      Quarters
8 sales <- c(125, 153, 106, 88, 118, 161, 133, 102,
  138, 144, 113, 80, 109, 137, 125, 109, 130, 165,
9      128, 96)
10
11 DF <- data.frame(year_quart, sales)
12
13 # Install Library if not installed
14
15 # install.packages("ggplot2")
16
17 # Import Library
18
19 library(ggplot2)
20
21 ggplot(DF,aes(year_quart,sales, group = 1)) + geom_
  line() + geom_point() + ylim(c(0,180)) +
22   labs(title = "Years/quart V/S Sales Time Series
      Plot", x = "Year/Quarter", y = "Sales")
23
24
25 q1 <- c(1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0)
26 q2 <- c(0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0)
27 q3 <- c(0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0)
28
29 DF <- cbind(DF,q1,q2,q3)
30
31 regressor <- lm(sales ~ q1 + q2 + q3, data = DF)
32 summary(regressor)
33
34 b0 <- regressor$coefficients[1]
35 b1 <- regressor$coefficients[2]

```



```

36 b2 <- regressor$coefficients[3]
37 b3 <- regressor$coefficients[4]
38
39 cat("Equation is sales = ",b0,"+",b1," Qtr1 +",b2,"
      Qtr2 +",b3," Qtr3")

```

R code Exa 18.5b Seasonality andTrend

```

1                                     # Page no. : 823 –
                                     824
2
3 # Seasonality and Trend
4
5 year_quart <- c("Y1 Q1", "Y1 Q2", "Y1 Q3", "Y1 Q4",
6               "Y2 Q1", "Y2 Q2", "Y2 Q3", "Y2 Q4", "Y3 Q1",
7               "Y3 Q2", "Y3 Q3", "Y3 Q4", "Y4 Q1",
8               "Y4 Q2", "Y4 Q3", "Y4 Q4")
9
10 # Years and Quarters
11 sales <- c(4.8, 4.1, 6.0, 6.5, 5.8, 5.2, 6.8, 7.4,
12           6.0, 5.6, 7.5, 7.8, 6.3, 5.9, 8.0, 8.4)
13
14 DF <- data.frame(year_quart, sales)
15
16 # Install Library if not installed
17
18 # install.packages("ggplot2")
19
20 # Import Library
21
22 library(ggplot2)
23
24 ggplot(DF,aes(year_quart,sales, group = 1)) + geom_
25   line() + geom_point() + ylim(c(0.0,9.0)) +
26   labs(title = "Years/quarter V/S Sales Time Series
27   Plot", x = "Year/Quarter", y = "Sales")

```

```

22
23 q1 <- c(1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0)
24 q2 <- c(0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0)
25 q3 <- c(0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0)
26 period <- c(1:16)
27
28 DF <- cbind(DF,q1,q2,q3,period)
29
30 regressor <- lm(sales ~ q1 + q2 + q3 + period, data
  = DF)
31 summary(regressor)
32
33 b0 <- regressor$coefficients[1]
34 b1 <- regressor$coefficients[2]
35 b2 <- regressor$coefficients[3]
36 b3 <- regressor$coefficients[4]
37 b4 <- regressor$coefficients[5]
38
39 cat("Equation is sales = ",b0,"+",b1,"Qtr1 +",b2,"
  Qtr2 +",b3,"Qtr3 +",b4,"t")

```

R code Exa 18.6a Time Series Decomposition

```

1                                     # Page no. :
                                     832 - 833
2
3 # Time Series Decomposition
4
5 year_quart <- c("Y1 Q1", "Y1 Q2", "Y1 Q3", "Y1 Q4",
  "Y2 Q1", "Y2 Q2", "Y2 Q3", "Y2 Q4", "Y3 Q1",
6               "Y3 Q2", "Y3 Q3", "Y3 Q4", "Y4 Q1",
  "Y4 Q2", "Y4 Q3", "Y4 Q4")
7 # Years and Quarters
8 sales <- c(4.8, 4.1, 6.0, 6.5, 5.8, 5.2, 6.8, 7.4,
  6.0, 5.6, 7.5, 7.8, 6.3, 5.9, 8.0, 8.4)

```

```

9 moving_avg <- c(NA
  ,5.350,5.600,5.875,6.075,6.300,6.350,6.450,6.625,6.725,6.800,6.875
10
  ,7.15,NA,NA)
11 centered_avg <- c(NA,NA
  ,5.475,5.738,5.975,6.188,6.325,6.400,6.538,6.675,6.763,6.838,6.938
12
  ,NA,NA)
13
14 DF <- data.frame(year_quart, sales, moving_avg,
  centered_avg)
15
16 # Install Library if not installed
17
18 # install.packages("ggplot2")
19
20 # Import Library
21
22 library(ggplot2)
23
24 ggplot(DF,aes(year_quart, group = 1)) + geom_line(
  aes(y = sales),color = "red") +
25   geom_point(aes(y = sales)) + geom_line(aes(y =
  centered_avg),color = "blue") +
26   geom_point(aes(y = centered_avg))+
27   ylim(c(0.0,9.0)) +
28   labs(title = "Years/quarter V/S Sales Time Series
  Plot", x = "Year/Quarter", y = "Sales")

```

R code Exa 18.6b Deseasonalizing the Time Series

```

1
2
3 # Deseasonalizing the Time Series

```

Page no. : 835 –
836

```

4
5 year_quart <- c("Y1 Q1", "Y1 Q2", "Y1 Q3", "Y1 Q4",
  "Y2 Q1", "Y2 Q2", "Y2 Q3", "Y2 Q4", "Y3 Q1",
6           "Y3 Q2", "Y3 Q3", "Y3 Q4", "Y4 Q1",
           "Y4 Q2", "Y4 Q3", "Y4 Q4")
7 # Years and Quarters
8 period <- c(1:16)
9 sales <- c(4.8, 4.1, 6.0, 6.5, 5.8, 5.2, 6.8, 7.4,
  6.0, 5.6, 7.5, 7.8, 6.3, 5.9, 8.0, 8.4)
10 index <- c
  (0.93,0.84,1.09,1.14,0.93,0.84,1.09,1.14,0.93,0.84,1.09,1.14,0.93
11 deseasonalized_sales <- c
  (5.16,4.88,5.50,5.70,6.24,6.19,6.24,6.49,6.45,6.67,6.88,6.84,6.77
12           7.02,7.34,7.37)
13
14 DF <- data.frame(year_quart,period,sales,index,
  deseasonalized_sales)
15
16 # Install Library if not installed
17
18 # install.packages("ggplot2")
19
20 # Import Library
21
22 library(ggplot2)
23
24 ggplot(DF,aes(year_quart,deseasonalized_sales, group
  = 1)) + geom_line() + geom_point() +
25   ylim(c(0.0,9.0)) +
26   labs(title = "Years/ quart V/S Deseasonalized Sales
  Time Series Plot", x = "Year/Quarter",
27         y = "Deseasonalized Sales")
28
29 regressor <- lm(deseasonalized_sales ~ period, data
  = DF)
30 summary(regressor)

```

```
31 anova(regressor)
32
33 b0 <- regressor$coefficients[1]
34 b1 <- regressor$coefficients[2]
35
36 cat("Equation is deseasonalized sales = ",b0,"+",b1,
      "Period")
```

Chapter 19

Non Parametric Tests

R code Exa 19.1a Rank Correlation

```
1                                     # Page no. : 887
                                     - 889
2
3 # Rank Correlation
4
5 sales_person <- c('A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I',
6                   ', 'J')
7 x <- c(2,4,7,1,6,3,10,9,8,5)      # Ranking of
   Potential
8 y <- c(400,360,300,295,280,350,200,260,220,385)  #
   Two Years Sales
9 z <- c(1,3,5,6,7,4,10,8,9,2)     # Ranking According
   to y
10 DF <- data.frame(sales_person,x,y,z)
11
12 d <- DF$x - DF$z
13 d_sq <- d**2
14
15 DF <- cbind(DF,d,d_sq)
16
```

```

17 total_d_sq <- sum(DF$d_sq)
18
19 n <- nrow(DF)
20
21 r_s <- 1 - ((6 * total_d_sq)/(n * (n**2 + 1))) #
      Spearman Rank-Correlation Coefficient
22
23 mean_rs <- 0
24
25 sigma_rs <- sqrt(1 / (n - 1))
26
27 z_val <- (r_s - mean_rs) / sigma_rs
28
29 alpha <- 0.05
30
31 # Two Tail Test
32
33 # P-value Approach
34
35 pval <- 2 * pnorm(z_val, lower.tail = F)
36
37 if(pval >= alpha)
38 {
39   cat("Since pval", pval, "is greater than or equal to
        0.05 therefore we cannot reject the Null
        Hypothesis")
40 } else{
41   cat("Since pval", pval, "is less than 0.05 therefore
        we can reject the Null Hypothesis")
42 }

```

R code Exa 19.2a Sign Test

1

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- 861

```

2
3 # Sign Test
4
5 store <- c(56, 19, 36, 128, 12, 63, 39, 84, 102, 44)
6 sales <- c(485, 562, 415, 860, 426, 474, 662, 380,
            515, 721)
7
8 DF <- data.frame(store, sales)
9
10 median <- 450
11 sign <- c()
12
13 for (i in 1:nrow(DF)) {
14   if(DF$sales[i] >= median)
15     {
16       sign[i] = "+"
17     }else
18     {
19       sign[i] <- "-"
20     }
21 }
22
23 DF <- cbind(DF, sign)
24 View(DF)
25
26 positive <- table(DF$sign)[[2]]
27 n <- nrow(DF)
28
29 test <- binom.test(positive, n)
30 test
31
32 if(test$p.value >= 0.05)
33 {
34   cat("We cannot reject null hypothesis")
35 } else
36 {
37   cat("We can reject null hypothesis")
38 }

```



```

39
40
41 N <- 60
42 n1 <- 22 # "+ sign
43 n2 <- 38 # "- sign
44 med <- 236000
45
46 mean <- 0.50 * N
47 sd <- sqrt(0.25 * N)
48
49 CF <- 22.5 # Correction Factor
50
51 p <- pnorm(CF, mean = mean, sd = sd)
52
53 if(p >= 0.05)
54 {
55   cat("We cannot reject null hypothesis")
56 } else
57 {
58   cat("We can reject null hypothesis")
59 }

```

R code Exa 19.3a Wilcoxon Signed Rank Test

```

1                                     # Page no. : 866 –
2                                     868
3 # Wilcoxon Signed – Rank Test
4
5 worker <- c(1:11)
6 A <- c(10.2, 9.6, 9.2, 10.6, 9.9, 10.2, 10.6, 10.0,
7       11.2, 10.7, 10.6)
8 B <- c(9.5, 9.8, 8.8, 10.1, 10.3, 9.3, 10.5, 10.0,
9       10.6, 10.2, 9.8)

```

```

9 DF <- data.frame(worker, A, B)
10
11 options(warn = -1)
12
13 test <- wilcox.test(DF$A, DF$B, paired = T)
14 test
15
16 if(test$p.value >= 0.05)
17 {
18   cat("We cannot reject null hypothesis")
19 } else
20 {
21   cat("We can reject null hypothesis")
22 }

```

R code Exa 19.4a Mann Whitney Wilcoxon Test

```

1                                     # Page no. : 873 -
                                     875
2
3 # Mann - Whitney - Wilcoxon - Test
4
5 college <- c(1:4)
6 m1 <- c(15,3,23,8)
7
8 high <- c(1:5)
9 m2 <- c(18,20,32,9,25)
10
11 test <- wilcox.test(m1, m2, correct = F)
12 test
13
14 if(test$p.value >= 0.05)
15 {
16   cat("We cannot reject null hypothesis")
17 } else

```

```

18 {
19   cat("We can reject null hypothesis")
20 }

```

R code Exa 19.4b Mann Whitney Wilcoxon Test Eg2

```

1                                     # Page no. :
                                     876-878
2
3 # Mann - Whitney - Wilcoxon - Test Eg - 2
4
5 account1 <- c(1:12)
6 account2 <- c(1:10)
7
8 balance1 <- c(1095, 955, 1200, 1195, 925, 950, 805,
9               945, 875, 1055, 1025, 975)
10 balance2 <- c(885, 850, 915, 950, 800, 750, 865,
11              1000, 1050, 935)
12
13 test <- wilcox.test(balance1, balance2, correct = F)
14 test
15
16 if(test$p.value >= 0.05)
17 {
18   cat("We cannot reject null hypothesis")
19 } else
20 {
21   cat("We can reject null hypothesis")
22 }

```

R code Exa 19.5a Kruskal Wallis Test

```
1                                     # Page no. : 883 –
2                                     884
3 # Kruskal – Wallis Test
4
5 A <- c(25, 70, 60, 85, 95, 90, 80)
6 B <- c(60, 20, 30, 15, 40, 35)
7 C <- c(50, 70, 60, 80, 90, 70, 75)
8
9 x <- list(A,B,C)
10
11 test <- kruskal.test(x)
12 test
13
14 if(test$p.value >= 0.05)
15 {
16   cat("We cannot reject null hypothesis")
17 } else
18 {
19   cat("We can reject null hypothesis")
20 }
```

Chapter 20

Statistical Process Control

R code Exa 20.1a Sample Mean Chart Process Mean and SD Unknown

```
1                                     # Page no. : 913 –
                                     919
2
3 # Sample Mean Chart : Process Mean and SD Unknown
4
5 o1 <- c(3.5056, 3.4882, 3.4897, 3.5153, 3.5059,
6         3.4977, 3.4910, 3.4991, 3.5099, 3.4880, 3.4881,
7         3.5043, 3.5043, 3.5004, 3.4846, 3.5145,
8         3.5004, 3.4959, 3.4878, 3.4969)
9 o2 <- c(3.5086, 3.5085, 3.4898, 3.5120, 3.5113,
10        3.4961, 3.4913, 3.4853, 3.5162, 3.5015, 3.4887,
11        3.4867, 3.4769, 3.5030, 3.4938, 3.4832,
12        3.5042, 3.4823, 3.4864, 3.5144)
13 o3 <- c(3.5144, 3.4884, 3.4995, 3.4989, 3.5011,
14        3.5050, 3.4976, 3.4830, 3.5228, 3.5094, 3.5141,
15        3.4946, 3.4944, 3.5082, 3.5065, 3.5188,
16        3.4954, 3.4964, 3.4960, 3.5053)
17 o4 <- c(3.5009, 3.5250, 3.5130, 3.4900, 3.4773,
18        3.5014, 3.4831, 3.5083, 3.4958, 3.5102, 3.5175,
19        3.5018, 3.5014, 3.5045, 3.5089, 3.4935,
20        3.5020, 3.5082, 3.5070, 3.4985)
```

```

13 o5 <- c(3.5030, 3.5031, 3.4969, 3.4837, 3.4801,
          3.5060, 3.5044, 3.5094, 3.5004, 3.5146, 3.4863,
14          3.4784, 3.4904, 3.5234, 3.5011, 3.4989,
          3.4889, 3.4871, 3.4984, 3.4885)
15
16 DF <- data.frame(o1, o2, o3, o4, o5)
17
18 sample_mean <- rowMeans(DF)
19 sample_range <- c(0.0135, 0.0368, 0.0233, 0.0316,
                    0.0340, 0.0099, 0.0213, 0.0264, 0.0270, 0.0266,
20                    0.0312, 0.0259, 0.0274, 0.0230,
                    0.0243, 0.0356, 0.0153, 0.0259,
                    0.0206, 0.0259)
21
22 DF <- cbind(DF, sample_mean, sample_range)
23 View(DF)
24
25 AR <- mean(DF$sample_range) # Average Range
26 OM <- mean(DF$sample_mean) # Overall Mean
27 n <- 5 # Sample Observations
28 d2 <- 2.362
29 A2 <- 3 / (d2 * sqrt(n))
30
31 UCL <- OM + (A2 * AR) # Upper Control Limit
32 LCL <- OM - (A2 * AR) # Lower Control Limit
33
34 cat("UCL is ", UCL)
35 cat("LCL is ", LCL)
36
37 library(qicharts2)
38
39 qic(DF$sample_mean, xlab = "Sample Number", ylab = "
    Sample Mean", title = "Sample Mean Chart")
40
41 d3 <- 0.864
42
43 D1 <- 1 + (3 * (d3 / d2))
44 D2 <- 1 - (3 * (d3 / d2))

```

```

45
46 UCL2 <- AR * D1
47 LCL2 <- AR * D2
48
49 cat("UCL is ",UCL2)
50 cat("LCL is",LCL2)    # Book answer is different
51
52 qic(DF$sample_range, xlab = "Sample Number", ylab =
    "Sample Range", title = "R Chart")
53
54 p <- 0.03
55 n <- 200
56
57 sigma <- sqrt((p * (1 - p)) / n)
58
59 UCL3 <- p + 3 * sigma
60 LCL3 <- p - 3 * sigma
61
62 cat("UCL is ",UCL3)
63 cat("LCL is",LCL3)
64
65 # Data for P chart is not available in Book
66
67 UCL4 <- n * p + 3 * sqrt(n * p * (1 - p))
68 LCL4 <- n * p - 3 * sqrt(n * p * (1 - p))
69
70 cat("UCL is ",UCL4)
71 cat("LCL is",LCL4)

```

Chapter 21

Decision Analysis

R code Exa 21.1a Problem Formulation

```
1                                     # Page no. :  
                                     940 – 941  
2  
3 # Problem Formulation  
4  
5 decision <- factor(c("Small Complex, d1", "Medium  
   Complex, d2", "Large Complex, d3"))  
6 demand1 <- c(8, 14, 20)  
7 demand2 <- c(7, 5, -9)  
8  
9 DF <- data.frame(decision, demand1, demand2)  
10  
11 # Install Library if not install  
12  
13 install.packages("rpart")  
14 install.packages("rpart.plot")  
15  
16 # Import Library  
17  
18 library(rpart)  
19 library(rpart.plot)
```



```
20
21 ans <- rpart(decision ~ ., data = DF, method = "
    class" )
22 rpart.plot(ans)
23
24 # Decision Tree is Different from Book
```
