R Textbook Companion for Introduction to Probability and Statistics for Engineers and Scientists by Sheldon M. Ross[1]

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Book Description

Title: Introduction to Probability and Statistics for Engineers and Scientists

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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.

Contents

List of R Codes

Chapter 2

Descriptive Statistics

R code Exa 2.2.a Relative Frequency

```
starting_salary<-c(47, 48, 49 ,50 ,51, 52, 53, 54, 56, 57, 60)
frequency <-c(4, 1 ,3 ,5 ,8 ,10, 0 ,5 ,2, 3, 1)
total = sum(frequency)
relative_frequency = frequency/total
cat("The relative frequencies are ",relative_frequency)
```

R code Exa 2.2.b Pie Chart

```
slices<-c(42, 50, 32, 55, 9 ,12)
lbls<-c("Lung ", "Breast ", "Colon ", "Prostate ", "Melanoma ", "Bladder ")
pct <- round(slices/sum(slices)*100)
lbls <- paste(lbls, pct) # add percents to labels
lbls <- paste(lbls,"%",sep="") # ad % to labels
pie(slices,labels = lbls, col=rainbow(length(lbls)), main="Pie Chart")
```

R code Exa 2.3.a Sample mean

```
scores<-c(284, 280, 277, 282, 279, 285, 281, 283,
    278, 277)
new_scores=(scores - 280)
final_mean = mean(new_scores)+ 280
cat("Final Mean = ", final_mean)
```

R code Exa 2.3.b Sample mean of age

```
age<-c(15, 16, 17, 18, 19, 20)
frequencies<-c(2, 5, 11, 9 ,14, 13)
product  = age*frequencies
total_people = sum(frequencies)
mean_age = sum(product)/total_people
cat("The sample mean of the ages is",mean_age)
```

R code Exa 2.3.c Sample Median

```
age<-c(15, 16, 17, 18, 19, 20)
frequencies<-c(2, 5, 11, 9 ,14 ,13)
final_age = matrix(0,1,length(age))
i=1
for (j in 1:6){
  for (k in 1:frequencies[j]){
    final_age[i] = age[j]
    i = i +1
  }
}
```

```
final_median = median(final_age)
final_median
```

R code Exa 2.3.d Mean and Median

```
germ_free_mice<-c(158, 192, 193, 194, 195, 202, 212,
    215, 229, 230, 237, 240, 244, 247, 259, 301,
   301, 321, 337, 415 ,434 ,444 ,485 ,496 ,529 ,537,
    624, 707 ,800)
conventional_mice<-c(159, 189, 191, 198, 235 ,245,
   250, 256, 261, 265, 266 ,280 ,343 ,356, 383, 403,
    414 ,428 ,432)
cat("Sample mean for germ-free mice is ",mean(germ_
   free_mice))
cat("Sample median for germ-free mice is ",median(
   germ_free_mice))
cat("Sample mean for conventional mice is ",mean(
   conventional_mice))
cat("Sample mean for conventional mice is ",median(
   conventional_mice))
```

R code Exa 2.3.e Mean Median and Mode

```
value<-c(1, 2, 3, 4, 5, 6)
frequencies<-c(9, 8 ,5 ,5, 6 ,7)
final_value = matrix(0,1,length(value))
i=1
for (j in 1:6){
  for (k in 1:frequencies[j]){
    final_value[i] = value[j]
    i = i +1
  }
}
```

```
product  = value*frequencies;
product
sum(product)

total_value = sum(frequencies);
mean_value = sum(product)/total_value #the answer in the textbook is incorrect
which(frequencies==max(frequencies))
m1= max(frequencies);
n= which(frequencies==max(frequencies))

cat("The sample mean is",mean_value)
cat("The median is",median(final_value))
cat("The mode is",value[n])
```

R code Exa 2.3.f sample variance

```
A <-c(3, 4, 6, 7, 10)
B <-c(-20, 5 ,15 ,24)
cat("The sample variance of A is",var(A))
cat("The sample variance of B is",var(B))
```

R code Exa 2.3.g sample variance of accidents

```
accidents<-c(22, 22, 26, 28, 27, 25 ,30, 29, 24)
new_accidents = accidents - 22
cat("The variance of the number of accidents is",var(new_accidents))
```

R code Exa 2.3.h Percentile

```
population<-c(7333253, 3448613, 2731743, 1702086,
   1524249, 1151977, 1048949 ,1022830 ,998905,
   992038, 816884, 752279, 734676, 702979, 665070,
   635913, 617044 ,614289 ,579307, 567094, 547727
   ,520947 ,514013, 504505, 493559)
cat("The sample 10 percentile is",quantile(
   population, .10))
cat("The sample 50 percentile is",quantile(
   population, .50))
cat("The sample 80 percentile is",quantile(
   population, .80))
cat("The median is",median(population))
```

R code Exa 2.3.i Quartiles

```
noise<-c(82, 89, 94, 110, 74,  122, 112, 95, 100,
   78, 65, 60, 90 ,83 ,87 ,75 ,114 ,85 ,69 ,94 ,124
   ,115 ,107 ,88  ,97 ,74 ,72 ,68 ,83 ,91 ,90 ,102,
   77, 125, 108 ,65)
cat("The quartiles are",quantile(noise))
```

R code Exa 2.4.a Chebyshev Inequality

```
cars<-c(448162, 404192, 368327, 318308, 272122,
   260486, 249128, 234936, 218540, 207977)
interval1 = mean(cars) - (1.5*sd(cars));
interval2 = mean(cars) + (1.5*sd(cars));
data = 100*5/9;
cat("Atleast 55.55% of the data lies in the interval
   ",interval1 ,"to",interval2)
```

R code Exa 2.5.a Empirical Rule

```
data<-c(90, 91 ,94 ,83 ,85 ,85 ,87 ,88 ,72, 74, 74,
   75, 77, 77, 78, 60, 62 ,63, 64, 66, 66, 52 ,55
   ,55 ,56 ,58 ,43, 46)
cat("According to the empirical rule 68% of the data
    lies between",mean(data)-sd(data),"and",mean(
   data)+sd(data))
cat("95% of the data lies between",mean(data)-(2*sd(
   data)),"and",mean(data)+(2*sd(data)))
cat("99.7% of the data lies between", mean(data)-(3*
   sd(data)),"and",mean(data)+(3*sd(data)))
```

R code Exa 2.6.a Sample Correlation Coefficient

```
temp<-c(24.2, 22.7 ,30.5, 28.6, 25.5, 32.0, 28.6,
   26.5, 25.3, 26.0, 24.4 ,24.8 ,20.6, 25.1, 21.4,
   23.7, 23.9, 25.2, 27.4, 28.3 ,28.8 ,26.6)
defects<-c(25, 31 ,36 ,33 ,19 ,24 ,27 ,25 ,16 ,14
   ,22 ,23 ,20 ,25 ,25 ,23 ,27 ,30 ,33 ,32 ,35, 24)
temp_new = temp- mean(temp)
defects_new = defects - mean(defects)
num=0
s1 =0;
s2=0;
for (i in 1:22){
  num = num + (temp_new[i]*defects_new[i])
  s1 = s1 + (temp_new[i]*temp_new[i])
  s2 = s2 + (defects_new[i]*defects_new[i])
}
coefficient = num/sqrt(s1*s2)
coefficient
```

R code Exa 2.6.b Sample Correlation Coefficient

```r
year<-c(12, 16, 13, 18, 19 ,12, 18, 19, 12, 14)
pulserate<-c(73, 67, 74, 63 ,73 ,84 ,60 ,62, 76, 71)
year_new = year- mean(year)
pulserate_new = pulserate - mean(pulserate)
num=0
s1 =0
s2=0
for (i in 1:10){
  num = num + (year_new[i]*pulserate_new[i])
  s1 = s1 + (year_new[i]*year_new[i])
  s2 = s2 + (pulserate_new[i]*pulserate_new[i])
}
coefficient = num/sqrt(s1*s2)
coefficient
```

Chapter 3

Elements Of Probability

R code Exa 3.4.a Union

```
cigarette = 0.28;
cigar = 0.07;
cigar_and_cigarette = 0.05 ;
cigar_or_cigarette = cigarette + cigar - cigar_and_
    cigarette;
cat((1-cigar_or_cigarette)*100 ,"% of the males
    smoke neither cigar nor cigarette")
```

R code Exa 3.5.a Basic Principle of Counting

```
white_balls= 6;
black_balls = 5;
total = white_balls + black_balls;
probability_whiteandblack = white_balls*black_balls/
    (total*(total-1));
probability_blackandwhite = white_balls*black_balls/
    (total*(total-1));
reqd_probability = probability_whiteandblack +
    probability_blackandwhite;
```

```
cat("Thus, the required probability is",reqd_probability)
```

R code Exa 3.5.b Basic Principle of Counting

```
maths = 4;
chemistry = 3;
history = 2;
language = 1;
total_arrangements = factorial(4)*factorial(maths)*factorial(chemistry)*factorial(history)*factorial(language);
cat("The total number of possible arrangements is ",total_arrangements)
```

R code Exa 3.5.c Basic Principle of Counting

```
men = 6;
women = 4;
cat("No of different rankings possible is",factorial(men+women))
women_top4 = factorial(women)*factorial(men);
prob = women_top4/factorial(men+women);
cat("Probability that women receive the top 4 scores is",prob)
```

R code Exa 3.5.d Committee Probability

```
men = 6;
women = 9;
```

```
reqd_size =5;
total =factorial(men+women)/(factorial(reqd_size)*
   factorial(men+women-reqd_size));
given_committee = factorial(men)*factorial(women)/(
   factorial(3)*factorial(2)*factorial(men-3)*
   factorial(women-2));
prob = given_committee/total;
cat("Probability that the committee consists of 3
   men and 2 women is",prob)
```

R code Exa 3.5.f Pairing Probability

```
black_p = 6;
white_p = 6;
pair = 2;
total_p = black_p + white_p;

total_pairs  = 1;
while(total_p >0){
  total_pairs = total_pairs*factorial(total_p)/(
     factorial(pair) * factorial(total_p - pair) )
  total_p = total_p -2
}
total_pairs= total_pairs/factorial(6);
black_pairs  = 1;
while(black_p >0){
  black_pairs = black_pairs*factorial(black_p)/((
     factorial(pair) * factorial(black_p - pair) ))
  black_p = black_p -2
}
black_pairs= black_pairs/factorial(3);
white_pairs = black_pairs;
allowed_pairs = black_pairs * white_pairs;
probb = allowed_pairs/ total_pairs;
cat(" Probability that a random pairing will not
```

```
    result in any of the white and black players
    rooming together is ",probb)
```

R code Exa 3.6.a Acceptable Transistor

```
defective =5;
partially_defective = 10;
acceptable = 25;
cat("The required probability is",acceptable/(
    acceptable+partially_defective))
```

R code Exa 3.6.b Both Boys

```
prob_bb = 0.25;
prob_bg = 0.25;
prob_gb = 0.25;
prob_gg = 0.25;
cat("Probability that both are boys is",prob_bb/(
    prob_bg+prob_gb+prob_bb))
```

R code Exa 3.6.c Branch Manager

```
prob_phoenix = 0.3;
prob_manager = 0.6;
cat("Probability that Perez will be a Phoenix branch
     office manager is",prob_phoenix*prob_manager)
```

R code Exa 3.7.a Accident Probability

```
accident_prone= 0.4;
nonaccident_prone= 0.2;
pop_accident = 0.3;
prob = pop_accident*accident_prone + (1-pop_accident)*nonaccident_prone;
cat("The required probability is ",prob)
```

R code Exa 3.7.b Accident within a year

```
accident_prone= 0.4;
nonaccident_prone= 0.2;
pop_accident = 0.3;
prob_of_accident = pop_accident*accident_prone + (1-pop_accident)*nonaccident_prone;
prob = pop_accident * accident_prone /prob_of_accident;
cat("The required probability is",prob)
```

R code Exa 3.7.c Multiple Choice Test

```
m = 5;
p =1/2;
cat("The required probability is", (m*p)/(1+((m-1)*p)))
```

R code Exa 3.7.d blood test

```
detect_present = 0.99;
```

```
detect_notpresent = 0.01;
pop_disease = 0.005;
prob = detect_present*pop_disease/((detect_present*
   pop_disease) +(detect_notpresent*(1-pop_disease))
    ) ;
cat("The required probability is",prob)
```

R code Exa 3.7.e Criminal Investigation

```
criminal_char = 0.9
convinced= 0.6;
pop_char = 0.2;
prob = (convinced*criminal_char) /((convinced*
   criminal_char) + (pop_char*(1-convinced)));
cat("The required probability is",prob)
```

R code Exa 3.7.f Missing Plane

```
alpha1 = 0.4;
plane_in_region1 = 1/3;
plane_in_region2 = 1/3;
plane_in_region3 = 1/3;
prob1 = (alpha1*plane_in_region1)/((alpha1*plane_in_
   region1)+ 1*plane_in_region2 + 1*plane_in_region3
   );
prob2 = (1*plane_in_region2)/((alpha1*plane_in_
   region1)+ 1*plane_in_region2 + 1*plane_in_region3
   );
cat("The probability that the planes is in region 1
   given that the search of region 1 did not uncover
    it ",prob1)
```

```
cat("The probability that the planes is in region 2/3 given that the search of region 1 did not uncover it ",prob2)
```

R code Exa 3.8.a Independent Events

```
prob_A = 4/52;
prob_H = 13/52;
cat("P(AH) is",prob_A*prob_H)
```

Chapter 4

Random Variables And Expectation

R code Exa 4.1.a sum of two fair dice

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)

#First we set up the sample space with the rolldie function
S <- rolldie(2, makespace = TRUE)
#Next, we add random variables U and V with the addrv function.
S <- addrv(S, FUN = max, invars = c("X1", "X2"), name = "U")
S <- addrv(S, FUN = sum, invars = c("X1", "X2"), name = "V")
head(S)
UV <- marginal(S, vars = c("U", "V"))
xtabs(round(probs, 3) ~ U + V, data = UV)
```

```
marginal(UV, vars = "U")
marginal(UV, vars = "V")

temp <- xtabs(probs ~ U + V, data = UV)
rowSums(temp)
colSums(temp)
colSums(temp)

'
data = sample(1:6,10000000,replace=TRUE)+sample
    (1:6,10000000,replace=TRUE)
table(data)/length(data)
sum(table(data)/length(data))

table(sample(1:6,10000000,replace=TRUE))/length(
    sample(1:6,10000000,replace=TRUE))
'
```

R code Exa 4.1.c X exceeds 1

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)

"
F(x) = 0 -- { x <= 0}
F(x) = 1 - exp(-x^2) -- {x >0}

P{X>1} = ?
"
P = 1 - (1 - exp(-(1^2)))
P
```

R code Exa 4.2.a sum of pmf

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)

P1 = 1/2
P2 = 1/3
P3 = 1 - P1 - P2
P3
```

R code Exa 4.2.b pdf

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)


integrand <- function(x) {(4*(x) - 2*(x^2))}
R = integrate(integrand,lower = 0,upper = 2)
C = 1/R$value
C

# P {X>1}
integrand <- function(x) {C*(4*(x) - 2*(x^2))}
```

```
P = integrate(integrand,lower = 1,upper = 2)
P
```

R code Exa 4.3.a Joint distribution of batteries

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)


p_0_0 = (length(combn(5, 3))/3)/(length(combn(12, 3)
    )/3)
p_0_1 = (length(combn(4, 1))/1)*(length(combn(5, 2))
    /2)/(length(combn(12, 3))/3)
p_0_1 = (length(combn(4, 2))/2)*(length(combn(5, 1))
    /1)/(length(combn(12, 3))/3)
p_0_3 = (length(combn(4, 3))/3)/(length(combn(12, 3)
    )/3)
p_1_0 = (length(combn(3, 1))/1)*(length(combn(5, 2))
    /2)/(length(combn(12, 3))/3)
p_1_1 = (length(combn(3, 1))/1)*(length(combn(4, 1))
    /1)*(length(combn(5, 1))/1)/(length(combn(12, 3))
    /3)
p_1_2 = (length(combn(3, 1))/1)*(length(combn(4, 2))
    /2)/(length(combn(12, 3))/3)
p_2_0 = (length(combn(3, 2))/2)*(length(combn(5, 1))
    /1)/(length(combn(12, 3))/3)
p_2_1 = (length(combn(3, 2))/2)*(length(combn(4, 1))
    /1)/(length(combn(12, 3))/3)
p_3_0 = (length(combn(3, 3))/3)/(length(combn(12, 3)
```

```
)/3)
```

R code Exa 4.3.b Joint distribution of boys and girls

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
'
library(discreteRV)
d<-RV(c("Boy","Girl"),odds=c(0.5,0.5))
e<-RV(c("0","1","2","3"),odds = c
    (0.15,0.20,0.35,0.3))
f<-joint(d,e)
probs(f)
'

#P{B=0,G=0} = P{no children}
P = .15
P
#P{B=0,G=1} = P{1 Girl and total of 1 child}  = P{1
    child} P{1 girl | 1 child}
P = .20 * (1/2)
P
#P{B=0,G=2} = P{2 Girls and total of 2 children}  =
    P{2 children} P{2 girls | 2 children}
P = .35*(1/2)^2
P
#P{B=0,G=3} = P{3 Girls and total of 3 children}  =
    P{3 children} P{3 girls | 3 children}
```

```
P = .3*(1/2)^3
P
#P{B=1,G=0} = P{1 Boy and total of 1 child}  = P{1
    child} P{1 boy | 1 child}
P = .2*(1/2)
P
#P{B=1,G=1} = P{1 Boy, 1Girl and total of 2 children
    }  = P{2 children} P{1 boy | 2 children}
P = .35*.5
#P = .35*((1/2)^2+(1/2)^2)
P
#P{B=1,G=2} = P{1 Boy, 2Girls and total of 3
    children}  = P{2 children} P{2 Girls | 2 children
     + 1 boy|1 child}
P = .3*((1/2)^3+(1/2)^2)
P
```

R code Exa 4.3.c Joint Density Function

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)
#1
fun0 = function(x,y,z) { exp(-x)*exp(-2*y)*z }
fun01 <- function(z) {
  integrate(function(y) {
    sapply(y, function(y) {
```

```
      integrate(function(x) fun0(x,y,z), 1, Inf)$value
    })
  }, 0, 1)$value
}

fun01(2)
#(1-exp(-2))*exp(-1)

#2
fun0 = function(x,y,z) { exp(-x)*exp(-2*y)*z }
fun01 <- function(z) {
  integrate(function(y) {
    sapply(y, function(y) {
      integrate(function(x) fun0(x,y,z), 0, y)$value
    })
  }, 0, Inf)$value
}

fun01(2)


'
library(cubature)
f <-function(x) 2*exp(-x[1])*exp(-2*x[2])
adaptIntegrate(f,lowerLimit = c(1,0),upperLimit = c(Inf,1))

require(pracma)
f <- function(x, y) 2*exp(-x)*exp(-2*y)
quad2d(f, 0, 1, 1, Inf)

http://stackoverflow.com/questions/23901682/double-integration-in-r-with-additional-argument
'
```

R code Exa 4.3.d Density of Independent Random Variables

```
#install.packages("IPSUR")
#install.packages("prob")
#install.packages("discreteRV")
#install.packages("pracma")
#install.packages("cubature")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)

fun0 = function(x,y,a) { exp(-x)*exp(-y) }
fun01 <- function(z) {
  integrate(function(y) {
    sapply(y, function(y) {
      integrate(function(x) fun0(x,y,z), 0, a*y)$
         value
    })
  }, 0, Inf)$value
}

fun01(1)
fun01(2)
```

R code Exa 4.3.e Density of Independent Random Variables

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)

#P{X1 = 1,X2 = 2, X3 = 0}
P = 0.20*0.10*0.30
```

R code Exa 4.3.f Conditional Probability Mass Function

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)

#P{G=1} = 0.3875
C = 0.3875
#P{B=0|G=1}=((P{B=0,G=1})/(P{G=1}))
P = 0.1/C
P
#P{B=1|G=1}
```

```
P   = .175/C
P
#P{B=2|G=1}
P = .1125/C
P
#P{B=3|G=1}
P = 0
P
```

R code Exa 4.3.g Conditional Probability Mass Function

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)

#P(0,0)
P_0_0 = .4
#P(0,1)
P_0_1 = .2
#P(1,0)
P_1_0 = .1
#P(1,1)
P_1_1 = .3

#P{Y = 1}   = P(0,1) + #P(1,1)
P_Y = P_0_1 + P_1_1

```

```
#P{X = 0|Y=1} = P(0,1)/P{Y=1}
P1 = P_0_1 / P_Y
P1

#P{X = 1|Y=1} = P(1,1)/P{Y=1}
P2 = P_1_1 / P_Y
P2
```

R code Exa 4.4.a Expectation of a fair die

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


S <- rolldie(1, makespace = TRUE)
Ex = sum(S$X1*S$probs)
Ex
```

R code Exa 4.4.d Expectation of the message time

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
```

```
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


integrand <- function(x) {x / 1.5}
R = integrate(integrand,lower = 0,upper = 1.5)
R
```

R code Exa 4.5.a Expectation

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


# P {X}
PY0 = .2
PY1 = .5
PY2 = .3
# E[X^2] = E[Y] = Y0 * PY0 + Y1 * PY1 + Y2 * PY0
E = 0 * PY0 + 1 * PY1 + 4 * PY2
E
```

R code Exa 4.5.b Expected cost of breakdown

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


integrand <- function(x) {x*(1/3)*(x^(-2/3))}
R = integrate(integrand,lower = 0,upper = 1)
```

R code Exa 4.5.c Expectation

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)
```

```
# P {X}
P0 = .2
P1 = .5
P2 = .3
# E[X^2] = X0^2*P0 + X1^2*P1 + X2^2*P2
E = (0^2)*P0 + (1^2)*P1 + (2^2)*P2
E
```

R code Exa 4.5.d Expectation

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


integrand <- function(x) {x^(3)}
R = integrate(integrand,lower = 0,upper = 1)
```

R code Exa 4.5.e Expected profit

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
```

```
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


profits <-c(10,20,40)
probs <- c(.2,.8,.3)
E1 = profits[1]*probs[1]+0*(1-probs[1])
E2 = profits[2]*probs[2]+0*(1-probs[2])
E3 = profits[3]*probs[3]+0*(1-probs[3])
E = E1 + E2 + E3
E
```

R code Exa 4.5.g Different types of coupons

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


EX = 20 * (1 - (19/20)^10)
EX
```

R code Exa 4.6.a Variance of a fair die

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


S <- rolldie(1, makespace = TRUE)
Ex = sum(S$X1*S$probs)
Ex2 = sum((S$X1)^2*S$probs)
Ex2
Varx = Ex2 - (Ex)^2
Varx
```

R code Exa 4.7.a Variance of 10 rolls of a fair die

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
```

```r
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)

S <- rolldie(1, makespace = TRUE)
Ex = sum(S$X1*S$probs)
Ex2 = sum((S$X1)^2*S$probs)
Ex2
Varx = Ex2 - (Ex)^2
Varx
Varx10 = 10 * Varx
Varx10
```

R code Exa 4.7.b Variance of 10 tosses of a coin

```r
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)

Var = .5 * (1 - .5)
Var

Var10 = 10 * Var
Var10
```

R code Exa 4.9.a Inequalities

```
#install.packages("IPSUR")
#install.packages("prob")
library(IPSUR)
#read(IPSUR)
library(prob)
#read(prob)
#install.packages("combinat")
library(combinat)
library(discreteRV)
require(pracma)
library(cubature)


# Markov
# P {X > 75}
meanX = 50
P = meanX / 75
P

#Chebyshev
# P {|X - 50| > = 10 } < = (SigmaX^2 / 10^2)
VarX = 25
P = 1 - (VarX / 10^2)
P
```

Chapter 5

Special Random Variables

R code Exa 5.1.a Returning of disks

```
#Probability that the package will have to be replaced
library(IPSUR)
P = 1 - choose(10,0)*(0.01)^0*(0.99)^10-choose(10,1)*(0.01)^1*(0.99)^9
P
#Probability that exactly one of the three packages will be returned
PP = choose(3,1)*P*(1-P)^2
PP
```

R code Exa 5.1.b Colour of Eyes

```
library(IPSUR)
#The probability that a child recieves the blue eyed gene from both parents
Pblue = (1/2)*(1/2)
Pblue
```

```
#the probability that exactly two of them have blue eye color
P = choose(4,2)*(1/4)^2*(3/4)^2
P
```

R code Exa 5.1.e Binomial Random Variable

```
library(IPSUR)
install.packages("binom")
library(binom)
pbinom(q = 0, size = 6,prob = 0.4)
pbinom(q = 1, size = 6,prob = 0.4) - pbinom(q = 0, size = 6,prob = 0.4)
pbinom(q = 2, size = 6,prob = 0.4) - pbinom(q = 1, size = 6,prob = 0.4)
pbinom(q = 3, size = 6,prob = 0.4) - pbinom(q = 2, size = 6,prob = 0.4)
pbinom(q = 4, size = 6,prob = 0.4) - pbinom(q = 3, size = 6,prob = 0.4)
pbinom(q = 5, size = 6,prob = 0.4) - pbinom(q = 4, size = 6,prob = 0.4)
pbinom(q = 6, size = 6,prob = 0.4) - pbinom(q = 5, size = 6,prob = 0.4)
```

R code Exa 5.1.f Binomial Distribution

```
pbinom(q = 70, size = 100,prob = 0.75) - pbinom(q = 69, size = 100,prob = 0.75)
pbinom(q = 70, size = 100,prob = 0.75)
```

R code Exa 5.2.a Probability of accident

```
#P{X>=1} = 1 - P{X = 0}
1-ppois(0,3)
#Or
1-dpois(0,3)
```

R code Exa 5.2.b Defective Items

```
ppois(1,1)
```

R code Exa 5.2.c Number of Alpha particles

```
ppois(2,3.2)
```

R code Exa 5.2.d Claims handled by an insurance company

```
#Proportion of days have less than 3 claims
ppois(2,5)

dpois(4,lambda = 5)

#the probability that 3 of the next 5 days will have
    claims is
library(IPSUR)
choose(5,3) *(dpois(4,lambda = 5))^3 *(1-dpois(4,
  lambda = 5))^2
```

R code Exa 5.2.f Defective stereos

```
i<-seq(0, 3, 1)
sum(dpois(i,8))
```

R code Exa 5.3.a Functional system

```
dhyper(4, m = 15, n = 5, k = 6)+dhyper(5, m = 15, n
   = 5, k = 6)+dhyper(6, m = 15, n = 5, k = 6)
```

R code Exa 5.3.b Determining Population Size

```
hyper <- function(N, M, n, i) {
  factorial(N)*factorial(M)*factorial(n)*factorial(N
     +M-n)/(factorial(i)*factorial(N-i)*factorial(n-
     i)*factorial(M-n+i)*factorial(N+M))
}

r= 50
n=100
X=25
cat("Estimate of the number of animals in the region
    is",r*n/X)
```

R code Exa 5.3.c Conditional Probability

```
bino <- function(n, k, p) {
  factorial(n)*(p^k)*((1-p)^(n-k))/(factorial(k)*
     factorial(n-k))
}
```

```

condprob <- function(n,k,p,i) {
  bino(n,i,p)*bino(m,k-i,p)/bino(n+m,k, p);
}

#The function condprob will give P{X=i|X+Y=k}
```

R code Exa 5.4.a Probabilities of a uniform random variable

```
beta = 10
alpha = 0
#a
a = 2
b = 9
(b-a)/(beta-alpha)
#b
a = 1
b = 4
(b-a)/(beta-alpha)
#c
a = 0
b = 5
(b-a)/(beta-alpha)
#d
a = 6
b = 10
(b-a)/(beta-alpha)
```

R code Exa 5.4.b Bus Timings

```
beta = 30
alpha = 0
#a
```

```
a1 = 10
b1 = 15
a2 = 25
b2 = 30
(b1-a1)/(beta-alpha)+(b2-a2)/(beta-alpha)

#b
a1 = 0
b1 = 3
a2 = 15
b2 = 18
(b1-a1)/(beta-alpha)+(b2-a2)/(beta-alpha)
```

R code Exa 5.4.c Current in a diode

```
I0 = 10^-6
a = 5
integrand <- function(x) {0.5*exp(a*x)}
R = integrate(integrand,lower = 1,upper = 3)
(I0*R$value)-I0
```

R code Exa 5.5.a Normal Random Variable

```
#a
pnorm(11,3,sqrt(16))
#b
1-pnorm(-1,3,sqrt(16))
#c
pnorm(7,3,sqrt(16))-pnorm(2,3,sqrt(16))
```

R code Exa 5.5.b Noise in Binary Message

```
#a
pnorm(-1.5)
#b
1-pnorm(2.5)
```

R code Exa 5.5.c Power dissipation

```
mu = 6
sigma = 1
#a
E = 3*(mu^2+sigma^2) #ref page 169
#b
1-pnorm(sqrt(40),mu,sigma)
```

R code Exa 5.5.d Yearly precipitation

```
#a
1-pnorm(25,24.16,sqrt(19.22))
#b
1-pnorm(3,0,sqrt(19.22))
```

R code Exa 5.6.a Wearing of Battery

```
1-pexp(5000, rate = 10000)
```

R code Exa 5.6.b Working Machines

```r
#When C is put to use, one other machine(either A or
    B ) will still be working .
#The probability of this machine or C failing is
   equal due to
#the memoryless propoerty of exponential random
   variables.

cat("The probability that machine which is still
   operable is machine C is ",1/2)
```

R code Exa 5.6.c Series System

```r
new <- function(lamda,n, t ) {
  newsum = 0;
  for (i in 1:n){
    newsum= newsum + lamda[i]
    result=(exp(1))^(-1*newsum*t)
  }
}
```

R code Exa 5.8.a Chi square random variable

```r
pchisq(30,df =26)
```

R code Exa 5.8.b Chi square random variable

```r
qchisq((1-0.05),df =15)
```

R code Exa 5.8.c Locating a Target

```
1-pchisq(9/4,df =3)
```

R code Exa 5.8.d Locating a Target in 2D space

```
1-pchisq(9/4,df =2)
#or
1-pexp(9/4,1/2)
```

R code Exa 5.8.e T distribution

```
#a
pt(1.4,12)
#b
-qt(0.025,9)
```

R code Exa 5.8.f F Distribution

```
pf(1.5,6,14)
```

Chapter 6

Distribution of Sampling Statistics

R code Exa 6.3.a Claims handled by an insurance company

```
1-pnorm(8300000,320*25000,540*sqrt(25000))
```

R code Exa 6.3.c Class strength

```
1-pnorm((150.5-(450*0.3))/sqrt(450*.3*(1-.3)))
```

R code Exa 6.3.d Weights of workers

```
#a
2*pnorm(.8889)-1
#b
2*pnorm(1.7778)-1
```

R code Exa 6.3.e Distance of a start

```
qnorm(((1+.95)/2),0,1)
n = (1.96*4)^2
n
```

R code Exa 6.5.a Processing time

```
n = 15
sigmasq = 9
Ssq = 12
1-pchisq(((n-1)*Ssq/sigmasq),n-1)
```

R code Exa 6.6.a Candidate winning an election

```
favour = 0.45;
samplesize = 200;
expec= favour*samplesize;
sd = sqrt(samplesize*favour*(1-favour));
cat("The expected value is",expec)
cat("The standard deviation is",sd)

#b
prob = 1-pbinom(q = samplesize/2, size = samplesize,
   prob = favour)
cat("Probability that more than half the members of
   the sample favour the candidate",prob)
```

R code Exa 6.6.b Pork consumption

```
meaneach = 147;
sdeach  = 62;
samplesize = 25;
lim =150;
samplemean = meaneach;
samplesd= sdeach/sqrt(samplesize)
prob = 1 - pnorm(q = lim,mean = samplemean,sd =
   samplesd)
prob
```

Chapter 7

Parameter Estimation

R code Exa 7.2.a Maximum likelihood estimator of a bernoulli parameter

```
samplesize = 1000;
acceptable =921;
cat("The maximum likelihood estimate of p is",
   acceptable/samplesize)
```

R code Exa 7.2.b Errors in a manuscript

```
totalerror<-function(n1, n2, n12){
  totalerror = n1*n2/n12
  return(totalerror)
}
totalerror(n1 = 33000,n2 = 33000,n12 = 17000)
```

R code Exa 7.2.c Maximum likelihood estimator of a poisson parameter

```
total_people = 857;
```

```
days= 20;
cat("The maximum likelihood estimate of lambda",
   total_people/days)
```

R code Exa 7.2.d Number of traffic accidents

```
accidents<-c(4,0,6,5,2,1,2,0,4,3)
lambda= mean(accidents)
cat("lambda:",lambda)
prob = ppois(q = 2, lambda = lambda)
cat("Proportion of non-rainy days that had 2 or
   fewer accidents that year:",prob)
```

R code Exa 7.2.e Maximum likelihood estimator in a normal population

```
normal <-function(X, Xmean, n){
  u= Xmean;
  newsum = 0;
  for (i in 1:n){
    newsum= newsum + (X(i)-Xmean)^2
  }
  sigmasquared = sqrt((newsum/n));
  return(u,sigmasquared)
}
```

R code Exa 7.2.f Kolmogorovs law of fragmentation

```
X<-c(2.2,3.4,1.6,0.8,2.7,3.3,1.6,2.8,2.5,1.9)
upperlimX = 3
lowerlimX = 2
```

```
upperlimlogX= log(upperlimX)
lowerlimlogX = log(lowerlimX)

logX = log(X)
samplemean= mean(logX)
samplesd= sqrt(var(logX))
samplemean
samplesd
prob = pnorm(upperlimlogX, samplemean, samplesd) - pnorm(lowerlimlogX, samplemean, samplesd)
prob
```

R code Exa 7.2.g Estimating Mean of a Uniform Distribution

```
unif <- function(X, n) {
  max(X)/2
}
```

R code Exa 7.3.a Error in a signal

```
avg = 0;
var = 4;
num = 9;
X<-c(5,8.5,12,15,7,9,7.5,6.5,10.5)
samplemean= mean(X);
lowerlim = samplemean - (1.96*sqrt(var/num))
upperlim = samplemean + (1.96*sqrt(var/num))
cat("The 95% confidence interval is ",lowerlim,"to ",upperlim)
```

R code Exa 7.3.b Confidence interval

```
avg = 0;
var = 4;
num = 9;
X<-c(5,8.5,12,15,7,9,7.5,6.5,10.5)
samplemean= mean(X);
lowerlim = samplemean - (1.645*sqrt(var/num))
upperlim = samplemean + (1.645*sqrt(var/num))

cat("The 95% upper confidence interval is ",lowerlim,"  to infinity")
cat("The 95% upper confidence interval is minus infinity to ",upperlim)
```

R code Exa 7.3.c Confidence interval

```
var = 4;
num = 9;
X<-c(5,8.5,12,15,7,9,7.5,6.5,10.5)
samplemean= mean(X);
samplesd = sd(X)
alpha= 0.005;
zalpha = qnorm(p = alpha,mean = 0,sd = 1,lower.tail = FALSE)
zalpha
lowerlim = samplemean - (zalpha*sqrt(var/num))
upperlim = samplemean + (zalpha*sqrt(var/num))
cat("The 95% confidence interval is ",lowerlim, "to ",upperlim)

alpha= 0.01;
zalpha = qnorm(p = alpha,mean = 0,sd = 1,lower.tail = FALSE)
lowerlim = samplemean - (zalpha*sqrt(var/num))
```

```
upperlim = samplemean + (zalpha*sqrt(var/num))
cat("The 95% upper confidence interval is ",lowerlim
    ," to infinity")
cat("The 95% upper confidence interval is minus
    infinity to ",upperlim)
```

R code Exa 7.3.d Weight of a salmon

```
sd= 0.3;
lim = 0.1;
num = (1.96*sd/lim)^2;
cat("Sample size should be greater than",round(num))
```

R code Exa 7.3.e Error in a signal

```
X<-c(5, 8.5, 12, 15, 7, 9, 7.5, 6.5, 10.5)
num = 9;
meanX= mean(X);
X2 = X^2;
s2= (sum(X2)- (num*(meanX^2)))/(num-1);
s= sqrt(s2);
tval =  qt(.975,8)
upperlim = meanX + (tval*s)/sqrt(num);
lowerlim = meanX - (tval*s)/sqrt(num);
cat("The 95% confidence interval is ",  lowerlim, "
    to ",upperlim )

#7.3a
s2= 4
s= sqrt(s2);
tval =  qt(.975,8)
upperlim = meanX + (tval*s)/sqrt(num);
lowerlim = meanX - (tval*s)/sqrt(num);
```

```
cat("The 95% confidence interval is ",  lowerlim, "
    to ",upperlim )
```

R code Exa 7.3.f Average resting pulse

```
X<-c(54, 63, 58, 72, 49, 92, 70, 73, 69, 104, 48,
   66, 80, 64, 77)
num = 15;
meanX= mean(X);
X2 = X^2;
s2= (sum(X2)- (num*(meanX^2)))/(num-1);
s= sqrt(s2);
tval =  qt(.975,num-1)
upperlim = meanX + (tval*s)/sqrt(num);
lowerlim = meanX - (tval*s)/sqrt(num);
cat("The 95% confidence interval is ",lowerlim,"to "
   ,upperlim)
alpha = 0.05;
tval =  qt(1-alpha,num-1)
lim = meanX + (tval*s)/sqrt(num);
cat("The 95% lower confidence interval is from minus
     infinity to ",lim)
```

R code Exa 7.3.g Evaluating integrals

```
#Method 1: Monte Carlo Integration
#install.packages("functional")
library(functional)
funct<-function(sampleXVals) {
  oned = sqrt(1-(sampleXVals*sampleXVals))
  return(oned)
}
MCIntegrate <- function(funct, a,b,N) {
```

```
  sampleXVals = matrix(0,N)
  set.seed(148)
  sampleXVals = a + (b-a)*runif(N)
  Integral = (b-a)* mean(funct(sampleXVals))
  return(Integral)
}
MCIntegrate(funct,0,1,50000000)


#Method 2
meanX = 0.786;
s= 0.03;
num = 100;
alpha = 0.05;
tval =  qt(1-alpha,num-1)
upperlim = meanX + (tval*s)/sqrt(num);
lowerlim = meanX - (tval*s)/sqrt(num);
cat("The 95% confidence interval is ",lowerlim,"to "
   ,upperlim)
```

R code Exa 7.3.h Thickness of washers

```
num=10;
X<-c(0.123, 0.133, 0.124, 0.126, 0.120, 0.130,
   0.125, 0.128, 0.124, 0.126)
var(X)
s2 = var(X)
chi1 = qchisq(1-.95,num-1)
chi2 = qchisq(.95,num-1)
lowerlim = (num-1)*s2/chi2;
lowerlim
upperlim = (num-1)*s2/chi1;
upperlim
cat("The 90% confidence interval is ",sqrt(lowerlim)
   , "to ",sqrt(upperlim))
```

R code Exa 7.4.a Cable insulation

```
A<-c(36, 44, 41, 53, 38, 36, 34, 54, 52, 37, 51, 44,
    35, 44)
B<-c(52, 64, 38, 68, 66, 52, 60, 44, 48, 46, 70, 62)
sigmaA= 40;
sigmaB= 100;
alpha = 1-0.95;
beta= alpha/2;
meanA = mean(A);
meanB= mean(B);
zbeta = qnorm(1-beta)

lowerlim= mean(A) - mean(B) - (zbeta*sqrt((sigmaA/
   length(A)) + (sigmaB/length(B)))) ;
upperlim= mean(A) - mean(B) + (zbeta*sqrt((sigmaA/
   length(A)) + (sigmaB/length(B)))) ;
cat("The 95% confidence interval is ",lowerlim, "to
   ",upperlim)

beta=alpha;
zbeta = qnorm(1-beta)

upperlim= mean(A) - mean(B) + (zbeta*sqrt((sigmaA/
   length(A)) + (sigmaB/length(B)))) ;
cat("A value that exceed the difference of the means
    with 95% confidence is",upperlim)
```

R code Exa 7.4.b Battery production

```
tech1<-c(140, 136, 138, 150, 152, 144, 132, 142,
   150, 154, 136, 142)
```

```
tech2<-c(144, 132, 136, 140, 128, 150, 130, 134, 130, 146, 128, 131, 137, 135)
num1= 12;
num2= 14;
mean1= mean(tech1);
mean2= mean(tech2);
alpha = 0.9;
S1 = var(tech1)
S2 = var(tech2)
Sp = (((num1-1)*S1) + ((num2-1)*S2))/(num1+ num2 -2);
Sp= sqrt(Sp);
num= (1/num1)+(1/num2);
betaa = (1-alpha)/2;
tval = qt(1-betaa,num1+num2-2)
upperlim = mean1-mean2 + (tval*Sp)*sqrt(num);
lowerlim = mean1-mean2 - (tval*Sp)*sqrt(num);
cat("The 90% confidence interval is ",lowerlim, "to ", upperlim)
alpha = 0.95
betaaa = 1-alpha;
tval = qt(1-betaa,num1+num2-2)
lowerlim = mean1-mean2 - (tval*Sp)*sqrt(num);
cat("the upper confidence interval is",lowerlim," to infinity")
```

R code Exa 7.5.a Transistors

```
phat = 0.8;
zalpha = 1.96;

samplesize = 100;
lowerlim = phat - (zalpha*sqrt(phat*(1-phat)/samplesize));
upperlim = phat + (zalpha*sqrt(phat*(1-phat)/
```

```
    samplesize));
cat("The 95% confidence interval is ",lowerlim, "to
    ",upperlim)
```

R code Exa 7.5.b Survey

```
phat = 0.52;
error = 0.04;
zalpha = 1.96;
samplesize = (error/zalpha)^2/(phat*(1-phat));
1/samplesize
```

R code Exa 7.5.c Acceptable chips

```
initialsample = 30;
acceptable= 26;
phat = acceptable/initialsample;
error = 0.05/2;
zalpha = 2.58;

samplesize = (error/zalpha)^2/(phat*(1-phat));
finalsize = round(1/samplesize);
acceptablenew= 1040 + acceptable;
phat = acceptablenew/finalsize;
lowerlim = phat - (zalpha*sqrt(phat*(1-phat)/
    finalsize));
upperlim = phat + (zalpha*sqrt(phat*(1-phat)/
    finalsize));
cat("The 99% confidence interval is ",lowerlim, "to
    ",upperlim)
```

R code Exa 7.6.a Life of a product

```
sum_lives = 1740;
num = 10;
alpha = (1-0.95)/2;
chi1= qchisq(1-alpha,2*num)
chi2 = qchisq(alpha,2*num)
lowerlim = 2*sum_lives/chi1;
upperlim = 2*sum_lives/chi2;
cat("The 95% confidence interval is ",lowerlim, "to ",upperlim)

'
Textbook confidence interval is from 101.847 to 360.211
whereas in above solution is 101.84489 to 362.8485 because of the difference in the value of chi-square(0.975, 20).
The textbook says the value is 9.661 whereas R calculates its value as 9.59
'
```

R code Exa 7.7.a Point estimator

```
estimator1 <- function(x) {
  X[1]
}
estimator2 <- function(variables) {
  mean(X)
}
```

R code Exa 7.7.b Point estimator

```r
estimate <- function(d, sigma) {
  sigmainv = 1/sigma
  new = d/sigma
  result1 = sum(new)/sum(sigmainv)
}

mserror <- function(sigma) {
  sigmainv = 1/sigma
  result1 = 1/sum(sigmainv)
}
```

R code Exa 7.7.c Point estimator of a uniform distribution

```r
unbiasedestimator <- function(X, n) {
  c=(n+2)/(n+1)
  result = c*max(X)
}
```

R code Exa 7.8.a Bayes estimator

```r
estimator <- function(X, n) {
  (sum(X) +1)/(n+2)
}
```

R code Exa 7.8.b Bayes estimator of a normal population

```r
meanestimator <- function(sigma0 , u, sigma , n, X) {
  meanX= mean(X)
  result = (n*meanX/sigma0)/((n/sigma0)+(1/sigma)) +
      (u/sigma)/((n/sigma0)+(1/sigma))
```

```
}

varestimator <- function(sigma0 , sigma, n) {
  (sigma0*sigma)/((n*sigma)+sigma0)
}
```

R code Exa 7.8.d estimator of the signal value

```
meanestimator <- function(sigma0 , u, sigma, n, X) {
  meanX= mean(X);
  result = (n*meanX/sigma0)/((n/sigma0)+(1/sigma)) +
      (u/sigma)/((n/sigma0)+(1/sigma));
  return(result)
}

varestimator <- function(sigma0 , sigma, n) {
  result = (sigma0*sigma)/((n*sigma)+sigma0);
  return(result)
}

u = 50;
sigma= 100;
sigma0 = 60;
n =1;
X =40;
expec = meanestimator(sigma0 , u, sigma, n, X);
var  = varestimator (sigma0, sigma,n);

zalpha = 1.645
lowerlim = -1*sqrt(var)*zalpha+expec;
upperlim = sqrt(var)*zalpha+expec;
cat("With probability 0.9, the sent signal lies
   between ",lowerlim, "to ", upperlim  )
```

Chapter 8

Hypothesis Testing

R code Exa 8.3.a Noise in a Signal

```
noise_var = 4;
noise_mean= 0;
num = 5;
Xbar = 9.5;
u = 8;
statistic = sqrt(num/noise_var)*(Xbar - u);
compare = qnorm(0.975,0, 1);
if(statistic<compare){
  cat("Hypothesis is accepted");
} else{
  cat("Hypothesis is not accepted")
}
```

R code Exa 8.3.b Error in a signal

```
noise_var = 4;
noise_mean= 0;
num = 5;
```

```
Xbar = 8.5;
u = 8;
statistic = sqrt(num/noise_var)*(Xbar - u);

prob = 2*pnorm(-1*statistic , 0,1 );
cat("P-value is",prob)

Xbar = 11.5;
statistic = sqrt(num/noise_var)*(Xbar - u);
prob = pnorm(-1*statistic , 0,1 );
cat("P-value is",prob)
```

R code Exa 8.3.c Error in a signal

```
noise_var = 4;
num = 5;
Xbar = 10;
u = 8;
statistic = sqrt(num/noise_var)*(Xbar - u);
compare = qnorm(0.975,0, 1);
lim1 = statistic + compare;
lim2 = statistic - compare;
prob = pnorm(lim1 , 0,1 ) - pnorm(lim2 , 0,1 );
prob
```

R code Exa 8.3.d Number of signals to be sent

```
alpha = 0.025;
betaa = 0.25;
u1 = 9.2;
uo = 8;
var =4;
zalpha = qnorm(1-alpha,0, 1);
```

```
zbeta = qnorm(1-betaa,0, 1);
n = ((zalpha + zbeta)/(u1-uo))^2 *var;
cat("Required number of samples is",ceiling(n))
statistic = sqrt(ceiling(n)/var)*(u1 - uo);
lim1 = -1*statistic + zalpha;
lim2 = -1*statistic - zalpha;
prob = pnorm(lim1 , 0,1 )- pnorm(lim2 , 0,1 );
cat("Thus, if the message is sent the reqd number of
    times is , then the probability that the null
    hypothesis will be rejected is",1-prob)
```

R code Exa 8.3.e Number of signals to be sent

```
n =5;
Xbar = 9.5;
u = 8;
var = 4;
statistic = sqrt(n/var)*(Xbar - u);
p = 1 - pnorm(statistic, 0, 1);
cat("The test would call for rejection at all
    significance levels greater than or equal to ",p)
```

R code Exa 8.3.f Nicotine content in a cigarette

```
n =20;
Xbar = 1.54;
uo = 1.6;
sd = 0.8;
statistic = sqrt(n)*(Xbar - uo)/sd;
cat("Test statistic is",statistic)
p =  pnorm(statistic, 0, 1);
cat("P-value is",p)
```

R code Exa 8.3.g Blood cholesterol level

```
n = 50;
Xbar = 14.8;
S = 6.4;
T = sqrt(n)*Xbar/S;
cat("The T value is",T)
```

R code Exa 8.3.h Water usage

```
X<-c(340, 356, 332, 362, 318, 344, 386, 402, 322,
    360, 362, 354, 340, 372, 338, 375, 364, 355, 324,
    370)
uo = 350;
Xbar = mean(X);
var =  var(X);
S = sqrt(var)
n = length(X)
T = sqrt(n)*(Xbar - uo)/S;
Tvalue = qt(0.95,n-1)
cat("The T value is ",T)
if(T<Tvalue){
  cat("Null hypothesis is accepted at 10% level of
     significance")
}else{
  cat("Null hypothesis is not accepted at 10% level
     of significance")
}
cat("P value of the test data",2*pnorm(-1*T,0,1))
```

R code Exa 8.3.i Life of a tire

```
X<-c(36.1, 40.2, 33.8, 38.5, 42, 35.8, 37, 41, 36.8,
    37.2, 33, 36)
n = length(X);
uo = 40;
Xbar=mean(X);
sd = sqrt(var(X));
T = sqrt(n)*(Xbar - uo)/sd;
Tvalue = qt(0.05,n-1);
cat("The T value is ",T)
if(T<Tvalue){
  cat("Null hypothesis is rejected at 5% level of
     significance")
}else{
  cat("Null hypothesis is  accepted at 5% level of
     significance")
}

cat("P value of the test data",pnorm(T,0,1))
'
There is a mismatch between book answer for the P
   value of the test data.
'
```

R code Exa 8.3.j Service Time

```
X<-c(8.6, 9.4, 5.0, 4.4, 3.7, 11.4, 10.0, 7.6, 14.4,
    12.2, 11.0, 14.4, 9.3, 10.5, 10.3, 7.7, 8.3,
   6.4, 9.2, 5.7, 7.9, 9.4, 9.0, 13.3, 11.6, 10.0,
   9.5, 6.6)
n = length(X);
uo = 8;
Xbar=mean(X);
sd = sqrt(var(X));
```

```
T = sqrt(n)*(Xbar - uo)/sd;
cat("The test statistic is ",T)
p = 1- pt(T, n-1);
cat("P-value is",p)
cat("A small p value indicates that the mean service
    time exceeds 8 minutes")
```

R code Exa 8.4.a Tire lives

```
A<-c(61.1, 58.2, 62.3, 64, 59.7, 66.2, 57.8, 61.4,
   62.2, 63.6)
B<-c(62.2, 56.6, 66.4, 56.2, 57.4, 58.4, 57.6, 65.4)
uA = mean(A);
uB = mean(B);
varA = 40^2;
varB =60^2;
n= length(A);
m =length(B);
den = sqrt((varA/n)+ (varB/m));
statistic = (uA -uB)/den;
cat("The test statistic is",statistic);
cat("A small value of the test statistic indicates
   that the null hypothesis is accepted")
```

R code Exa 8.4.b Medicine for cold

```
X<-c(5.5, 6.0, 7.0, 6.0, 7.5, 6.0, 7.5, 5.5, 7.0,
   6.5)
Y<-c(6.5, 6.0, 8.5, 7.0, 6.5, 8.0, 7.5, 6.5, 7.5,
   6.0, 8.5, 7.0)
n = length(X);
m= length(Y);
Xbar= mean(X);
```

```
Ybar = mean(Y);
Sx = var(X);
Sy = var(Y);
Sp = ((n-1)*Sx/(n+m-2)) + ((m-1)*Sy/(n+m-2));
den = sqrt(Sp*((1/n)+(1/m)));
TS = (Xbar -Ybar)/den;
cat("The test statistic is",TS);
tvalue = qt( 0.95, m+n-2)
if(TS<tvalue){
  cat("Null hypothesis is rejected at 5% level of significance")
}else{
  cat("Null hypothesis is  accepted at 5% level of significance")
}
cat("The Pvalue is",pt(TS,m+n-2))
```

R code Exa 8.4.c Unknown population variance

```
A<-c(61.1, 58.2, 62.3, 64, 59.7, 66.2, 57.8, 61.4, 62.2, 63.6)
B<-c(62.2, 56.6, 66.4, 56.2, 57.4, 58.4, 57.6, 65.4)
uA = mean(A);
uB = mean(B);
n= length(A);
m =length(B);
Sx = var(A);
Sy = var(B);
Sp = ((n-1)*Sx/(n+m-2)) + ((m-1)*Sy/(n+m-2));
den = sqrt(Sp*((1/n)+(1/m)));
TS = (uA-uB)/den;
cat("The test statistic is",TS);
pvalue = 2*(1- pt(TS,m+n-2));
cat("Null hypothesis is accepted at any significance level less than",pvalue)
```

R code Exa 8.4.d effectiveness of safety program

```
A<-c(30.5, 18.5, 24.5, 32, 16, 15, 23.5, 25.5, 28,
    18)
B<-c(23, 21, 22, 28.5, 14.5, 15.5, 24.5, 21, 23.5,
    16.5)
n= length(A);
W = B-A;
Wbar = mean(W);
S = sqrt(var(W));
T = sqrt(n)*Wbar/S;
cat("The test statistic is",T);
pvalue =  pt(T, n-1);
cat("The p value is",pvalue)
```

R code Exa 8.5.a effectiveness of machine

```
n =20;
S2= 0.025;
chk = 0.15;
compare = (n-1)*S2/(chk^2);
pvalue = 1- pchisq(compare, n-1);
cat("The p-value is",pvalue)
cat("Thus , the null hypothesis is accepted")
```

R code Exa 8.5.b Catalyst

```
S1 = 0.14;
S2 = 0.28;
```

```
n= 10;
m= 12;
ratio  = S1/S2;
prob1 = pf(ratio, n-1, m-1);
prob2 = 1-prob1;
prob = min(prob1,prob2);
pvalue = 2*prob;
cat("The p value is",pvalue)
cat("So the hypothesis of equal variance cannot be rejected")
```

R code Exa 8.6.a Computer chip manufacturing

```
samplesize = 300;
p =0.02;
defective=9;
val = pbinom(defective, samplesize, p, 1-p);
cat("P0.02{X>10} = ",val);
cat("Manufacturers claim cannot be rejected at the 5% level of significance")
```

R code Exa 8.6.b Finding p value

```
samplesize = 300;
p =0.02;
defective=9;
compare = 10;
npo = samplesize*p;
sd = sqrt(npo*(1-p));
tol = 0.5;
pvalue = 1- pnorm(compare-tol, npo,sd );
cat("The pvalue is",pvalue)
```

R code Exa 8.6.c Change in manufacturing pattern

```
samplesize = 500;
p =0.04;
defective=16;
prob1 = 1-pbinom(defective, samplesize, p, 1-p)
prob2 = pbinom(defective-1, samplesize, p, 1-p);
pvalue = 2*min(prob1,prob2);
cat("The pvalue is",pvalue)
```

R code Exa 8.7.a Mean number of defective chips

```
x<-c(28, 34, 32, 38, 22)
claim = 25;
total = sum(x);
pval = 1 - ppois(total-1, (claim*length(x)));
cat("The pvalue is",pval)
```

R code Exa 8.7.b Safety Conditions in a plant

```
plant1<-c(16, 18, 9, 22, 17, 19, 24, 8)
plant2<-c(22, 18, 26, 30, 25, 28)
X1= sum(plant1);
X2 = sum(plant2);
n =length(X1);
m= length(X2);
prob1 = 1 - pbinom(X1, X1+X2,(4/7),(3/7));
prob2 = pbinom(X1-1 ,X1+X2, 4/7, 3/7 );
cat(prob1, prob2)
```

```
pvalue = 2*min(prob1,prob2);
cat("The pvalue is",pvalue)
```

R code Exa 8.7.c Better proof reader

```
Aerror =28;
Berror = 18;
common =10;
N2 = Aerror - common;
N3 =Berror- common;
pval = pbinom(N2-1, N2 + N3, 0.5, 0.5);
cat("P-value is",pval)
```

Chapter 9

Regression

R code Exa 9.1.a Scatter Diagram

```
X<-c(100, 110, 120, 130, 140, 150, 160, 170, 180,
   190);
Y<-c(45, 52, 54, 63, 62, 68, 75, 76, 92, 88)
dev.new(width=5, height=4)
plot(X, Y)
cat("A linear regression model seems appropriate")
```

R code Exa 9.2.a Relative humidity and moisture content

```
A<-c(46, 53, 29, 61, 36, 39, 47, 49, 52, 38, 55, 32,
    57, 54, 44)
B<-c(12, 15, 7, 17, 10, 11, 11, 12, 14, 9, 16, 8,
   18, 14, 12)
plot(A, B,xlab ="Relative humidity",ylab = "Moisture
    content",main = "Estimated regression line")
X = lm(B~A)
Y = X$coefficients[1]
X = X$coefficients[2]
```

```
p = seq(0,65,0.1)
q = p*X + Y
lines(p, q)
```

R code Exa 9.3.a Moisture against Density

```
x<-c(5, 6, 7, 10, 12, 15, 18, 20)
y<-c(7.4, 9.3, 10.6, 15.4, 18.1, 22.2, 24.1, 24.8)
plot(x,y);

xbar = mean(x);
ybar= mean(y);
n= 8;
SxY = 0;
for (i in (1:n)){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar)
}

Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}

B = SxY/Sxx;
A = ybar - (B*xbar);
cat("A is",A);
cat("B is",B);
p= seq(0,20,0.1)
q= A + B*p;
lines(p,q)
```

```
SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
cat("The SSR is",SSR)
```

R code Exa 9.4.a Effect of speed on mileage

```
x<-c(45, 50, 55, 60, 65, 70, 75)
y<-c(24.2, 25.0, 23.3, 22.0, 21.5, 20.6, 19.8)
xbar = mean(x);
ybar= mean(y);
n= 7;
SxY = 0;
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar)
}

Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}
SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}
B = SxY/Sxx;
A = ybar - (B*xbar);
cat("A is",A);
cat("B is",B);

SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
cat("The SSR is",SSR)

ts = sqrt(((n-2)*Sxx)/SSR)*abs(B);
cat("the test statistic is",ts);
tvalue= qt(0.995,5);
```

```
cat("tvalue is",tvalue);

if(tvalue < ts){
  cat("Hypothesis beta= 0 is rejected at 1% level of
      significance")
} else{
  cat("Hypothesis beta= 0 is accepted at 1% level of
      significance")
}
```

R code Exa 9.4.b Confidence interval estimate

```
x<-c(45, 50, 55, 60, 65, 70, 75)
y<-c(24.2, 25.0, 23.3, 22.0, 21.5, 20.6, 19.8)
xbar = mean(x);
ybar= mean(y);
n= 7;
SxY = 0;
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar)
}

Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}
SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}
B = SxY/Sxx;
A = ybar - (B*xbar);
cat("A is",A);
cat("B is",B);

```

```
SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
cat("The SSR is",SSR)

tvalue= qt(0.975, 5);
cat("tvalue is",tvalue);

k = sqrt(SSR/((n-2)*Sxx))*tvalue;
int1 = B + k;
int2= B-k;
cat("The 95% confidence interval is ",int2, "to ",
   int1)
```

R code Exa 9.4.c Regression to the mean

```
x<-c(60, 62, 64, 65, 66, 67, 68, 70, 72, 74)
y<-c(63.6, 65.2, 66, 65.5, 66.9, 67.1, 67.4, 68.3,
   70.1, 70)
plot(x,y,xlab ="Father's Height",ylab = "Son's
   Height")
xbar = mean(x)
ybar= mean(y)
n= 10;
SxY = 0
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar);
}

Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
```

```
}

B = SxY/Sxx;
A = ybar - (B*xbar);
cat("A is",A);
cat("B is",B);
p= seq(60,72,0.1)
q= A + B*p;
lines(p,q)
SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
ts = sqrt(((n-2)*Sxx)/SSR)*(B-1)
ts
tvalue= qt(0.99,n-2)
tvalue
if(ts<(-1*tvalue)){
  cat("Null hypotheis is rejected at 1% level of
     significance")
} else{
  cat("Null hypotheis is accepted at 1% level of
     significance")
}
```

R code Exa 9.4.d Motor vehicle deaths

```
x<-c(121, 96, 85, 113, 102, 118, 90, 84, 107, 112,
   95, 101)
y<-c(104, 91, 101, 110, 117, 108, 96, 102, 114, 96,
   88, 106)

plot(x,y,xlab = "Deaths in 1988",ylab = "Deaths in
   1989");

xbar = mean(x);
ybar= mean(y);
n= 12;
```

```
SxY = 0
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar);
}

Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}

B = SxY/Sxx;
A = ybar - (B*xbar);
cat("A is",A);
cat("B is",B)
```

R code Exa 9.4.e Confidence interval for height

```
x<-c(60, 62, 64, 65, 66, 67, 68, 70, 72, 74)
y<-c(63.6, 65.2, 66, 65.5, 66.9, 67.1, 67.4, 68.3,
    70.1, 70)
x0 = 68;
xbar = mean(x);
ybar= mean(y);
n= 10;
SxY = 0
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar);
}

```

```
Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}
B = SxY/Sxx;
A = ybar - (B*xbar);
tvalue= qt(0.975, n-2);
SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
intvl = A + (B*x0);
change = sqrt((1/n)+(((x0-xbar)^2)/Sxx))* sqrt(SSR/(
   n-2))*tvalue;
intvl1 = intvl - change;
intvl2= intvl + change;
cat("The 95% confidence interval is ",intvl1, "to ",
    intvl2)
```

R code Exa 9.4.f Confidence interval for height

```
x<-c(60, 62, 64, 65, 66, 67, 68, 70, 72, 74)
y<-c(63.6, 65.2, 66, 65.5, 66.9, 67.1, 67.4, 68.3,
   70.1, 70)
x0 = 68;
xbar = mean(x);
ybar= mean(y);
n= 10;
SxY = 0
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar);
}

```

```
Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}
B = SxY/Sxx;
A = ybar - (B*xbar);
tvalue= qt(0.975, n-2);
SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
intvl = A + (B*x0);
change = sqrt(((n+1)/n)+(((x0-xbar)^2)/Sxx))* sqrt(
   SSR/(n-2))*tvalue;
intvl1 = intvl - change;
intvl2= intvl + change;
cat("The 95% confidence interval is ",intvl1, "to ",
    intvl2)
```

R code Exa 9.5.a Height of son and father

```
x<-c(60, 62, 64, 65, 66, 67, 68, 70, 72, 74)
y<-c(63.6, 65.2, 66, 65.5, 66.9, 67.1, 67.4, 68.3,
   70.1, 70)

xbar = mean(x);
ybar= mean(y);
n= 10;

SxY = 0
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar);
}
```

```
Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}

B = SxY/Sxx;
A = ybar - (B*xbar);

SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
R2 = 1 - (SSR/SYY);
cat("The coefficient of determination is",R2)
```

R code Exa 9.7.a Percentage of chemical used

```
x<-c(5, 10, 20, 30, 40, 50, 60, 80)
yold<-c(0.061, 0.113, 0.192, 0.259, 0.339, 0.401,
   0.461, 0.551)
plot(x, yold);
y = -1*log(1-yold);
plot(x, y);


xbar = mean(x);
ybar= mean(y);
n= 8;

SxY = 0
for (i in 1:n){
  SxY = SxY + (x[i]*y[i]) - (xbar*ybar);
```

```
}

Sxx = 0;
for (i in 1:n){
  Sxx= Sxx + (x[i]*x[i]) - (xbar*xbar);
}

SYY = 0;
for (i in 1:n){
  SYY = SYY + (y[i]*y[i]) - (ybar*ybar);
}

B = SxY/Sxx;
A = ybar - (B*xbar);
SSR = ((Sxx*SYY)- (SxY*SxY))/Sxx ;
chat = exp(-1*A);
dhat = 1 - exp(-1*B);
phat = 1 - chat*(1-dhat)^x
pres = yold - phat
cat("chat is",chat);
cat("dhat is",dhat);
cat("phat is",phat);
cat("p - phat, i.e. the residuals are",pres)
```

R code Exa 9.8.b Distance vs Travel Time

```
x<-c(0.5, 1, 1.5, 2, 3, 4, 5, 6, 8, 10)
y<-c(15, 15.1, 16.5, 19.9, 27.7, 29.7, 26.7, 35.9,
    42, 49.4)
w<-c()
for (i in 1:10){
  w[i] = 1/x[i]
}
n = 10;
p = matrix(0,2,2)
```

```
q = matrix(0,2,1)
p[1, 1] = sum(w);
p[1,2] = n;
p[2,1] = n;
p[2,2] = sum(x);
new<-c()
for (i in 1:10){
  new[i] = w[i]*y[i]
}

q[1,1]= 1*sum(new);
q[2,1] = 1*sum(y);
sol = solve(p,q);
A = sol[1,1];
B = sol[2,1];
cat("A is",A);
cat("B is",B);
plot(x,y)
l = seq(0,10,0.1)
k = A + B*l
lines(l,k)
```

R code Exa 9.9.a Polynomial Fitting

```
x<-seq(1,10,1);
y<-c(20.6, 30.8, 55, 71.4, 97.3, 131.8, 156.3,
   197.3, 238.7, 291.7)
plot(x, y,xlab = "X",ylab = "Y");
n = length(x)
xsquared = x^2;
xcube = x^3;
xfour = x^4;
xy = x*y;
x2y = xy*x;
p= matrix(0,3,3);
```

```
q = matrix(0,3,1);
p[1,1] = n;
p[1,2] = sum(x);
p[1,3]=sum(xsquared);
p[2,1] = sum(x);
p[2,2] = sum(xsquared);
p[2,3]=sum(xcube);
p[3,1] = sum(xsquared);
p[3,2] = sum(xcube);
p[3,3]=sum(xfour);
q[1,1]= 1*sum(y);
q[2,1] = 1*sum(xy);
q[3,1] = 1*sum(x2y);
B= solve(p, q);
cat("B0 is",B[1,1]);
cat("B1 is",B[2,1]);
cat("B2 is",B[3,1])
```

R code Exa 9.10.a Multiple Linear Regression

```
x1<-c(679, 1420, 1349, 296, 6975, 323, 4200, 633)
x2<-c(30.4, 34.1, 17.2, 26.8, 29.1, 18.7, 32.6,
   32.5)
y = matrix(1,8,1);
n = 8
y<-c(11.6,16.1, 9.3, 9.1, 8.4, 7.7, 11.3, 8.4)
x = matrix(1,8,3);
for (i in 1:8){
  x[i,2]= x1[i];
  x[i,3]= x2[i];
}

pro1 = t(x)
pro2= pro1%*%x;
pro3 = solve(pro2);
```

```
pro4 = pro3%*%pro1;
pro5 = pro4%*%y;

B<-matrix(0,3,8)
matrix(1,3,1);
for (i in 1:3){
  B[i,1]= 0;
  for (k in 1:8){
    B[i,1]=B[i,1]+(pro4[i, k]*y[k]);
  }
}
cat(B);
SSR = t(y)
SSR= SSR%*%y;
sub = t(B);
sub = sub%*%t(x);
sub= sub%*%y;
SSR =SSR[1,1] - sub[1,1];
cat("SSr is",SSR)
```

R code Exa 9.10.b Estimate of variance

```
x1<-c(679, 1420, 1349, 296, 6975, 323, 4200, 633)
x2<-c(30.4, 34.1, 17.2, 26.8, 29.1, 18.7, 32.6, 32.5)
y = matrix(1,8,1);
n = 8
y<-c(11.6,16.1, 9.3, 9.1, 8.4, 7.7, 11.3, 8.4)
x = matrix(1,8,3);
for (i in 1:8){
  x[i,2]= x1[i];
  x[i,3]= x2[i];
}

pro1 = t(x)
```

```
pro2= pro1%*%x;
pro3 = solve(pro2);
pro4 = pro3%*%pro1;
pro5 = pro4%*%y;

B<-matrix(0,3,8)
matrix(1,3,1);
for (i in 1:3){
  B[i,1]= 0;
  for (k in 1:8){
    B[i,1]=B[i,1]+(pro4[i, k]*y[k]);
  }
}
cat(B);
SSR = t(y)
SSR= SSR%*%y;
sub = t(B);
sub = sub%*%t(x);
sub= sub%*%y;
SSR =SSR[1,1] - sub[1,1];
cat(”SSr is”,SSR)

k=2;
den = n-k-1;
sigma = SSR/den;
cat(”The variance is”,sigma)
```

R code Exa 9.10.c Diameter of a tree

```
x1<-c(44, 33, 33, 32, 34, 31, 33, 30, 34, 34, 33,
   36, 33, 34, 37)
x2<-c(1.3, 2.2, 2.2, 2.6, 2.0, 1.8, 2.2, 3.6, 1.6,
   1.5, 2.2, 1.7, 2.2, 1.3, 2.6)
x3<-c(250, 115, 75, 85, 100, 75, 85, 75, 225, 250,
   255, 175, 75, 85, 90)
```

```
x4<-c(0.63, 0.59, 0.56, 0.55, 0.54, 0.59, 0.56,
    0.46, 0.63, 0.60, 0.63, 0.58, 0.55, 0.57, 0.62)
y<-c(18.1, 19.6, 16.6, 16.4, 16.9, 17.0, 20.0, 16.6,
    16.2, 18.5, 18.7, 19.4, 17.6, 18.3, 18.8)
n =length(x1);
x= matrix(1,15, 5);
for (i in 1:15){
  x[i,2]= x1[i]
  x[i,3]= x2[i]
  x[i,4]= x3[i]
  x[i,5]= x4[i]
}

pro1 = t(x)
pro2= pro1%*%x
pro3 = solve(pro2)
pro4 = pro3%*%pro1
pro5 = pro4%*%y
B<-matrix(0,5,15)
for (i in 1:5){
  B[i,1]= 0
  for (k in 1:15){
    B[i,1]=B[i,1]+(pro4[i, k]*y[k])
  }
}
SSR = t(y)
SSR= SSR%*%y
sub = t(B)
sub = sub%*%t(x)
sub= sub%*%y
SSR =SSR[1,1] - sub[1,1]
SSR
xxinv = 0.379;
k= 4;
ts = sqrt((n-k-2)/SSR)*B[2]/0.616;
pvalue = 2*(1- pt(ts, n-k-2))
cat("The p-value is",pvalue)
'
```

```
The SSR calculated by R is 19.34 whereas the
    textbook gives the value as 19.26 , thus the
    difference in the final answer.
'
```

R code Exa 9.10.d Estimating hardness

```
y<-c(79.2, 64.0, 55.7, 56.3, 58.6, 84.3, 70.4, 61.3,
     51.3, 49.8)
x1<-c(0.02, 0.03, 0.03, 0.04, 0.10, 0.15, 0.15,
    0.09, 0.13, 0.09)
x2<-c(1.05, 1.20, 1.25, 1.30, 1.30, 1.00, 1.10,
    1.20, 1.40, 1.40)
tvalue= 2.365;
x = matrix(1,10,3);
for (i in 1:10){
  x[i,2]= x1[i]
  x[i,3]= x2[i]
}

pro1 = t(x)
pro2= pro1%*%x
pro3 = solve(pro2)
pro4 = pro3%*%pro1
pro5 = pro4%*%y
B= matrix(1,3,1)

for (i in 1:3){
  B[i,1]= 0
  for ( k in 1:10){
    B[i,1]= B[i,1]+(pro4[i, k]*y[k])
  }
}

SSR = t(y)
```

```
SSR= SSR%*%y
sub = t(B)
sub = sub%*%t(x)
sub= sub%*%y
SSR =SSR[1,1] - sub[1,1]
cat("SSr is",SSR)

smallx<-c(1, 0.15, 1.15)
product = smallx %*% B
n = 10;
k=2;
val= sqrt(SSR/(n-k-1));

pro5 = smallx %*% pro3
pro6 = pro5 %*% (smallx)
pro7 = val*sqrt(pro6)*tvalue

up = product + pro7;
low = product - pro7;
cat(" 95% confidence interval is from ",low,"to",up)
```

R code Exa 9.11.a Animal sick falling

```
cancer = 84;
total = 111;
level = 250;
alpha= -1*log((total-cancer)/total)/level;
cat("Alpha is ",alpha)
```

Chapter 10

Analysis of Variance

R code Exa 10.3.a Dependence of mileage on gas used

```
Xij<-matrix(c(220, 251, 226, 246, 260, 244, 235,
   232, 242, 225, 252, 272, 250, 238, 256),nrow = 3,
   ncol = 5,byrow = TRUE)
Xi = matrix(0,3,1);
n= 5;
m=3;
for (i in 1:3){
  for (j in 1:5){
    Xi[i]= Xi[i] + Xij[i,j]
  }
}
Xi
Xi = Xi/n;
SSW= 0;
for (i in 1:3){
  for (j in 1:5){
    SSW = SSW + ((Xij[i,j]-Xi[i])^2)
  }
}
SSW
sigma1 = SSW/((n*m)-m);
```

```
Xdotdot = sum(Xi)/m;
new = (Xi - Xdotdot)^2;
SSb= n*sum(new);
sigma2 = SSb/(m-1);
TS = sigma2/sigma1;
cat("Value of the test statistic is",TS)
pvalue = 1 - pf(TS,m-1, ((n*m)-m))
cat("The p-value is",pvalue)
if(pvalue>0.05){
  cat( "Since the p-value is greater than .05, the
     null hypothesis that the mean mileage is the
     same for all 3 brands of gasoline cannot be
     rejected. ")
}
```

R code Exa 10.3.b Dependence of mileage on gas used

```
Xijold<-matrix(c(220, 251, 226, 246, 260, 244, 235,
   232, 242, 225, 252, 272, 250, 238, 256),nrow = 3,
   ncol = 5,byrow = TRUE)
Xij = Xijold - 220;
m=3;
n=5;
Xidot = matrix(0,3,1);
for (i in 1:m){
  for (j in 1:n){
    Xidot[i]=Xidot[i] + Xij[i,j]
  }
}
Xidot = Xidot/n;
Xdotdot = sum(Xidot)/m;
SSb=0;
for (i in 1:m){
  SSb = SSb + (Xidot[i]-Xdotdot)^2
}
```

```
SSb = SSb*n;
Xijsquared = Xij^2;
SSW = sum(Xijsquared) - (m*n*(Xdotdot^2)) - SSb;
sigma1 = SSW/((n*m)-m);
sigma2 = SSb/(m-1);
TS = sigma2/sigma1;
cat("Value of the test statistic is",TS)
```

R code Exa 10.3.c Difference in GPA

```
Xij<-matrix(c(3.2, 3.4, 3.3, 3.5, 3.4, 3.0, 3.7,
    3.3, 2.8, 2.6, 3.0, 2.7),nrow = 3,ncol = 4,byrow
    = TRUE)
Xi = matrix(0,3,1);
n= 4;
m=3;
for (i in 1:3){
  for (j in 1:4){
    Xi[i]= Xi[i] + Xij[i,j]
  }
}
Xi = Xi/n;
SSW= 0;
for (i in 1:3){
  for (j in 1:4){
    SSW = SSW + ((Xij[i,j]-Xi[i])^2)
  }
}
sigma1 = SSW/((n*m)-m);
Xdotdot = sum(Xi)/m;
new = (Xi - Xdotdot)^2;
SSb= n*sum(new);
sigma2 = SSb/(m-1);
TS = sigma2/sigma1;
cat("Value of the test statistic is",TS)
```

```
pvalue = 1 - pf(TS,m-1, ((n*m)-m) );
cat("The p-value is",pvalue)
C = 3.95; #from table A5
W = C*sqrt(SSW/(9*4));
W
cat("Mean1 - Mean2 lies between ", Xi[1]-Xi[2]-W ,"
   and ", Xi[1]-Xi[2]+W)
cat("Mean1 - Mean3 lies between ", Xi[1]-Xi[3]-W ,"
   and ", Xi[1]-Xi[3]+W)
cat("Mean2 - Mean3 lies between ", Xi[2]-Xi[3]-W ,"
   and ", Xi[2]-Xi[3]+W)
```

R code Exa 10.4.b Estimating Parameters

```
X<-matrix(c(75, 73, 60, 70, 86, 78, 71, 64, 72, 90,
   80, 69, 62, 70, 85, 73, 67, 63, 80, 92),nrow = 4,
   ncol = 5,byrow = TRUE)
Xidot = matrix(0,4,1);
for (i in 1:4){
  for (j in 1:5){
    Xidot[i]=Xidot[i] + X[i,j]
  }
}
Xidot = Xidot/5;
Xjdot = matrix(0,5,1);
for (j in 1:5){
  for (i in 1:4){
    Xjdot[j]=Xjdot[j] + X[i,j]
  }
}
Xjdot = Xjdot/4;
Xdotdot = sum(Xidot)/4;
meanhat = Xdotdot;
alphahat = Xidot - meanhat;
betahat = Xjdot - meanhat;
```

```
cat("The estimator of the mean is",meanhat)
cat("The alphas are-",alphahat)
cat("The betas are-",betahat)
```

R code Exa 10.5.a Species collected

```
X<-matrix(c(53, 35, 31, 37, 40, 43, 36, 34, 17, 21,
   30, 18, 47, 37, 17, 31, 45, 26, 55, 31, 17, 23,
   43, 37, 40, 32, 19, 26, 45, 37, 52, 42, 20, 27,
   26, 32, 39, 28, 21, 21, 36, 28, 40, 32, 21, 21,
   36, 35),nrow =8,ncol = 6, byrow = TRUE)
m= 8;
n = 6;
Xidot = matrix(0,8,1);

for (i in 1:8){
  for (j in 1:6){
    Xidot[i]=Xidot[i] + X[i,j]
  }
}
Xidot = Xidot/6;
Xjdot = matrix(0,6,1);

for (j in 1:6){
  for (i in 1:8){
    Xjdot[j]=Xjdot[j] + X[i,j]
  }
}

Xjdot = Xjdot/8;
Xdotdot = sum(Xidot)/8;
new = (Xidot - Xdotdot)^2;
SSr = n*sum(new);
new1 = (Xjdot - Xdotdot)^2;
SSc = m*sum(new1);
```

```
SSe = 0;
for (i in 1:m){
  for (j in 1:n){
    SSe = SSe + (X[i,j]-Xidot[i]-Xjdot[j]+ Xdotdot)^2
    }
}

N =(m-1)*(n-1)
TS1 = SSr*N/((m-1)*SSe)
TS2 = SSc*N/((n-1)*SSe)
pvaluec = 1- pf(TS1, m-1, N)
pvaluer = 1- pf(TS2, n-1, N)
cat("The value of the F-statistic for testing that there is no row effect is",TS1)
cat("The p-value for testing that there is no row effect is",pvaluec)
cat("The value of the F-statistic for testing that there is no column effect is",TS2)
cat("The p-value for testing that there is no column effect is",pvaluer)
```

Chapter 11

Goodness of Fit Tests and Categorical Data Analysis

R code Exa 11.2.a Relation between death date and birth date

```
X<-c(90, 100, 87, 96, 101, 86, 119, 118, 121, 114,
   113, 106)
pi= matrix(1,12,1);
pi= pi/12;
new = X^2;
npi= sum(X)*pi;
T = sum(new);
T = T/npi;
T = T - sum(X);
cat("When there are 12 regions")
cat("The test statistic is",T[1])
pvalue = 1- pchisq(T[1], 11);
cat("The pvalue is ",pvalue)

X<-c(277, 283, 358, 333)
pi= matrix(1,4,1);
pi= pi/4;
new = X^2;
npi= sum(X)*pi;
```

```
T = sum(new);
T = T/npi;
T = T - sum(X);
cat("When there are 4 regions")
cat("The test statistic is",T[1])
pvalue = 1- pchisq(T[1], 3);
cat("The pvalue is ",pvalue)
```

R code Exa 11.2.b Quality of bulbs

```
X<-c(3, 6, 9, 7, 5)
p<-c(0.15, 0.25, 0.35, 0.20, 0.05)
T= 0;
n3=sum(X);
np = p*n3;
Xsqu = (X-np)^2;
cat(Xsqu);
XT = Xsqu/np;
T = sum(XT);

cat("The test statistic is",T)
pvalue = 1- pchisq(T[1], 4)
cat("The pvalue is ",pvalue)
cat("Thus, the hypothesis would not be rejected at
    5% level of significance")
```

R code Exa 11.2.d Six outcomes

```
X<-c(3, 3, 5, 18, 4, 7)
p<-c(0.1, 0.1, 0.05, 0.4, 0.2, 0.15)
psimu = 0.1843
num= 10000;
T= 0;
```

```
n=sum(X);
np = n*p;
Xsqu = X^2;
for (i in 1:6){
  T = T + (Xsqu[i]/np[i])
}
T = T - sum(X)

cat("The test statistic is",T[1])
pvalue = 1- pchisq(T[1], 5);
int1 = psimu - (1.645*sqrt(psimu*(1-psimu)/num));
int2 = psimu + (1.645*sqrt(psimu*(1-psimu)/num));
cat("With 90% confidence p-value lies between ",int1
   ,"and",int2)
```

R code Exa 11.3.a Weekly accidents

```
Y<-c(8, 0, 0, 1, 3, 4, 0, 2, 12, 5, 1, 8, 0, 2, 0,
   1, 9, 3, 4, 5, 3, 3, 4, 7, 4, 0, 1, 2, 1, 2)
weeks = 30;
lamda = sum(Y)/weeks;
p = matrix(0,5,1);
p[1] = ppois(0, lamda);
p[2] = ppois(1, lamda) - p[1];
p[3] = ppois(3, lamda) - ppois(1, lamda);
p[4] = ppois(5, lamda) - ppois(3, lamda);
p[5] = 1 - ppois(5, lamda);

X = matrix(0,5,1);
for (i in 1:30){
  if(Y[i]==0){
    X[1] = X[1] +1;
  } else if(Y[i]==1){
    X[2] = X[2] +1;
  } else if(Y[i]==2){
```

```
      X[3] = X[3] +1;
    } else if(Y[i]==3){
      X[3] = X[3] +1;
    } else if(Y[i]==4){
      X[4] = X[4] +1;
    } else if(Y[i]==5){
      X[4] = X[4] +1;
    } else if(Y[i]>5){
      X[5] = X[5] +1;
    }
}

T= 0;
npi = weeks * p;
for (i in 1:5){
  T = T + ((X[i]-npi[i])^2)/npi[i]
}
cat("T is",T)
pvalue = 1- pchisq(T, 3)
cat("The p-value is",pvalue)
cat("Hypothesis of an underlying poisson
   distribution is rejected")
```

R code Exa 11.4.a Political affliation and Gender

```
Nij<-matrix(c(68, 56, 32, 52, 72, 20),nrow = 2,ncol
   = 3,byrow = TRUE)
n= sum(Nij);
Ni = matrix(0,2,1);
Mj = matrix(0,3,1);
for (i in 1:2){
  for (j in 1:3){
    Ni[i] = Ni[i] + Nij[i,j]
  }
}
```

```
for (j in 1:3){
  for (i in 1:2){
    Mj[j] = Mj[j] + Nij[i,j]
  }
}
NM = matrix(1,2,3);
for (i in 1:2){
  for (j in 1:3){
    NM[i,j]= Ni[i]*Mj[j]
  }
}
NM= NM/n;
TS = 0
for (i in 1:2){
  for (j in 1:3){
    TS = TS + ((Nij[i,j]-NM[i,j])^2)/NM[i,j]
  }
}
cat("The test statistic is",TS)
compare = pchisq(2, 0.95, 0.05)
if(TS>compare){
  cat("The null hypothesis is rejected at the 5%
     level of significance")
  } else {
    disp("The null hypothesis is accepted at the 5%
       level of significance")
  }
```

R code Exa 11.4.b Machine Breakdown and shift

```
Nij<-matrix(c(10, 12, 6, 7, 10, 24, 9, 10, 13, 20,
   7, 10),nrow = 3,ncol = 4,byrow = TRUE)
n= sum(Nij);
Ni = matrix(0,3,1);
Mj = matrix(0,4,1);
```

```
for (i in 1:3){
  for (j in 1:4){
    Ni[i] = Ni[i] + Nij[i,j]
  }
}
for (j in 1:4){
  for (i in 1:3){
    Mj[j] = Mj[j] + Nij[i,j]
  }
}
NM = matrix(1,3,4);
for (i in 1:3){
  for (j in 1:4){
    NM[i,j]= Ni[i]*Mj[j]
  }
}
NM= NM/n;
TS = 0
for (i in 1:3){
  for (j in 1:4){
    TS = TS + ((Nij[i,j]-NM[i,j])^2)/NM[i,j]
  }
}
cat("The test statistic is",TS)
pvalue = 1- pchisq(TS, 6)
cat("the hypothesis that the machine that causes a
   breakdown is independent of the shift on which
   the breakdown occurs is accepted.")
```

R code Exa 11.5.a Lung cancer and smoking

```
Nij<-matrix(c(62, 14, 9938, 19986),nrow = 2,ncol =
   2,byrow = TRUE)
n= sum(Nij);
Ni = matrix(0,2,1);
```

```
Mj = matrix(0,2,1);
for (i in 1:2){
  for (j in 1:2){
    Ni[i] = Ni[i] + Nij[i,j]
  }
}
Ni
for (j in 1:2){
  for (i in 1:2){
    Mj[j] = Mj[j] + Nij[i,j]
  }
}

NM = matrix(1,2,2);
for (i in 1:2){
  for (j in 1:2){
    NM[i,j]= Ni[i]*Mj[j]
  }
}
NM= NM/n;
NM
TS = 0
for (i in 1:2){
  for (j in 1:2){
    TS = TS + ((Nij[i,j]-NM[i,j])^2)/NM[i,j]
  }
}
cat(”The test statistic is”,TS)
compare = pchisq(1, 0.99, 0.01)
compare
if(TS>compare){
  cat(”The null hypothesis is rejected at the 1% level of significance”);
} else{
  cat(”The null hypothesis is accepted at the 1% level of significance”);
}
```

R code Exa 11.5.b Females reporting abuse

```
Nij<-matrix(c(28, 30, 58, 55, 472, 470, 442, 445),
    nrow = 2,ncol = 4,byrow = TRUE)
n= sum(Nij);
Ni = matrix(0,2,1);
Mj = matrix(0,4,1);
for (i in 1:2){
  for (j in 1:4){
    Ni[i] = Ni[i] + Nij[i,j]
  }
}
for (j in 1:4){
  for (i in 1:2){
    Mj[j] = Mj[j] + Nij[i,j]
  }
}
NM = matrix(1,2,4);
for (i in 1:2){
  for (j in 1:4){
    NM[i,j]= Ni[i]*Mj[j]
  }
}
NM= NM/n;

TS = 0
for (i in 1:2){
  for (j in 1:4){
    TS = TS + ((Nij[i,j]-NM[i,j])^2)/NM[i,j]
  }
}
cat("The test statistic is",TS)

compare = pchisq(3, 0.99, 0.01)
```

```
pvalue = 1- pchisq(TS, 3)
cat("The p-value is",pvalue)

compare
if(TS>compare){
  cat("The null hypothesis is rejected at the 1% level of significance");
} else{
  cat("The null hypothesis is accepted at the 1% level of significance");
}
```

R code Exa 11.6.a Testing distribution of a population

```
X<-c(66, 72, 81, 94, 112, 116, 124, 140, 145, 155);
D= 0.4831487;
n= 10;
Dgiven = 1.480;
Dstar = (sqrt(n) + 0.12 + (0.11/sqrt(n)))*D;
cat("Dstar is ",Dstar);
if(Dstar>Dgiven){
  cat("Null hypothesis is rejected at 2.5% level of significance")
  } else{
    cat("Null hypothesis is accepted at 2.5% level of significance")
  }
```

Chapter 12

Non parametric Hypothesis Tests

R code Exa 12.2.a testing the median

```
n= 200;
v = 120;
p =0.5;
if(v < (n/2)){
  pvalue = 2*pbinom(v, n, p)
} else{
  pvalue = 2*pbinom(n-v, n, p)
}
cat("Pvalue is ",pvalue)
```

R code Exa 12.2.b testing the median

```
n= 80;
v = 28;
p =0.5;

```

```
pvalue = pbinom(v, n, p);
cat("Pvalue is ",pvalue);
cat("Thus, the null hypothesis that the median
   income is less than or equal to $90,000 is
   rejected")
```

R code Exa 12.3.b Signed Rank Test

```
n =4;
mo = 2;
X<-c(4.2, 1.8, 5.3, 1.7)
t =3; #value of the test statistic (Ex12_3a)
tstar= min(t, (n*(n+1)/2) - t);
P = matrix(0,4,4);
P[1,1]= 0.5;
P[1,2] = 1;
P[1,3] = 1;
P[1,4] = 1;
for (i in 2:4){
  for (j in 1:4){
    if (j-i <1) {
      P[i,j] = 0.5*P[i-1, j]
    } else{
      P[i,j] = 0.5*(P[i-1,j-i]+P[i-1,j])
    }
  }
}
P
```

R code Exa 12.3.c Determining Population Distribution

```
n =20;
t =142;
```

```
tstar= min(t, (n*(n+1)/2) - t);
P = matrix(1,20,tstar+1);
P[1,1]= 0.5;
P[1,2] = 1;
for (i in 2:20){
  for (j in 1:(tstar+1)){
    if (j-i <1){
      P[i,j] = 0.5*P[i-1, j]
    } else{
      P[i,j] = 0.5*(P[i-1,j-i]+P[i-1,j])
    }
    }
  }
pvalue= 2*P[20,tstar+1];
cat("Pvalue is",pvalue)
cat("Thus the hypothesis that the population
   distribution is symmetric about 0 is accepted at
   the alpha = 10% level of significance")
```

R code Exa 12.4.a Treatments against corrosion

```
X<-c(65.2, 67.1, 69.4, 78.2, 74, 80.3)
Y<-c(59.4, 72.1, 68, 66.2, 58.5)
Z = append(X,Y)
Z = sort(Z);
n= length(X);
q = length(Z)
T = 0;
for (i in 1:n){
  test = X[i];
  for (j in 1:q){
    if(test== Z[j]){
      T = T+ j;
    }
  }
```

```
}

cat("The test statistic is ",T)
```

R code Exa 12.4.b Determining P

```
prob <- function(N, M, K) {
  if(N==1 & M==0){
    if(K >0){
      cat(result = 1)
    } else {
      cat(result =0)
    }
    } else if (N==0 & M==1){
        if(K <0){
          cat(result = 0)
        } else {
          cat(result =1)
        }
      } else if (N==0 & M==0 &K==0){
        cat(result =1)
      } else{
        cat(result = (prob(N-1, M, K-N-M)*(N/(N+M)))
            + (prob(N, M-1, K)*(M/(N+M))))
      }
}

pval <- function(n,m,t) {
  result = 2*min(prob(n,m,t), 1-prob(n,m,t-1));
}

'> pval(2,1,3)
001
Error: C stack usage 19923984 is too close to the
   limit
```

```

C:\Program Files\RStudio\bin>rstudio.exe --max-ppsize=5000000000

'
```

R code Exa 12.4.c Finding p value

```
prob <- function(N, M, K) {
  if(N==1 & M==0){
    if(K >0){
      cat(result = 1)
    } else {
      cat(result =0)
    }
  } else if (N==0 & M==1){
    if(K <0){
      cat(result = 0)
    } else {
      cat(result =1)
    }
  } else if (N==0 & M==0 &K==0){
    cat(result =1)
  } else{
    cat(result = (prob(N-1, M, K-N-M)*(N/(N+M))) + (
       prob(N, M-1, K)*(M/(N+M))))
  }
}

pval <- function(n,m,t) {
  result = 2*min(prob(n,m,t), 1-prob(n,m,t-1));
}

'> pval(2,1,3)
001
```

```
Error: C stack usage  19923984 is too close to the
   limit

C:\Program Files\RStudio\bin>rstudio.exe --max-
   ppsize=5000000000

'
'> pval(5,6,21)
Error: C stack usage  19923984 is too close to the
   limit'
```

R code Exa 12.4.d Comparing production methods

```r
prob <- function(N, M, K) {
  if(N==1 & M==0){
    if(K >0){
      cat(result = 1)
    } else {
      cat(result =0)
    }
  } else if (N==0 & M==1){
    if(K <0){
      cat(result = 0)
    } else {
      cat(result =1)
    }
  } else if (N==0 & M==0 &K==0){
    cat(result =1)
  } else{
    cat(result = (prob(N-1, M, K-N-M)*(N/(N+M))) + (
       prob(N, M-1, K)*(M/(N+M))))
  }
}

pval <- function(n,m,t) {
```

```
  result = 2*min(prob(n,m,t), 1-prob(n,m,t-1));
}

'> pval(9,13,72)
001
Error: C stack usage  19923984 is too close to the limit

C:\Program Files\RStudio\bin>rstudio.exe --max-ppsize=5000000000

'
```

R code Exa 12.4.e Determining p value

```
n1 =5;
m1= 6;

t1 =21;
num1 = n1*(n1+m1+1)/2;
d1=abs(t1 - num1);
val = d1/sqrt(n1*m1*(n1+m1+1)/12);
pval = 2*(1- pnorm(val, 0,1))
cat("The p-value for eg 12.4a is",pval)
n2 =9;
m2= 13;
t2 =72;
d2=abs(t2 - n2*(n2+m2+1)/2);
val = d2/sqrt(n2*m2*(n2+m2+1)/12);
pval = 2*(1-pnorm(val, 0,1));
cat("The p-value for eg 12.4d is",pval)
```

R code Exa 12.5.a Testing randomness

```
fact <- function(num) {
  if(num<=0){
    result= 1
  } else {
    result = factorial(num)
  }
}

proba <- function(n,m,k) {
  if(k%%2==0){
    k=k/2;
    result = 2*fact(m-1)*fact(n-1)*fact(n)*fact(m)/(
       fact(k-1)^2*fact(m-k)*fact(n-k)*fact(n+m));
  } else {
    k = (k-1)/2;
    result = fact(m-1)*fact(n-1)*fact(n)*fact(m)/(
       fact(k-1)*fact(k)*fact(m-k)*fact(n-k-1)*fact(
       n+m)) + fact(m-1)*fact(n-1)*fact(n)*fact(m)/(
       fact(k-1)*fact(k)*fact(m-k-1)*fact(n-k)*fact(
       n+m));
  }
}


r1 = 20;
n1 = 20;
m1=10;
ans1 =0;
for (i in 1:19){
  ans1 =ans1 + proba(n1,m1,i);
}
if(ans1<0.5){
  pvalue1 = 2*ans1;
} else {
  pvalue1 = 2*(1-ans1);
}

cat("P-value is",pvalue1)
```

R code Exa 12.5.c Determining p value

```
u = 61;
sigma = 5.454;
r =75;
val = pnorm((r-u)/sigma, 0,1)
if(val>0.5){
  pvalue = 2*(1-val)
} else{
  pvalue = 2*val
}
cat("P-value is",pvalue)
```

Chapter 13

Quality Control

R code Exa 13.2.a Steel shaft diameter

```
X<-c(3.01, 2.97, 3.12, 2.99, 3.03, 3.02, 3.10, 3.14,
    3.09, 3.20)
Y<-seq(1,10,1)
u = 3;
sigma = 0.1;
n=4;
ucl = u + (3*sigma/sqrt(n));
lcl = u - (3*sigma/sqrt(n));
Z<-seq(0.1,10,0.1)
P= matrix(1,1,100)
Q= matrix(1,1,100)
P =P*ucl;
Q =Q*lcl;
plot(Y, X)
plot(Z, P)
plot(Z, Q)
cat('ucl is',ucl)
cat('lcl is',lcl)
```

R code Exa 13.2.b unknown mean and variance

```
Xbar<-c(3.01, 2.97, 3.12, 2.99, 3.03, 3.02, 3.10,
    3.14, 3.09, 3.20)
S<-c(0.12, 0.14, 0.08, 0.11, 0.09, 0.08, 0.15, 0.16,
     0.13, 0.16)
c<-c(0.7978849, 0.8862266, 0.9213181, 0.9399851,
    0.9515332, 0.9593684, 0.9650309, 0.9693103,
    0.9726596)
n=4;
Xbarbar= mean(Xbar);
Sbar =mean(S);
lcl = Xbarbar - (3*Sbar/(sqrt(n)*c(n-1)));
ucl = Xbarbar + (3*Sbar/(sqrt(n)*c(n-1)));
u = Xbarbar;
sigma= Sbar/c[n-1];
prob = pnorm(3.1, u, sigma) - pnorm(2.9, u, sigma);
cat("Percentage of the items that will meet the
    specifications is",prob*100)
```

R code Exa 13.3.a determining control limits

```
Xbar<-c(35.1, 33.2, 31.7, 35.4,  34.5, 36.4, 35.9,
    38.4, 35.7, 27.2, 38.1, 37.6, 38.8, 34.3, 43.2,
    41.3, 35.7, 36.3, 35.4, 34.6)
S<-c(4.2, 4.4, 2.5, 3.2, 2.6, 4.5, 3.4, 5.1, 3.8,
    6.2, 4.2, 3.9, 3.2, 4, 3.5, 8.2, 8.1, 4.2, 4.1,
    3.7)
c<-c(0.7978849, 0.8862266, 0.9213181, 0.9399851,
    0.9515332, 0.9593684, 0.9650309, 0.9693103,
    0.9726596)
Y<-seq(1,20,1)
n =5;
Z<-seq(0.1,20,0.1)
Xbarbar = mean(Xbar);
```

```
Sbar = mean(S);
lclX = Xbarbar - (3*Sbar/(sqrt(n)*c[n-1]));
uclX = Xbarbar + (3*Sbar/(sqrt(n)*c[n-1]));
val1 = 1/c[n-1]
val1 = val1^2;
val1 = val1 - 1;
val = sqrt(val1);
ucls = Sbar*(1+(3*val));
lcls = Sbar*(1-(3*val));
plot(Y, Xbar)
P<-matrix(1,1, 200)
Q<-matrix(1,1, 200)
P= P*lclX;
Q=Q*uclX;
cat('UCL(X)=',uclX)
cat('LCL(X)=',lclX)
plot(Z, P)
plot(Z, Q,main = 'Control Chart for X')
cat('UCL(S)=',uclX)
cat('LCL(S)=',lclX)
plot(Y, S)
P= P*lcls/lclX;
Q=Q*ucls/uclX;
plot(Z, P)
plot(Z, Q,main = 'Control Chart for S')
```

R code Exa 13.4.a Defectives Screws

```
defect<-c(6, 5, 3, 0, 1, 2, 1, 0, 2, 1, 1, 3, 2, 0,
   1, 1, 0, 2, 1, 2)
F<-c(0.12, 0.10, 0.06, 0.00, 0.02, 0.04, 0.02, 0.00,
    0.04, 0.02, 0.02, 0.06, 0.04, 0.00, .02, 0.02,
   0.00, 0.04, 0.02, 0.04)
total = 1000;
Fbar = sum(defect)/total;
```

```
n=50;
val = sqrt(Fbar*(1-Fbar)/n);
lcl = Fbar - (3*val);
ucl = Fbar + (3*val);
cat("LCL is" ,lcl)
cat("UCL is",ucl)
for (i in 1:20){
  if( F[i]>ucl | F[i]<lcl) {
    totald=sum(defect)-defect[i]
  }
}
total =  total - 50;
Fbar = totald/total;
val = sqrt(Fbar*(1-Fbar)/n);
cat("After recomputation");
lcl = Fbar - (3*val);
ucl = Fbar + (3*val);
cat("LCL is",lcl)
cat("UCL is",ucl)
```

R code Exa 13.5.a Control during production of cars

```
X<-c(141, 162, 150, 111, 92, 74, 85, 95, 76, 68, 63,
    74, 103, 81, 94, 68, 95, 81, 102, 73)
total = sum(X);
num = 20;
Xbar = mean(X);
lcl = Xbar - 3*sqrt(Xbar);
ucl = Xbar + 3*sqrt(Xbar);
cat("UCL is",ucl)
cat("LCL is",lcl)
for (i  in 1:20){
  if(X[i]> ucl){
    total = total - X[i]
    num= num -1
```

```
  }
}
Xbar = total/num
lcl = Xbar - 3*sqrt(Xbar);
ucl = Xbar + 3*sqrt(Xbar);
cat("After recomputation")
cat("UCL is",ucl)
cat("LCL is",lcl)
total = total - X[4]
num = num-1;
cat("Xbar is",Xbar)
cat(" is",X[4])
Xbar = total/num
lcl = Xbar - 3*sqrt(Xbar);
ucl = Xbar + 3*sqrt(Xbar);
cat("After second recomputation")
cat("UCL is",ucl);
cat("LCL is",lcl);
cat("It appears that the process is in control with mean",Xbar);

'The mean after the second recomputation is incoreectly calculated in the textbook. It should be
((17*84.41)-111 )/16 = 82.748 whereas the value given in the book is 82.56. The values of UCL and LCL
change accordingly.'
```

R code Exa 13.6.b Service Time

```
X<-c(48, 52, 70, 62, 57, 81, 56, 59, 77, 82, 78, 80, 74, 82, 68, 84)
u = 62;
n = 4;
```

```
sigma = 24;
alpha = 0.25;
W = matrix(0,17);
W[1] = 60;
for (i in 2:17){
  W[i] = (0.25*X[i-1]) + (0.75*W[i-1])
}
cat("The values of W are",W)
val = 3*sigma*sqrt(alpha/(n*(2-alpha)));
lcl = u- val;
ucl = u+ val;
cat("LCL is",lcl)
cat("UCL is",ucl)
```

R code Exa 13.6.c Exponentially weighted moving average control

```
X<-c(9.617728, 10.25437, 9.867195, 10.79338,
   10.60699, 10.48396, 13.33961, 9.462969, 10.14556,
    11.66342,  11.55484, 11.26203, 12.31473,
   9.220009, 11.25206, 10.48662, 9.025091, 9.693386,
    11.45989, 12.44213, 11.18981, 11.56674,
   9.869849, 12.11311, 11.48656)
t<-seq(1,26,1)
alpha = 2/9;
val = 9.915051 - (alpha*9.617728);
val = val/(1-alpha);
cat("val is",val)
u = 10;
n = 5;
sigma = 2;

W = matrix(0,26)
W[1] = 10.;
for (i in 2:26){
  W[i] = (alpha*X[i-1]) + ((1-alpha)*W[i-1])
```

```
}
cat("The values of W are",W)
val = 3*sigma*sqrt(alpha/(n*(2-alpha)));
lcl = u- val;
ucl = u+ val;
cat("LCL is",lcl)
cat("UCL is",ucl)
plot(t,W,xlab ="t",ylab = "W")
nlcl = matrix(1,1, 26)
nlcl= nlcl* lcl;
lines(t,nlcl)
nucl = matrix(1, 1, 26);
nucl= nucl * ucl;
lines(t,nucl)

'The asymptpotic lines for UCL and LCL have been
   plotted '
```

R code Exa 13.6.d Finding control limit

```
X<-c(29, 33, 35, 42, 36, 44, 43, 45)
u =30;
sig = 8;
d =0.5;
B =5;
Y = X - u - (d*sig);
S = matrix(0,9);
S[1] =0;
for (i in 2:9){
  S[i]= max(S[i-1] + Y[i-1], 0)
}
cat("S is",S)
cl = B*sig;
cat(cl)
answer =100;
```

```
for ( i in 1:9){
  if(S[i]>cl){
    answer = i
  }
}
cat("The mean has increased after observing the ",
   answer-1," subgroup average")
```

Chapter 14

Life Testing

R code Exa 14.3.a Lifetime of a transistor

```
total =50;
failure = 15;
alpha = 0.05;
t =525;
val1 = qchisq(alpha/2,2*failure)
val2 = qchisq(1-alpha/2,2*failure)

int1 = 2*t/val1;
int2 = 2*t/val2;
cat("The 95% confidence interval is",int2,"to",int1)

'The confidence interval is from 22.35 to 62.17 whereas solution in R is 22.35 to 62.53
because of the difference in the value of chi-square (0.975, 30).
The textbook says the value is 16.89 whereas R calculates its value as 16.79'
```

R code Exa 14.3.b Lifetime of Battery

```
t = 1800;
theta = 150;
r =20;
pvalue = 1 - pchisq(2*r,2*t/theta)
cat("P-value is ",pvalue)
```

R code Exa 14.3.c One at a time sequential test

```
T = 500;
alpha = 0.05;
r = 10;
val1 = qchisq(1-alpha/2, 2*r)
val2 = qchisq(alpha/2, 2*r)
int1= 2*T/val1;
int2= 2*T/val2;
cat("The 95% confidence interval is",int1,"to",int2)

'The confidence interval is from 29.27 to 103.52
    whereas solution in R is 29.265774 to
104.26683 because of the difference in the value of
    chi-square(0.975, 30).
The textbook says the value is 9.66 whereas scilab
    calculates its value as 9.5907774 '
```

R code Exa 14.3.d Lifetime of semiconductors

```
r = 30;
T = 600;
theta = 25;
val1 = pchisq(2*T/theta,2*r)
val2 = 1 - pchisq(2*T/theta,2*(r+1))
val2
pvalue = min(val1, val2);
```

```
cat("The pvalue is",pvalue)
cat("H0 would be accepted when the significance
   level is 0.10")
```

R code Exa 14.3.e Bayes estimator

```
X<-c(5, 7, 6.2, 8.1, 7.9, 15, 18, 3.9, 4.6, 5.8)
Y<-c(3, 3.2, 4.1, 1.8, 1.6, 2.7, 1.2, 5.4, 10.3,
   1.5)
t = sum(X)+sum(Y);
R =10;
a = 20;
b = 2;
estimate = (R+b)/(a+t);
cat("Bayes estimate of lambda is",estimate)
```

R code Exa 14.4.a Lifetime of items produced by two plants

```
Xlife = 420;
Ylife = 510;
Xnum=  10;
Ynum =15;
ts = Xlife*Ynum/(Ylife*Xnum);
cat( "The value of the test statistic is",ts)
val = pf(ts, Xnum, Ynum)
pvalue = 2*(1-val);
cat("The p-value is",pvalue)
cat("We cannot reject H0");
```