

R Textbook Companion for  
Probability, Random Variables, and Stochastic  
Processes  
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May 19, 2020

<sup>1</sup>Funded 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:** Probability, Random Variables, and Stochastic Processes

**Author:** Athanasios Papoulis and S. Unnikrishna Pillai

**Publisher:** Mcgraw Hill Education (India) Private Limited

**Edition:** 4

**Year:** 2002

**ISBN:** 9780070486584

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 1

## The Meaning of Probability

**R code Exa 1.2** probability that the sum of the numbers that show equals 7 when two dice are rolled

```
1 #page no. 7
2 #LOAD PACKAGE —————>prob
3 #example 1-2
4 #function used: rolldie(): This function is used to
  get sample space for the experiment of rolling a
  die repeatedly.
5 #               nrow(): Gives the total number of
  rows
6
7 library(prob)
8 no_of_favourable_outcome= nrow(subset(s,X1+X2==7))
  #outcomes such that their sum equals 7 when two
  dices are rolled
9 total_outcomes=nrow(s)
                                     #all possible
  outcomes
10
11 probability=no_of_favourable_outcome/total_outcomes
12 print(probability)
```

---



**R code Exa 1.3** probability that the length of a randomly selected cord is greater than the length  $r$  times square root of 3 of the inscribed equilateral triangle

```
1 #page no. 8-9
2 #example 1-3
3
4 # this example shows that in different cases the
   probability can be different that's why conditions
   of probability
5 # should be specified correctly
6
7 #NOTE: assuming radius  $r = 1$  throughout the solution
   for simplicity
8
9     #CASE I
10 area_of_circle_with_radius_r= 3.14*1*1
11 area_of_circle_with_radius_half_r= (3.14*1*1)/4
12
13 probability_caseI=area_of_circle_with_radius_half_r/
   area_of_circle_with_radius_r
14 print(probability_caseI)
15
16     #CASE II
17
18 favourable_outcome_in_caseII=(2*3.14*1)/3
19 total_outcome_in_caseII=2*3.14*1
20
21 probability_caseII=favourable_outcome_in_caseII/total
   _outcome_in_caseII
22 print(probability_caseII)
23
24     #CASE III
25
```

```

26 favourable_outcome_in_caseIII=1
27 total_outcome_in_caseIII=2
28
29 probablity_caseIII=favourable_outcome_in_caseIII/
    total_outcome_in_caseIII
30 print(probablity_caseIII)

```

---

#### R code Exa 1.4 probability of finding particles in boxes

```

1 #page no. 10-11
2 #example 1-4
3
4 #the solution to this problem depends on the choice
    of possible and favorable outcomes
5 #therefore we shall consider three celebrated cases
6
7         #case I : maxwell-boltzmann statistics
8
9 m_caseI=6
10 n_caseI=2
11 p_caseI=factorial(n_caseI)/(m_caseI^n_caseI)
12 print(p_caseI)
13
14
15         #case II : bose-einstein statistics
16
17 m_caseII=6
18 n_caseII=2
19 p_caseII= (factorial(m_caseII-1)*factorial(n_caseII)
    )/(factorial(n_caseII + m_caseII - 1))
20 print(p_caseII)
21
22         #case III : fermi-dirac statistics
23
24 m_caseIII=6

```

```
25 n_caseIII=2
26 p_caseIII= (factorial(n_caseIII)*factorial(m_caseIII
    - n_caseIII))/factorial(m_caseIII)
27 print(p_caseIII)
```

---

# Chapter 2

## The Axioms of Probability

**R code Exa 2.1** subsets of faces

```
1 #page no. 16
2 #example 2-1
3
4 elements=6
5 subsets=2^elements
6 print(subsets)
```

---

**R code Exa 2.2** calculation of subsets

```
1 #page no. 16
2 #example 2-2
3
4 elements=4
5 subsets=2^elements
6 print(subsets)
```

---

**R code Exa 2.5** probability of first 2 heads when a coin is tossed 3 times

```
1 #page no. 24
2 #example 2-5 (b)
3
4 total_outcomes=8
5 three_heads=1
6 heads_in_first_two_tosses=2
7
8 #probability of getting "three heads"
9 p_three_heads=three_heads/total_outcomes
10 print(p_three_heads)
11
12 #probability of getting "two heads in first two
    tosses"
13 p_heads_in_first_two_tosses=heads_in_first_two_
    tosses/total_outcomes
14 print(p_heads_in_first_two_tosses)
```

---

**R code Exa 2.10** conditional probability

```
1 #page no. 29
2 #example 2-10
3
4 total_outcomes=6
5 favourable_A=1    #favourable outcome for event A={f2
    }
6 favourable_M=3    #favourable outcome for event M={f2
    ,f4,f6}
7
8 p_A=favourable_A/total_outcomes    #probability of
    occurrence of event A
9 p_M=favourable_M/total_outcomes    #probability of
    occurrence of event M
10
```

```

11 p_AM=p_A/p_M    #condition probability of event A
    after even M has happened
12 print(p_AM)

```

---

**R code Exa 2.11** condition probability of event A after even M has happened

```

1 #page no. 30
2 #example 2-11
3
4 alpha_t=function(t){3*10^-9*t^2*(100-t)^2}    #this
    is the function alpha(t)
5
6 p_A=integrate(alpha_t, lower = 60, upper = 70)    #p
    {60<=t<=70}
7 p_M=integrate(alpha_t, lower = 60, upper = 100)    #p
    {60<=t<=100}
8
9 p_AM=p_A$value/p_M$value    #condition
    probability of event A after even M has happened
10
11 print(p_AM)

```

---

**R code Exa 2.12** probability of second red ball event when first white ball event has happened

```

1 #page no. 30-31
2 #example 2-12
3
4 #First Solution is theoritical therefore only second
    solution is coded here
5
6 #Second Solution

```

```

7
8
9 p_W=3/5      #probability of first white ball
10 p_R=2/4     #probability of second red ball
11 p_RW=p_R*p_W # probability of second red ball
    event when first white ball event has happened
12
13 print(p_RW)

```

---

**R code Exa 2.13** calculation of smallest number of balls in the box

```

1 #page no. 31
2 #example 2-13
3
4 #part (a)
5
6 b=1
7
8 cat((sqrt(3)+1)*(b/2),"< a < ",1+(sqrt(3)+1)*(b/2))
    #(2-40) in the book
9
10 #therefore
11 a=2
12
13 p_w2_w1= ((a-1)*a)/((a+b-1)*(a+b))      #(2-39) in
    the book
14
15 print(p_w2_w1)
16
17 print("Thus the smallest number of balls required is
    3")

```

---

**R code Exa 2.15** calculation of probability that the person under test has that particular cancer

```
1 #page no. 33–34
2 #example 2–15
3
4 p_TC=0.95
5 p_C=0.02
6 p_TH=0.05
7 p_H=0.98
8
9 p_CT=(p_TC*p_C)/((p_TC*p_C)+(p_TH*p_H))      #this
      formula is obtained using Bayes' theorem
10
11 print(p_CT)
12
13 #this result states that if the test is taken by
      someone from this population without knowing
      whether that person
14 #has the disease or not, then even a positive test
      only suggests that there is a 27.6% chance of
      having a disease
```

---

**R code Exa 2.16** probability that the selected component is defective

```
1 #page no. 34–35
2 #example 2–16
3
4 #(part a)
5
6 p_B1=p_B2=p_B3=p_B4=1/4
7
8 p_DB1=0.05    #given in the question
9 p_DB2=0.4     #given in the question
10 p_DB3=0.1     #given in the question
```



```

11 p_DB4=0.1      #given in the question
12
13 p_D=p_DB1*p_B1 + p_DB2*p_B2 + p_DB3*p_B3 + p_DB4*p_
    B4
14
15 print(p_D)
16
17 #(part b)
18
19 p_B2D=p_DB2*p_B2/p_D
20
21 print(p_B2D)

```

---

**R code Exa 2.18** various probabilities related to arrival of trains

```

1 #page no. 36-38
2 #example 2-18
3
4 #part a
5
6 p_C_favourable=200      #area of the triange in the
    event
7 p_C_total=400           #total area
8 p_C=p_C_favourable/p_C_total
9 print(p_C)
10
11 #part b
12 p_D_favourable=159.5    #area of the region D
13 p_D_total=400           #total area
14 p_D=p_D_favourable/p_D_total
15 print(p_D)
16
17 #part c
18 p_CD_favourable=72      #area of the trapezoid CD
19 p_CD_total=159.5

```

```

20 p_CD=p_CD_favourable/p_CD_total
21 print(p_CD)

```

---

**R code Exa 2.20** probability that two or more persons will have the same birthday in a group

```

1 #page no. 39-40
2 #example 2-20
3
4 N=365      #number of days in one year
5
6     #PART (a)
7
8
9 n=23      #group of people
10 p=1-exp((-n*(n-1))/(2*N))
11
12 cat("In a group of 23 people it gives probability of
      at least one match to be",p)
13
14 n=50
15 p=1-exp((-n*(n-1))/(2*N))
16 cat("in a group of 50 person , the probability of
      birthday match is ",p)
17 #answer in the book is 0.97 which is due to
      approximation
18
19
20     #PART (b)
21
22
23
24 n=253
25 p_personal=1-exp(-n/N)      #probability of personal
      match

```

```
26 print("For a modest 50-50 chance in this case the
    group size needs to be about 253 ")
27
28 #if n=1000
29 n=1000
30 p_personal=1-exp(-n/N)
31
32 cat("In a group of 1000 people, chances are about ",
    p_personal*100,"% that there will be someone
    sharing your birthday")
```

---

## Chapter 3

### Repeated Trials

**R code Exa 3.3** probability that the ball from B1 box will be white and the ball from B2 box will be Red

```
1 #page no. 49
2 #example 3-3
3
4 w1_favourable=10      #number of white balls in box B1
5 w1_total=15           #total number of balls in box B1
6 p_w1=w1_favourable/w1_total
7
8 r2_favourable=20      #number of red balls in box B2
9 r2_total=40           #total number of balls in box B2
10 p_r2=r2_favourable/r2_total
11
12 p_w1r2=p_w1*p_r2
13 print(p_w1r2)
```

---

**R code Exa 3.7** probability that six will show twice when fair die is rolled five times

```

1 #page no. 54
2 #example 3-7
3
4
5
6 #this is the probability that "six" will show twice
  when fair die is rolled five times
7
8 p5_2=(factorial(5)/(factorial(2)*factorial(3)))*(1/
  6)^2*(5/6)^3 #usig the "FUNDAMENTAL THEOREM" of
  Success or Failure of an Event A in n
  Independent Trials
9
10 print(p5_2)

```

---

**R code Exa 3.8** probability of obtaining double six at least once when pair of dice is rolled n times

```

1 #page no. 54-55
2 #example 3-8
3
4
5 #PART (b)
6
7 p_b=1/36
8 p_b_bar=1-p_b
9 p=log(2)/(log(36)-log(35)) #using the
  equation (3-15)
10 print(p)
11
12 print("Thus in 25 throws one is more likely to get
  double six at least once than not to get it at
  all.")
13 print("Also in 24 or less throws, there is greater
  chance to fail than to succeed")

```

---

**R code Exa 3.12** kmax and k1 and k2 are calculated

```
1 #page no. 57
2 #example 3-12
3
4 #PART (a)
5
6
7 n=10      #(given)
8 p=1/3     #(given)
9
10 k_max=floor((n+1)*p)      #floor() function
    returns the largest integer not greater than the
    giving number and hence act as "greatest integer
    function" of mathematics
11
12 cat("hence Kmax=",k_max)
13
14
15
16 #PART (b)
17
18 n=11      #(given)
19 p=1/2     #(given)
20 k1=(n+1)*p
21 k2=k1-1
22 cat("hence k1=",k1," ,k2=",k2)
```

---

**R code Exa 3.13** probability that the total number of defective parts does not exceed 1100 in an order

```

1 #page no. 58
2 #example 3-13
3
4 #sum function is used to do the summation
5 #choose function is used to do the nCr
6
7
8 p=0.1      #probability that a part is defective (
              given)
9 n=10^4     #total parts
10 k=0:1100  #limit of defective parts
11
12 pb=sum(choose(n,k)*(p^k)*((1-p)^(n-k)))          #
              this is required probability
13
14 pb
15
16 print("The value tends to infinity therefore R is
          taking it as NaN")

```

---

**R code Exa 3.14** probability that a player has k matches in the lottery

```

1 #page no. 61-62
2 #example 3-14
3
4 p_winning_the_lottery=(6*5*4*3*2*1)/(51*50*49*48*47*
    46)      #probability of winning the lottery when
              total number of balls ,n=51 and number of good
              balls ,m=6
5 print(p_winning_the_lottery)
6
7 winning_prize=4000000
8 average_gain=(winning_prize*p_winning_the_lottery)-1
9 print(average_gain)
10

```

```

11 winning_prize_5matches=15000
12 odds_winning_5matches=66701
13 average_gain_5matches=(winning_prize_5matches/odds_
    winning_5matches) - 1
14 print(average_gain_5matches)
15
16 winning_prize_4matches=200
17 odds_winning_4matches=1213
18 average_gain_4matches=(winning_prize_4matches/odds_
    winning_4matches) - 1
19 print(average_gain_4matches)

```

---

**R code Exa 3.16** probability of winning the game

```

1 #page no. 67–68
2 #example 3–16
3
4 t_7_favourable=6           #ways in which total
    could be 7 when pair of dies are thrown
5 t_11_favourable=2          #ways in which total
    could be 11 when pair of dies are thrown
6 total_outcomes=36
7 p_t_7=t_7_favourable/total_outcomes    #probability
    of having sum equals 7 when two dies are thrown
8 p_t_11=t_11_favourable/total_outcomes  #probability
    of having sum equals 11 when two dies are thrown
9 p_p1=p_t_11 + p_t_7        #probability of winning
    the game by throwing a 7 or 11 on the first throw
10
11 print(p_p1)
12
13      #ak_n=p_k_n/p_k_n+(p_k_n+1/6)      this
    formula is used to calculate ak_n which
    is given by equation number 3–59 in
    the book

```



```

14
15 p_k_4=3/36 #probability of having sum
    equals 4 when two dies are thrown
16 ak_4=p_k_4/(p_k_4+1/6)
17
18 p_k_5=4/36 #probability of having sum
    equals 5 when two dies are thrown
19 ak_5=p_k_5/(p_k_5+1/6)
20
21 p_k_6=5/36 #probability of having sum
    equals 6 when two dies are thrown
22 ak_6=p_k_6/(p_k_6+1/6)
23
24 p_k_8=5/36 #probability of having sum
    equals 8 when two dies are thrown
25 ak_8=p_k_8/(p_k_8+1/6)
26
27 p_k_9=4/36 #probability of having sum
    equals 9 when two dies are thrown
28 ak_9=p_k_9/(p_k_9+1/6)
29
30 p_k_10=3/36 #probability of having
    sum equals 10 when two dies are thrown
31 ak_10=p_k_10/(p_k_10+1/6)
32
33 p_p2=ak_4*p_k_4 + ak_5*p_k_6 + ak_6*p_k_6 + ak_8*p_k
    _8 + ak_9*p_k_9 + ak_10*p_k_10
34 print(p_p2)
35
36 p_winning_the_game=p_p1+p_p2
37 print(p_winning_the_game)
38
39 #the answer in the book is 0.492929 but by the
    approximation in R the answer with the code is
    0.5040404

```

---

**R code Exa 3.17** probability that how many plays should A choose to win the game

```
1 #page no. 68-70
2 #example 3-17
3
4 #taking p=0.47
5
6 p=0.47
7 n1=(1/(1-(2*p)))-1
8 n2=(1/(1-(2*p)))+1
9
10 cat(n1,"<=2n<=",n2)          # this is equation (3-71)
11 print("therefore if p=0.47, then 2n=16")
12
13 #when p=0.48
14 p=0.48
15 n1=(1/(1-(2*p)))-1
16 n2=(1/(1-(2*p)))+1
17
18 cat(n1,"<=2n<=",n2)
19
20 #when p=0
21 p=0
22 n1=(1/(1-(2*p)))-1
23 n2=(1/(1-(2*p)))+1
24
25 cat(n1,"<=2n<=",n2)
26
27 print("Finally if p=0, then (3-71) gives the optimum
      number of plays to be 2")
```

---

# Chapter 4

## A Concept of a Random Variable

**R code Exa 4.1** function of random variable

```
1 #page no. 72
2 #example 4-1
3
4 #PART (a)
5
6 xfi=10*i
7
8 xf1=10*1
9 cat("x(f1)=",xf1)
10
11 xf2=10*2
12 cat("x(f2)=",xf2)
13
14 xf3=10*3
15 cat("x(f3)=",xf3)
16
17 xf4=10*4
18 cat("x(f4)=",xf4)
19
```

```

20 xf5=10*5
21 cat("x(f5)=",xf5)
22
23 xf6=10*6
24 cat("x(f6)=",xf6)
25
26 #part (b)
27
28
29 xf1=xf3=xf5=0
30 xf2=xf4=xf6=1
31
32 cat("x(f1)=x(f3)=x(f5)=",xf1)
33 cat("x(f2)=x(f4)=x(f6)=",xf2)

```

---

**R code Exa 4.4** probabilities at different values of x

```

1 #page no. 76
2 #example 4-4
3
4
5 xfi=10i
6
7 f100=1    #since it contain of the fi's therefore it
            is a certain event
8 f35=3/6   #since x<=35 will only include {f1,f2,f3}
9 f30.1=3/6 #since x<=35 will only include {f1,f2,f3}
            }
10 f30=3/6   #since x<=35 will only include {f1,f2,f3}
11 f29.99=2/6 #since x<=35 will only include {f1,f2}
12 cat("F(100)=",f100)
13 cat("F(35)=",f35)
14 cat("F(30.1)=",f30.1)
15 cat("F(30)=",f30)
16 cat("F(29.99)=",f29.99)

```

```

17
18 #distribution function of x is a staircase function
    as plotted below
19
20 x <- c(0,10,20,30,40,50,60)
21 y=c(0,1/6,2/6,3/6,4/6,5/6,6/6)
22 plot(x, y, type = "S", ylab = "F(x)")

```

---

**R code Exa 4.9** finding the function  $f_x$  for random variable  $x$

```

1 #page no. 81
2 #example 4-9
3
4 #for  $x < 0$ 
5  $f_x = 1/4$ 
6
7 #for  $1 \leq x \leq 2$ 
8
9  $f_x = 3/4$ 
10
11
12 print("the function  $f(x)$  comes out to be a staircase
    like function which is plotted below")
13 x <- c(0,1,2,3)
14 y<-c(0,1/4,3/4,1)
15 plot(x, y, type = "S", ylab = "F(x)")

```

---

**R code Exa 4.10** probability of the appliance that it will not fail in the next 5 years

```

1 #page no. 86-87
2 #example 4-10
3

```

```

4 p=exp(-5/10) #probability that appliance will not
   fail in next 5 years
5
6 print(p)
7 #the answer in the book is 0.368 which seems WRONG
   to me

```

---

**R code Exa 4.11** the conditional probability that the customer will spend an additional 10 minutes in the restaurant

```

1 #page no. 87
2 #example 4-11
3
4 p=exp(-10/5) #the probability that a customer
   will spend more than 10 minutes in the restaurant
5 print(p)
6
7 p_additional_10=exp(-2) #the conditional
   probability that the customer will spend an
   additional 10 minutes in the restaurant
8 print(p_additional_10)

```

---

**R code Exa 4.13** probabilities of team winning the games

```

1 #page no. 97
2 #example 4-13
3
4 #the choose() function calculate the nCr and sum()
   function calculates the summation
5
6 k=3:5
7 p=1/2
8 p_A_wins=sum(choose(k-1,2)*p^3*(1-p)^(k-3))

```

```

9
10 cat(" If p=",p," then P(A wins)=", p_A_wins)
11
12 k=4
13 p_4_games=choose(k-1,2)*p^3*(1-p)^(k-3)
14 cat("The probability that A will win in exactly four
    games is ", p_4_games)
15
16 k=3
17 p_3_games=choose(k-1,2)*p^3*(1-p)^(k-3)
18
19 cat("the probability that A will win in four games
    or less is ",p_4_games,"+",p_3_games,"=",p_4_
    games+p_3_games)
20
21 k=2:4
22 p_conditional=sum(choose(k-1,1)*((1/2)^2)*((1/2)^(k
    -2)))
23 cat("Given that A has won the first game, the
    conditional probability of A winning equals",p_
    conditional)

```

---

**R code Exa 4.14** the conditional probability of random variable  $x$  of fair die experiment

```

1 #page no. 98-99
2 #example 4-14
3
4 #probabilities are found out just by observing the
    different situation
5
6 # if  $x \geq 60$ 
7
8 p_M=3/6
9 p_XM=p_M/p_M

```

```

10 print(p_XM)
11
12 #if 40 <= x < 60
13
14 p_X=2/6
15 p_XM=p_X/p_M
16 print(p_XM)
17
18 #if 20 <= x < 40
19
20 p_X=1/6
21 p_XM=p_X/p_M
22 print(p_XM)
23
24 #if x<20
25
26 p_XM=0
27 print(p_XM)

```

---

**R code Exa 4.19** probability density function of a random variable x

```

1 #page no. 103–105
2 #example 4–19
3
4 k=6 #number of heads
5 n=10 #number of specific tosses
6 p_B=(k+1)/(n+2)
7 print(p_B)
8
9 #this example shows that if the probability density
  function of a random variable x is unknown, one
  should make
10 #noncommittal judgement about its a priori
  probability density function f(x). Usually, the
  uniform distribution

```



```

11 #is a reasonable assumption in the absence of any
    other information. then experimental results (A)
    are obtained
12 #and the knowledge about x is updated reflecting
    this new information. Bayes' rule helps to obtain
    the a posteriori
13 #probability density function of x given A. From
    that point on, this a posteriori probability
    density function  $f(x|A)$ 
14 #should be used to make further predictions and
    calculations

```

---

**R code Exa 4.20** probability of heads coming 500 and 510 times when the coin is tossed 1000 times

```

1 #page no. 107
2 #example 4-20
3
4 p=q=0.5 #probability of head/tail when a coin is
    tossed
5 n=1000 #number of times the coin is tossed
6
7 #part (a)
8 p_A=1/sqrt(2*3.14*n*p*q)
9 print(p_A)
10
11 #part (b)
12
13 p_B=(exp(-0.2))/(10*sqrt(5*3.14))
14 print(p_B)
15
16 #in book the solution of part (b) is rounded to
    0.0207

```

---

**R code Exa 4.21** example of FUNDAMENTAL THEOREM of Success or Failure of an Event A in n Independent Trials and The normal Approximation DeMoivre Laplace Theorem

```

1 #page no. 107
2 #example 4-21
3
4 p=0.5
5 n=10
6 k=5
7 q=1-p
8
9 #part (a)
10
11 p_n_k=choose(n,k)*(p^k)*(q^(n-k))           #usig the "
        FUNDAMENTAL THEOREM" of Success or Failure of an
        Event A in n Independent Trials
12 print(p_n_k)
13
14 #part (b)
15
16 pnk=(exp((- (k-n*p)^2)/(2*n*p*q)))/sqrt(2*3.14*n*p*q)
        #using "The normal Approximation (
        DeMoivre-Laplace Theorem)
17 print(pnk)

```

---

**R code Exa 4.22** probability that the number of heads is between 4900 and 5100 when coin is tossed 10000 times

```

1 #page no. 109
2 #example 4-22
3

```

```

4 n=10000      #number of times the coin is tossed (
    given)
5 p=q=0.5      #probability of getting head(or tail)
    in one toss
6 k1=4900
7 k2=5100
8 x2=(k2-n*p)/sqrt(n*p*q)
9 print(x2)
10 x1=(k1-n*p)/sqrt(n*p*q)
11 print(x1)
12
13 inte<-function(y){exp(-(y^2)/2)}

    #these two lines (13 and 14) gives the
    defination of function G(x)
14 Gx<-function(x){((1/(sqrt(2*3.14)))*integrate(inte,
    lower = 0,upper = x)[[1]])+0.5}      #which is
    given on page number 106
15
16 probability=(2*Gx(2))-1
17 cat("probability equals ",probability)
18
19 #answer in the book is 0.9545 with is by
    apprimation of different values

```

---

**R code Exa 4.23** probability of random calls in four hour interval

```

1 #page no. 109
2 #example 4-23
3
4 K=50:70      #number of calls is 50 to 70
5
6
7 probabilitySumation=sum((exp(-((K-60)^2)/80)/(4*sqrt
    (5*22/7))))

```

```

8 cat("probability using sumation formula ",
    probabilitySumation)
9
10 inte<-function(y){exp(-(y^2)/2)}

    #these two lines (10 and 11) gives the
    defination of function G(x)
11 Gx<-function(x){((1/(sqrt(2*3.14)))*integrate(inte,
    lower = 0,upper = x)[[1]])+0.5}    #which is
    given on page number 106
12
13 probability=(2*Gx(sqrt(2.5)))-1
14 cat("probability using G(x) function (The Normal
    Approximation) is ",probability)
15
16 print("probability by both the methods are similar
    as lot of approximation comes into play in
    sumation formula")

```

---

**R code Exa 4.24** probabilities for various values of n

```

1 #page no. 109
2 #example 4-23
3
4 p=q=0.5    #(given)
5 e=0.05
6
7
8    #taking n=100
9 n1=100
10 x1=e*sqrt(n1/(p*q))
11
12 inte<-function(y){exp(-(y^2)/2)}

    #these two lines gives the defination of

```

```

function G(x)
13 Gx<-function(x){((1/(sqrt(2*3.14)))*integrate(inte,
    lower = 0,upper = x)[[1]])+0.5}      #which is
    given on page number 106
14
15 probability1=(2*Gx(x1))-1
16
17
18 #taking n=400
19 n2=400
20 x2=e*sqrt(n2/(p*q))
21
22 inte<-function(y){exp(-(y^2)/2)}

    #these two lines gives the defination of
    function G(x)
23 Gx<-function(x){((1/(sqrt(2*3.14)))*integrate(inte,
    lower = 0,upper = x)[[1]])+0.5}      #which is
    given on page number 106
24
25 probability2=(2*Gx(x2))-1
26
27 #taking n=900
28 n3=900
29 x3=e*sqrt(n3/(p*q))
30
31 inte<-function(y){exp(-(y^2)/2)}

    #these two lines gives the defination of
    function G(x)
32 Gx<-function(x){((1/(sqrt(2*3.14)))*integrate(inte,
    lower = 0,upper = x)[[1]])+0.5}      #which is
    given on page number 106
33
34 probability3=(2*Gx(x3))-1
35
36
37

```

```

38
39 table <- matrix(c(n1,n2,n3,x1,x2,x3,probability1,
    probability2,probability3),ncol=3,byrow=TRUE)
40 #colnames(table) <- c("n")
41 rownames(table) <- c("n","0.1 sqrt(n)","2G(0.1 sqrt(n)
    )-1")
42 table<-as.table(table)
43
44 print("table shows the probability 2G(0.1 sqrt(n))-1
    that k is between 0.45n and 0.55n for various
    values of n ")
45
46 table

```

---

**R code Exa 4.26** probability when a fair die is rolled 10 times

```

1 #page no. 111
2 #example 4-26
3
4
5
6 p1=1/6      #A1={f1}
7 p2=3/6      #A2={f2 , f4 , f6 }
8 p3=2/6      #A3={f3 , f5 }
9
10 print(p1)
11 print(p2)
12 print(p3)
13
14 p_10=(factorial(10)/(factorial(3)*factorial(6)*
    factorial(1)))*((1/6)^3)*((1/2)^6)*(1/3)      #p10
    (3,6,1)
15 print(p_10)
16
17 #answer in the book is given 0.002 which is wrong

```

---

**R code Exa 4.27** probability that the system of 1000 components will function at the end of one month

```
1 #page no. 113
2 #example 4-27
3
4 p=10^-3 #probability of failure (given)
5 q=1-p
6 n=10^3 #number of components (given)
7
8 p_K=q^n
9
10
11
12 p_k=exp(-n*p) #after applying approximation
13 #techniques
14 print(p_k)
```

---

**R code Exa 4.28** the probability P that there will be more than five defective parts in a order of 3000 parts

```
1 #page no. 113-114
2 #example 4-28
3
4 k=0:5
5 p_K_lessthan_5=exp(-3)*sum(3^k/factorial(k))
6 print(p_K_lessthan_5)
7
8 p_K_greaterthan_5=1- p_K_lessthan_5
9 print(p_K_greaterthan_5)
10
```

```
11 #in book the answer is given 0.084 which is just
    round off
```

---

**R code Exa 4.29** probability of an insurance company to suffer loss or make profit

```
1 #page no. 114-115
2 #example 4-29
3
4 n=10^5    #number of people (given)
5 p=0.001   #probability of causality (given)
6 lambda=n*p
7
8
9     #part (a)
10
11 n0=(50*10^6)/200000
12
13
14 del=(lambda*exp((1-lambda/n0)))/n0
15
16 cat("del equals",del,"so that del^250 = 0 and the
    desired probability is essentially 0")
17
18
19
20     #part (b)
21
22 n1=((50*10^6)-(25*10^6))/200000
23 print(n1)
24
25 del=0.9771
26 deln1=del^n1
27 print(deln1)
28
```



```

29 p_x=1-(((deln1*1)/(sqrt(2*3.14*n1))*((1-lambda)/(n1
    +1))))
30 print(p_x)
31
32 #the answer in the book is 0.9904 which is
    approximation which signifies that the company is
    assured a profit of $25
33 #million with almost certainty

```

---

**R code Exa 4.30** probability of shots to hit an aircraft

```

1 #page no. 115
2 #example 4-30
3
4
5
6 #when lambda=4
7 lambda=4
8
9 p_not_hit=(1+lambda)*exp(-lambda)
10 print(p_not_hit)
11 #this is given as 0.0916 which is just round off
12
13
14 #when lambda=5
15 lambda=5
16 p_not_hit=(1+lambda)*exp(-lambda)
17 print(p_not_hit)
18
19 #if 5000 shots are fired at the aircraft then the
    probability of miss
20 p_miss=exp(-5)
21 print(p_miss)

```

---

**R code Exa 4.31** probabilities of winning a lottery

```
1 #page no. 115-116
2 #example 4-31
3
4 #the probability of buying a winning ticket
5 no_of_winning_tickets=100
6 total_no_of_tickets=10^6
7 p=no_of_winning_tickets/total_no_of_tickets      #the
   probability of buying a winning ticket
8 print(p)
9
10 n=100 #number of ticket purchased
11 lambda=n*p
12
13 #part (a)
14
15 p_win=1- exp(-lambda)
16 print(p_win)
17
18 #part (b)
19
20 #in this part we have to find lambda such that the
   probability of winning is >=0.95
21 #for that lambda should be >=3
22 #for which n>=30000
23 p_win=1- exp(-3)
24 print(p_win) #probability of winning comes out to
   be >=0.95
```

---

**R code Exa 4.32** probability that a spacecraft mission will be danger

```

1 #page no. 116
2 #example 4-32
3
4 k=0:4
5 n=20000    #number of components in spacecraft (given
              )
6 p=10^-4    #probability of any one component
              defective (given)
7 lambda=n*p
8
9 p_danger_mission=1-(exp(-2)*sum((lambda^k)/factorial
              (k)))
10 print(p_danger_mission)

```

---

# Chapter 5

## Functions of One Random Variable

**R code Exa 5.1** finding the function  $F_y$

```
1 #page no. 124-125
2 #example 5-1
3
4
5 #part (a)
6
7 #a and b are constant in the function therefore
  assuming b=4 and a=2 for the purpose of plotting
  graphs
8
9 curve((x-4)/2,from = -50, to= 50,main="part (a)",
  ylab ="y")
10
11 #part (b)
12
13 curve(1-((x-4)/2),from = -50, to= 50,main="part (b)"
  ,ylab ="y")
```

---

**R code Exa 5.2** the function  $y$  equals  $x$  square

```
1 #page no. 125–126
2 #example 5–2
3
4
5 # this is the cure of  $y=x^2$ 
6 curve(x^2,from = -20,to=20,ylab = "y",main="figure
  5–3a")
```

---

**R code Exa 5.5** the  $g_x$  function

```
1 #page no. 127–128
2 #example 5–5
3
4 #the function  $F_y(y)$  is a staircase function and is
  plotted below
5
6 x<-c(-2,-1,0,1,2)
7 y<-c(0,0.5,0.5,1,1)
8 plot(x, y, type = "s", ylab = " $F_y(y)$ ",xlab = "y" ,
  axes = TRUE)
```

---

**R code Exa 5.9** different probabilities for the function  $y$  equals  $x$  square

```
1 #page no. 129
2 #example 5–9
3
4 y=x^2    #given function
```

```

5
6 #part (a)
7
8 #for differenct values of x with probability 1/6 the
   respective values of y with probability 1/6
9 x=1
10 y=x^2
11 print(y)
12
13 x=2
14 y=x^2
15 print(y)
16
17 x=3
18 y=x^2
19 print(y)
20
21 x=6
22 y=x^2
23 print(y)
24
25 #part (b)
26
27 #y for different values of x with probability 1/6
28
29 x=-2
30 y=x^2
31 print(y)
32
33 x=-1
34 y=x^2
35 print(y)
36
37 x=0
38 y=x^2
39 print(y)
40
41 x=1

```

```

42 y=x^2
43 print(y)
44
45 x=2
46 y=x^2
47 print(y)
48
49 x=3
50 y=x^2
51 print(y)
52
53 print("on different values of x , y takes the values
      0,1,4,9 with probabilities 1/6,2/6,2/6,1/6,
      respectively")

```

---

#### R code Exa 5.10 random variable for voltage

```

1 #page no. 131
2 #example 5-10
3
4 i=0.01    #(given)
5 ro=1000   #(given)
6
7 #if r is between 900 and 1100
8 r1=900
9 v1=i*(r1+ro)
10
11 r2=1100
12 v2=i*(r2+ro)
13
14
15 cat("If the resistance r is a random varibale
      uniform between",r1,"and",r2,"ohm ,then v is
      uniform between ",v1,"and ",v2,"V")

```

---

**R code Exa 5.17** mean of random variable

```
1 #page no. 140
2 #example 5-17
3
4 ex=1/6*(1+2+3+4+5+6)
5
6 cat("If x takes the values 1,2,...,6 with probability
      1/6, then E{x}=",ex)
```

---

**R code Exa 5.27** mean and variance of resultant current

```
1 #page no. 150-121
2 #example 5-27
3
4
5 E=120 #voltage
6 n=10^3
7 sigma_square=(100^2)/3
8 gn=E/n
9
10 gnd=-1*E/(n^2)
11
12 gndd=2*E/(n^3)
13
14 cat("g(n)=",gn)
15 cat("g'(n)=",gnd)
16 cat("g''(n)=",gndd)
17
18 cat("E{i}=",gn,"+",gndd*sigma_square/2)
    #using (5-85)
```



```
19 cat("sigma_i_square=", gnd^2*sigma_square)  
    #using (5-87)
```

---

# Chapter 7

## Sequences of Random Variables

**R code Exa 7.4** measurement errors

```
1 #page no. 247–248
2 #example 7–4
3
4 x1=98.6
5 x2=98.8
6 x3=98.9
7 sigma1=0.20
8 sigma2=0.25
9 sigma3=0.28
10
11 E=(x1/sigma1^2 + x2/sigma2^2 + x3/sigma3^2)/(1/
    sigma1^2 + 1/sigma2^2 + 1/sigma3^2)
12
13 cat("estimate E obtained from (7–17) comes out to be
    ",E)
```

---

**R code Exa 7.16** The probability of k heads in six tosses

```

1 #page no. 280
2 #example 7-16
3
4
5 pk=function(k){choose(6,k)*(1/2^6)}
6 nk=function(k){exp(-((k-3)^2)/3)/(sqrt(3*22/7))}
7
8
9 table <- matrix(c(0,1,2,3,4,5,6,pk(0),pk(1),pk(2),pk
    (3),pk(4),pk(5),pk(6),nk(0),nk(1),nk(2),nk(3),nk
    (4),nk(5),nk(6)),ncol=7,byrow=TRUE)
10 #colnames(table) <- c("n")
11 rownames(table) <- c("k","Pk","N(n,sig)")
12 table<-as.table(table)
13 table
14
15 #the values of Pk varies a little bit from the book
    because of approximation

```

---

# Chapter 8

## Statistics

**R code Exa 8.1** life expectancy of the battery

```
1 #page no. 305
2 #example 8-1
3
4 #functions used
5 #qnorm():quantile function of the normal
   distribution:the quantile function maps from
   probabilities to values in normal distribution
6 #ceiling():ceiling(x) rounds to the nearest integer
   that's larger than x.
7
8
9 rho=0.05
10
11 z0.975=ceiling(qnorm(1-rho/2))
12
13 cat("we can expect with confidence coefficient 0.95
   that the life expectancy of our battery will be
   between ",4-(z0.975*0.5),"and ",4+(z0.975*0.5),"
   years")
```

---

**R code Exa 8.2** number of heads when a fair coin is tossed 100 times with given confidence coefficient

```
1 #page no. 306
2 #example 8-2
3
4 n=100 #number of times the coin is tossed (given)
5 p=0.5 #probability of getting head in one coin toss
   (given)
6 q=1-p
7 k1=n*p - 3*sqrt(n*p*q)
8 k2=n*p + 3*sqrt(n*p*q)
9
10
11 cat(" We predict ,therefore , with confidence
      coefficient 0.997 that the number of heads will
      be between ",k1,"and ",k2)
```

---

**R code Exa 8.3** finding the confidence interval of the voltage

```
1 #page no. 309
2 #example 8-3
3
4 #functions used
5 #qnorm():quantile function of the normal
   distribution:the quantile function maps from
   probabilities to values in normal distribution
6 #ceiling():ceiling(x) rounds to the nearest integer
   that's larger than x.
7
8 rho=0.05
9 z0.975=ceiling(qnorm(1-rho/2))
```

```

10
11 #part (a)
12
13 x_bar=112      #(given)
14 sigma=0.4      #(given)
15 n=25           #number of times the voltage is
                  measured
16 i=z0.975*sigma/sqrt(n)
17
18 cat("Insetting values into (8-11),we obtain the
      interval ",x_bar,"+-",i,"V")
19
20 #part (b)
21
22 s=0.6
23 i2=z0.975*s/sqrt(n)
24 cat("Insetting values into (8-14),we obtain the
      approximate estimate ",x_bar,"+-",i2,"V")
25
26 print("Since  $t_{0.975}(25)=2.06$  (from the table) the
      exact estimate (8-17) yields  $112 \pm 0.247$  V")

```

---

**R code Exa 8.4** finding confidence interval of light bulb

```

1 #page no. 311
2 #example 8-4
3
4 x_bar=210      # (given)
5
6 z=2
7 n=64          #number of bulbs
8 h1=x_bar/(1+(z/sqrt(n)))      #using the
      EXPONENTIAL DISTRIBUTION. given by equation
      (8-18) in the book
9 h2=x_bar/(1-(z/sqrt(n)))

```

```

10
11 cat("We thus expect with confidence coefficient 0.95
      that the mean time to failure of the bulb is
      between ",h1," and ",h2," hours.")

```

---

**R code Exa 8.5** finding confidence interval of particles emitted from a radioactive substance

```

1 #page no. 312
2 #example 8-5
3
4 x_bar=6
5
6 cat("(z^2)/n=0.0625 then the equation (8-19) yields
      the quadratic ")
7 cat("(lambda-6)^2=0.0625lambda")
8
9 #from the equation and comparing coefficient with ax
   ^2+bx+c=0
10 a=1
11 b=-12.0625
12 c=36
13
14 #finding solution of the quadratic equation
15
16 l1=(-b-sqrt(b^2 - 4*a*c))/(2*a)
17 l2=(-b+sqrt(b^2 - 4*a*c))/(2*a)
18
19 cat("We can thus claim with confidence coefficient
      0.95 that ",l1,"< lambda <",l2)

```

---

**R code Exa 8.6** confidence interval of the poll

```

1 #page no. 313
2 #example 8-6
3
4 z=2          #(given)
5 n=500        # total number of persons (given)
6 r=240        #person who reported Republican
7
8 x_bar=r/n
9
10 p=z*sqrt((x_bar*(1-x_bar))/n)      #using the
    equation (8-21)
11
12 cat("equation (8-21) yields the interval",x_bar,"+-"
    ,p)
13
14 #answers givent in the book are approximate answers

```

---

**R code Exa 8.7** finding interval estimate of variance

```

1 #page no. 314-315
2 #example 8-7
3
4 #part (a)
5
6 n=6
7 v_cap=0.25
8 x1=qchisq(0.975,6)      #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
9 x2=qchisq(0.025,6)      #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
10 c1=n*v_cap/x1
11 c2=n*v_cap/x2
12

```



```

13 cat("(8-23) yields ",c1,"< sigma^2 <",c2,". The
    corresponding interval for sigma is ",sqrt(c1),"<
    sigma <",sqrt(c2),"V")
14 #there is slight difference in the values in the
    book and that is due to approximation
15
16 #part (b)
17
18
19 n=5
20 s=0.6
21 x1=qchisq(0.975,5)      #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
22 x2=qchisq(0.025,5)      #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
23 c1=(n-1)*s^2/x1
24 c2=(n-1)*s^2/x2
25
26 cat("(8-24) yields ",c1,"< sigma^2 <",c2,". The
    corresponding interval for sigma is ",sqrt(c1),"<
    sigma <",sqrt(c2),"V")
27 #there is slight difference in the values in the
    book and that is due to approximation

```

---

**R code Exa 8.8** finding confidence interval of the median of x

```

1 #page no. 315
2 #example 8-8
3
4 #functions used
5 #qnorm():quantile function of the normal
    distribution:the quantile function maps from
    probabilities to values in normal distribution

```

```

6 #ceiling(): ceiling(x) rounds to the nearest integer
   that's larger than x.
7
8 rho=0.05
9 u=0.5
10 n=100    #samples of x (given)
11 z=ceiling(qnorm(1-rho/2))
12
13 k=n*u - z*sqrt(n*u*(1-u))           #using the
   equation (8-26)
14
15 k_plus_r=n*u + z*sqrt(n*u*(1-u))    #using the
   equation (8-26)
16
17 print(k)
18 print(k_plus_r)
19
20 cat("thus we can claim with condidence coefficient
   0.95 that the median of x is between y40 and y60"
   )

```

---

**R code Exa 8.21** testing the hypothesis related to voltage

```

1 #page no. 321
2 #example 8-21
3
4 x_bar=110.12
5 v0=110
6 n=25    #number of times V is measured
7
8    #part (a)
9
10 sigma=0.4
11 z=2
12 q=(x_bar-v0)/(sigma/sqrt(n))

```

```

13 print(q)
14
15 cat("since", q, "is in the interval(-2,2), we accept
      H0")
16
17
18 #part (b)
19
20 s=0.6
21 q=(x_bar-v0)/(s/sqrt(n))
22 print(q)
23 cat("since", q, "is in the interval(-2.06,2.06), we
      accept H0")

```

---

**R code Exa 8.22** testing the hypothesis that a coin is fair against the hypothesis that it is loaded in favor of heads

```

1 #page no. 360
2 #example 8-22
3
4 #functions used
5 #qnorm():quantile function of the normal
   distribution:the quantile function maps from
   probabilities to values in normal distribution
6
7
8 alpha=0.05
9 z=qnorm(1-alpha)
10
11 q=(62-50)/sqrt(25)
12
13
14 cat("since q=",q,">",z,"the fair coin hypothesis is
      rejected")

```

---

**R code Exa 8.24** Testing the hypothesis that the die is fair

```
1 #page no. 362
2 #example 8-24
3
4 k=c(55,43,44,61,40,57)          #(given)
5 np0=50                          #(given)
6 q=sum(((k-np0)^2)/np0)
7
8 x=qchisq(0.95,5)                #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
9
10 cat(" Since  $(X_{0.95}(5))^2 =", x, ">", q, "$  We accept the
    fair-die hypothesis")
```

---

**R code Exa 8.25** testing the independence hypothesis related to graduate students of a certain university

```
1 #page no. 363
2 #example 8-25
3
4 ki=c(168,68,131,33)
5 poi=c(0.45,0.15,0.3,0.1)
6
7 q=sum(((ki-400*poi)^2)/(400*poi))
8
9 x=qchisq(0.95,3)                #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
10
```

```
11 cat(" Since (X0.95(3))^2 =",x,">",q," We accept the  
indepndence hypothesis")
```

---

**R code Exa 8.26** testing the uniformity hypothesis related to computer generated decimal numbers

```
1 #page no. 364
2 #example 8-26
3
4 ki=c(43,56,42,38,59,61,41,57,46,57)      #(given)
5 m=500
6 poi=0.1
7
8 q=sum(((ki-m*poi)^2)/(m*poi))
9
10 x=qchisq(0.95,9)      #qchisq() is the function
    used to calculate Chi-square percentile value in
    R
11
12 cat(" Since (X0.95(9))^2 =",x,">",q," We accept the  
uniformaity hypothesis")
```

---

# Chapter 9

## General Concepts

**R code Exa 9.10** various probabilities related to normal process

```
1 #page no. 386
2 #example 9-10
3
4 #part (a)
5
6 inte<-function(y){exp(-(y^2)/2)}
7
8     #these two lines (6 and 7) gives the defination
9     of function G(x)
10 Gx<-function(x){((1/(sqrt(2*3.14)))*integrate(inte,
11     lower = 0,upper = x)[[1]])+0.5}    #which is
12     given on page number 106
13
14 p=Gx(-1/2)
15 print(p)
16
17 #part (b)
18
19 c=8*(1-exp(-0.6))    #variance
20 print(c)
21
```

```
17 p=2*Gx(1/1.9) - 1
18 print(p)
```

---

# Chapter 14

## Entropy

**R code Exa 14.1** calculation of entropy in a fair die experiment

```
1 #page no. 630
2 #example 14-1
3
4     #part (a)
5
6 Hu=(-1/2*log(1/2))-(1/2)*log(1/2)
7
8 print(Hu)
9
10 #which is log(2)
11
12
13     #part(b)
14
15 hv=(-1/6*log(1/6))-(1/6)*log(1/2)-(1/6)*log(1/6)-(1/
      6)*log(1/6)-(1/6)*log(1/6)-(1/6)*log(1/6)
16
17 print(hv)
18
19 #which is log(6)
```

---



**R code Exa 14.2** calculation of entropy in a coin experiment

```
1 #page no. 631
2 #example 14-2
3
4 hp=function(p){-p*log(p)-(1-p)*log(1-p)}
5
6 plot(hp,xlab="p",ylab = "h(p)")
7
8 print("The function h(p) is plotted for 0 <= p <= 1.
      This function is symmetrical, convex, even about
      the point p=0.5 and it reaches its maximum at
      that point. ")
9 print("furthermore , h(0)=h(1)=0")
```

---

**R code Exa 14.4** relation between entropy of partitions

```
1 #page no. 641
2 #example 14-4
3
4 p=0.4      #(given)
5 pa=0.22    #(given)
6 pb=0.18    #(given)
7
8 hu=-((p*log(p))+(0.35*log(0.35))+(0.25*log(0.25)))
9 print(hu)
10
11 hb=-(pa*log(pa)+pb*log(pb)+0.35*log(0.35)+0.25*log
      (0.25))
12 print(hb)
13
14 cat("thus H(U)=",hu,"<",hb,"= H(B)")
```

```
15
16 #the answers in the book are slightly different. I
    looks to me that they are wrong because I have
    done exactly same calculation and answers are
    little different.
```

---

**R code Exa 14.7** condition entropy of a partition in fair die experiment

```
1 #page no. 645
2 #example 14-7
3
4 p-fi-even-ieven=1/3      #if i is even
5 p-fi-even-iodd=0        #if i is odd
6 p-fi-odd-iodd =1/3      #if i is odd
7 p-fi-odd-ieven=0        #if i is even
8
9 hv_even=-(1/3*log(1/3) + 1/3*log(1/3) + 1/3*log(1/3)
    )      #which is log(3)
10 print(hv_even)      #which is log(3)
11
12 hv_b=0.5*log(3) + 0.5*log(3)      #which is log(3)
13
14 print(hv_b)      #which is log(3)
15
16 cat("Thus, in the absence of any information , our
    uncertainty about V equals H(V)=log6.")
17 print("If we know, however, whether at each trial '
    even' or 'odd' showed, then our uncertainty is
    reduced to H(v|B)) = log3")
```

---

**R code Exa 14.8** information about an element partition

```
1 #page no. 647
```

```

2 #example 14-8
3
4 H_V=log(6)      #given
5 H_VB=log(3)    #given
6 H_B=log(2)     #given
7 H_BV=0         #given
8
9 I_VB=log(2)    #this is obtain just by observing
10
11 print("Thus the information about the element
      partition V resulting from the observation of the
      even-odd partition B equals log2")

```

---