Punyashlok Ahilyadevi Holkar Solapur University, Solapur
Department of Statistics
M.Sc. (Biostatistics) Part-I (Sem-II)
Biostatistics Paper: HCT-2.2
Title of Paper: Statistical Inference-I
Question Bank

Short Answer

1 Define sufficient statistic and minimal sufficient statistic.
2 Define a minimal sufficient statistic. Provide minimal sufficient statistic for power series distribution.
3 Define minimal sufficient statistic. Give an example of a sufficient statistic which is not minimal sufficient.
4 Show that order statistics are always sufficient.
5 Define power series distribution. Give an example of the same. Obtain sufficient statistic for power series distribution.
6 Define power series distribution. Give any two examples of distributions that are members of power series distribution.
7 Define one parameter exponential family of distributions. Obtain minimal sufficient statistic for one parameter exponential family of distributions.
8 Define complete and bounded complete family of distributions.
9 State Basu's theorem. Illustrate the applicability of Basu's theorem with example.
10 Define ancillary statistic. Provide one example of the same.
11 Give an ancillary statistic based on two random variables X_1 and X_2 from exponential distribution with mean $1/\theta$. Explain why your statistic is ancillary.
12 State necessary and sufficient for existence of UMVUE.
13 Define Fisher information in a single observation and in n iid observations.
14 Define Fisher information matrix.
15 State Rao-Blackwell and Lehmann-Schffe theorems.
16 Define strongly consistent estimator. Does it imply weakly consistent?
17 Define weak consistency and strong consistency.
18 Define consistent estimator. State invariance property of consistent estimator.
19 Define consistent estimator. Give an example of consistent estimator that is not MLE.
20 Prove that, if there are two consistent estimators then we can construct infinitely many consistent estimators.

21 Define consistent estimator. State the consistent estimator of the population location parameter θ based on random sample of size n from $Cauchy(\theta, 1)$ population.

22 Define asymptotic relative efficiency and mean square consistency.

23 Define CAN estimator for real parameter θ. Give an example of CAN estimator which is not MLE.

24 State invariance properties of consistent and CAN estimators.

25 Based on random sample of size n from Poisson (λ), state the consistent estimators of $P_{\lambda}(X=0)$ and $P_{\lambda}(X=1)$.

Short Notes

1 Pitman family of distributions

2 Minimal sufficient statistic

3 Bounded completeness.

4 Basu's theorem and its applications.

5 Power series family

6 Minimal sufficient statistic for pitman family

7 Completeness and bounded completeness

8 Sufficiency in Power series distribution

9 Fisher information matrix

10 Cramer-Rao lower bound

11 Methods of finding consistent estimators.

12 Comparisons of consistent estimators.

13 Consistency in r^{th} mean

Long Answer

1 Define sufficient statistic. Examine whether one-to-one function of a sufficient statistic is also sufficient.

2 What do you mean by a sufficient statistic? Is every statistic sufficient? If not, give a counter example.

3 Define sufficient statistic. State Neyman-Fisher factorization theorem. Examine whether one-to-one function of a sufficient statistic is also sufficient.

4 Give an example to show that a sufficient statistic need not be complete.

5 Define sufficient statistic and minimal sufficient statistic. Explain the method of constructing sufficient statistic.

6 Define one parameter exponential family of distributions. Obtain a minimal sufficient statistic for this family.

7 State and prove Neyman factorization theorem for finding the sufficient statistic.

8 Define completeness. Prove or disprove that the family of binomial distributions is complete.

9 Define an ancillary statistic. Show that a complete sufficient statistic is uncorrelated with every ancillary statistic.

10 State and prove Basu's theorem. Illustrate its applicability with example.

11 State and prove Basu's theorem. Give its one application.

12 Define Pitman family of distributions. Show that the following distributions belong to Pitman family. (i) $U\ (0, \theta)$ (ii) Exponential with location θ

13 Define Power series family of distributions. show that $B\ (n, \theta)$ distribution belong to power series family.

14 Show that Poisson distribution belong to power series family.

15 Define one parameter exponential family of distributions. Obtain minimal sufficient statistic for this family and show that it is complete.

16 Obtain a sufficient statistic for θ based on a random sample of size n from a pdf / pmf $f(x, \theta)$ that belongs to exponential class of distributions.

17 If T is unbiased estimator of θ. Is it always true that T^2 is not unbiased estimator of θ^2.

18 State and prove Lehmann-Scheffe theorem.

19 State and prove Rao-Blackwell theorem.

20 State and prove a necessary and sufficient condition for an estimator of a parametric function $\psi(\theta)$ to be UMVUE.

21 Obtain UMVUE of $e^{-\theta}$ based on random sample of size n from Poisson distribution with mean θ.

22 Define UMVUE. Obtain UMVUE of $P(X = 1)$ based on a random sample of size n, where X has $Poisson\,(\lambda)$ distribution.

23 Define UMVUE. Obtain UMVUE of $p\,(1-p)$ based on a random sample of size n from $B\,(1, p)$ distribution.

24 Define Fisher information contained in a single observation and in $n\ (>1)$ independent and identically distributed observations.

25 Define Fisher information in a single observation. Find the same for $B\,(n, \theta)$ distribution, when n is known.

26 Define Fisher information matrix. Obtain Fisher information matrix in case of normal distribution with parameters μ and σ^2.

27 Based on random sample of size n from $N(\theta_1, \theta_2)$ distribution, obtain Fisher information matrix.

28 State and prove Cramer-Rao inequality with necessary regularity conditions.

29 State Cramer-Rao inequality. Give two examples of estimators such that the mean square error of one attains Cramer-Rao lower bound while that of the other does not.

30 State and establish Chapman-Robins-Kiefer inequality.

31 Obtain Bhattacharya bound under regularity conditions to be stated. Obtain C-R lower bound as a special case of Bhattacharya bound.

32 Obtain an expression for k^{th} Bhattacharya lower bound. Let X has $Poisson\ (\lambda)$ distribution. Obtain second order Bhattacharya lower bound for the estimator of λ^2.

33 Define a consistent estimator for a vector parameter. Show that joint consistency is equivalent to marginal consistency.

34 Define consistent estimator. State and prove invariance property of consistent estimator of a real valued parameter θ.

35 Show that sample distribution function at a given point is CAN for the population distribution function at the same point.

36 Define joint and marginal consistency for a vector parameter θ. Show that T is marginally consistent for θ if and only if it is jointly consistent.

37 Show that sample mean is consistent estimator of population mean whenever population mean is finite. .

38 Define CAN estimator for a real parameter θ. State and prove invariance property for a CAN estimator. .

39 Define joint and marginal consistency for a vector parameterθ. Show that joint consistency is equivalent to marginal consistency.

40 Describe the method of percentiles to obtain consistent estimator.

41 In case of one parameter exponential family, show that moment estimator based on sufficient statistic is CAN for the parameter.

42 Define CAN estimator. Show that sample distribution function at a given point is CAN for the population distribution function at the same point.

43 In case of one parameter exponential family of distributions, prove that moment estimator based on sufficient statistic is CAN for θ.

44 For a one parameter (θ) exponential family of distributions, prove that maximum likelihood estimator leads to a CAN estimator of θ.

45 Define a maximum likelihood estimator for a parameter θ, and state the large sample properties of this type of estimator under regularity conditions, to be stated clearly.

46 Describe the method of maximum likelihood estimation for estimating an unknown parameter.

47 Define MLE. Show that an MLE, if exists, is a function of sufficient statistic.

48 Define MLE. State and prove the invariance property of MLE.

49 Describe a method of moments for estimation and give an example for it.

50 Describe method of moments and method of minimum chi-square.

51 Describe the method of scoring for obtaining maximum likelihood estimator of a parametric function.

52 Explain the method of scoring for estimating the parameter θ for a multinomial distribution where the cell probabilities are known functions of a single parameter θ.

53 Describe the method of minimum Chi-square for estimating an unknown parameter.

Problems

1 Let random variable X has $B(n, \theta)$ distribution. Show that distribution of X is complete.

2 Let random variable X has Poisson (θ) distribution. Show that distribution of X is complete.

3 Let random variable X has $U(0,\theta), \theta > 0$ distribution. Show that distribution of X is complete.

4 Let random variable X has $N(\theta, 1)$ distribution. Show that family of X is complete.

5 Show that the family of discrete uniform distributions $\{f(x,N) = \frac{1}{N}, N \geq 1, is$ integer$\}$ is complete.

6 Let $X_1, X_2, \ldots, X_n$ be random sample from population with pmf $P(x,N) = \frac{1}{N}$, $x = 1,2,\ldots,N$, where N is unknown positive integer. Show that $T = X_{(n)}$ is complete sufficient statistic for N.

7 Let $X_1, X_2, \ldots, X_n$ be random sample from Poisson (θ) distribution. Show that $\sum X_i$ is complete sufficient statistic for θ.

8 Let $X_1, X_2, \ldots, X_n$ be random sample of size n from $U(0, \theta)$ distribution. Obtain complete sufficient statistic for θ.

9 Let $X_1, X_2, \ldots, X_n$ be random sample of size n from $N(\mu, \sigma^2)$ distribution with σ^2 known. Use Basu's theorem to show that $\overline{X}$ and $S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \overline{X})^2$ are independently distributed.

10 Let $X_1, X_2, \ldots, X_n$ be a random sample from $U(0,\theta), \theta > 0$ distribution. Show that $X_{(n)}$ is sufficient statistic for θ, but $X_{(1)}$ is not sufficient statistic.

11 Let $X_1, X_2, ..., X_n$ be a random sample from N$(0, \sigma^2)$. Show that $\sum_{i=1}^{n} X_i^2$ is a minimal sufficient statistic for σ^2.

12 Let $X_1, X_2, ..., X_n$ be a random sample from $U(0, \theta)$. Obtain a minimal sufficient statistic for θ.

13 Let X_1, X_2 are iid Poisson random variables with parameter λ. Let $T_1 = X_1 + X_2$ and $T_2 = X_1 + 2X_2$. Show that T_1 is sufficient statistic but T_2 is not sufficient

14 Let $X_1, X_2, ..., X_n$ $(n \geq 2)$ be a random sample from $B(1, \theta)$ distribution. Obtain UMVUE of $\psi(\theta) = \theta(1-\theta)$.

15 Use Rao-Blackwell theorem to derive UMVUE of $P(X_1 = 0)$ based on sample $X_1, X_2, ..., X_n$ from Poisson (λ), $\lambda > 0$ distribution.

16 Given a random sample of size n from Poisson distribution with mean λ, obtain UMVUE of $\lambda e^{-\lambda}$.

17 Let $X_1, X_2, ..., X_n$ be a random sample from

$$P(X = k) = \begin{cases} \dfrac{1}{N} & , k = 1, 2, ..., N \\ 0 & , \text{otherwise} \end{cases}$$

Find UMVUE of N.

18 Let $X_1, X_2, ..., X_6$ be iid distributed random variables with $P\{X_1 = 1\} = \theta = 1 - P\{X_1 = 0\}$, $0 < \theta < 1$. Obtain UMVUE of $\theta(1-\theta)$.

19 Let $X_1, X_2, ..., X_n$ be iid distributed $N(\mu, 1)$ random variables. Examine whether there exists an unbiased estimator of $\dfrac{1}{\mu}$ and UMVUE of $\dfrac{1}{\mu}$.

20 Obtain UMVUE of $p(1-p)$ based on a random sample of size n from $B(1, p)$ distribution.

21 Derive UMVUE of $1/\theta$ based on a random sample from $U(0, \theta)$ distribution.

22 Obtain UMVUE of $P((X = 1)$ based on a random sample of size n, where X has $Poisson$ (λ) distribution.

23 Obtain UMVUE of $P((X = 0)$ based on a random sample of size n, where X has $Poisson$ (λ) distribution.

24 Let $X_1, X_2, ..., X_n$ be iid random variables with common pdf $f(x, y) = k(1 + x\theta); -1 < x < 1, -1 < \theta < 1.$

Find the value of k. Find an unbiased estimator of θ based on all the random variables.

25 Let $X_1, X_2, ..., X_n$ is a random sample from the distribution having pdf

$$f(x,\theta) = \begin{cases} \theta x^{\theta - 1}, \ 0 < x < 1, \ \theta > 0 \\ 0 \ , \text{ otherwise} \end{cases}.$$

Show that $\overline{X}$ is an unbiased estimator of $\theta/(\theta + 1)$.

26 Let $X_1, X_2, ..., X_n$ be iid Poisson (λ) random variables. Obtain Cramer-Rao lower bound for unbiased estimator of λ.

27 Let random variable X has $NB(r, p)$ distribution. Show that $\dfrac{r}{X + r - 1}$ is unbiased estimator of p.

28 Let $X_1, X_2, ..., X_n$ be a random sample of size n from $N(\mu, \sigma^2)$. Obtain the Fisher information matrix.

29 Define Fisher information matrix and obtain the same in case of normal distribution with parameters θ and σ^2.

30 Let $\{X_n\}$ be a sequence of *iid* exponential with location θ. Show that $X_{(1)}$ is consistent but not CAN for θ.

31 Find consistent estimator of σ^2 based on random sample of size n from $N(\mu, \sigma^2)$ distribution.

32 Let $X_1, X_2, ..., X_n$ be *iid* exponential with location θ. Examine whether $X_{(1)}$ is CAN for θ.

33 Let $X_1, X_2, ..., X_n$ be *iid* $U(\theta, 1), \theta > 0$. Show that $2\overline{X}_n$ is CAN for θ but $X_{(n)}$ is not CAN for θ.

34 Based on random sample of size n from $N(\mu, \sigma^2)$, obtain MLE of (μ, σ^2). Show that it is CAN for (μ, σ^2).

35 Suppose X has Poisson (λ) distribution. Find CAN estimator for $P(X = 0)$ on the basis of sample of size n from X.

36 Based on random sample of size n from $U(0, \theta)$ distribution, consider $T_1 = X_{(n)}$ and $T_2 = 2\overline{X}_n$ two estimators of θ. Obtain ARE of T_1 with respect to T_2.

37 Let $\{X_n\}$ be a sequence of *iid* random variables with common *pdf* $f(x;\theta)=e^{-(x-\theta)}$, $x>\theta$, $\theta\in R$. Examine whether MLE of θ is CAN.

38 Let $X_1, X_2, ..., X_n$ be a random sample from $U(0,\theta)$. Find two consistent estimators of θ. Examine the CAN property of suggested estimators.

39 Let $X_1, X_2, ..., X_n$ be a random sample from exponential distribution with location parameter θ. Find two consistent estimators of θ. Examine the CAN property of suggested estimators.

40 Let $X_1, X_2, ..., X_n$ be a random sample from $N(\theta,\sigma^2)$. Find two consistent estimators of σ^2. Examine the CAN property of suggested estimators.

41 Let $X_1, X_2, ..., X_n$ be iid with pdf $f(x;\theta)=e^{-(x-\theta)}$, $x\geq\theta, \theta\in R$. Obtain consistent but not CAN estimator of θ.

42 Let $X_1, X_2, ..., X_n$ be *iid* exponential with location θ. Examine whether $X_{(1)}$ is CAN for θ.

43 Let $X_1, X_2, ..., X_n$ be *iid* exponential with location parameter θ, computing the actual probability show that $X_{(1)}$ is consistent estimator of θ.

44 Let $X_1, X_2, ..., X_n$ be *iid* exponential with location parameter θ. Examine whether $T_n = X_{(1)}$ is consistent estimator of θ.

45 Let $X_1, X_2, ..., X_n$ be *iid* $N(\theta,1)$, computing the actual probability show that $\overline{X}_n$ is consistent estimator of θ.

46 Let $X_1, X_2, ..., X_n$ be *iid* $U(0,\theta)$, computing the actual probability show that $X_{(n)}$ is consistent estimator of $U(0,\theta)$.

47 Based on random sample of size n from $U(0,\theta), \theta>0$, consider two estimators $T_1 = X_{(n)}$ and $T_2 = 2\overline{X}_n$. Obtain ARE of estimator T_1 with respect to T_2.

48 Let $X_1, X_2, ..., X_n$ be *iid* $U(0,\theta), \theta>0$, Show that $2\overline{X}_n$ is CAN for θ and obtain $\mathrm{AV}(2\overline{X}_n)$. Further show that $X_{(n)}$ is not CAN for θ.

49 Obtain maximum likelihood estimator for parameter N of hypergeometric distribution based on single observation X when other parameters are known.

50 Let X be $B(1,P)$, $p\in[\frac{1}{4},\frac{3}{4}]$. Obtain MLE of p.

51 Given a random sample from $NB(r,p)$ distribution, derive the MLE of p, assuming r is known.

52 Obtain the MLE of θ based on a random sample of size n from the distribution having p.m.f.

$$p(x, \theta) = \theta^x (1-\theta)^{1-x}, \ x = 0, \ 1; \ 0 < \theta < 1.$$

53 Let $X_1, X_2, \ldots, X_n$ be a random sample from exponential distribution with mean θ. Obtain MLE of θ. Examine if it is unbiased.

54 Let $X_1, X_2, \ldots, X_n$ be a random sample of size n from $N(\theta, \theta)$ distribution, $0 < \theta < \infty$. Find MLE of θ.

55 Let $X_1, X_2, \ldots, X_n$ be a random sample from $N(\theta, \theta^2), \theta \in R$. Obtain MLE of θ.

56 Let $X_1, X_2, \ldots, X_n$ be a random sample of size n from $N(\mu, \sigma^2)$ distribution. Find MLE of μ and σ^2.

57 Let $X_1, X_2, \ldots, X_n$ be *iid* $U(\theta - \frac{1}{2}, \theta + \frac{1}{2})$. Obtain MLE of θ. Is it unique? Justify your answer.

58 Let $X_1, X_2, \ldots, X_n$ be a random sample from a distribution with pdf

$$f(x, \theta) = \frac{1}{2} \exp\{-|x-\theta|\} \ , \ -\infty < x < \infty, \ -\infty < \theta < \infty.$$

Obtain MLE of θ.

59 Let X_i $(i = 1, 2, \ldots, n)$ be iid observations from

$$f(x, \theta) = \begin{cases} \theta \, x^{\theta-1} \ , 0 < x < 1; \ \theta > 0 \\ 0, \text{ otherwise} \end{cases}$$

Find the estimator of θ by the method of moments and maximum likelihood. What would be MLE of mean of the distribution.

60 Let $X_1, X_2, \ldots, X_n$ is a random sample of size n from the distribution having pdf

$$f(x, \theta) = \begin{cases} e^{-(x-\theta)}, \ x > \theta \\ 0 \ , \text{ otherwise} \end{cases}.$$

Obtain MLE of θ.

61 Let $X_1, X_2, \ldots, X_n$ be a random sample from exponential distribution with location parameter μ and scale parameter λ. Obtain MLE of (μ, λ). Examine if it is unbiased.

62 Let $X_1, X_2, \ldots, X_n$ is a random sample from the distribution having *pdf*

$$f(x, \theta) = (2/\theta^2)(\theta - x), \ 0 < x < \theta, \ \theta > 0.$$

Obtain estimator of θ by method of moments.

63 Let $X_1, X_2, ..., X_n$ be independent random variables each with *pdf* $f(x, \theta) = \frac{1}{2\theta}$, $-\theta < x < \theta$, $\theta > 0$. Find moment estimator of θ and show that it is biased estimator.

64 Let $X_1, X_2, ..., X_n$ be iid $U(0, \theta), \theta > 0$.

Find (i) Moment estimator θ (ii) MLE of θ.

65 A random sample of size is taken from log normal *pdf*

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \frac{1}{x} \exp\left[-\frac{1}{2}\left(\frac{\log x - \mu}{\sigma}\right)^2\right], \quad x > 0.$$

Find moment estimators of (μ, σ^2).

66 Let $X_1, X_2, ..., X_n$ be a random sample from $B(n, p)$ distribution. Obtain moment estimators of n and p.

67 Based on random sample of size n from $N(\mu, \sigma^2)$, derive the moment estimators of μ and σ^2.

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Punyashlok Ahilyadevi Holkar Solapur University, Solapur
Department of Statistics
M.Sc. (Biostatistics) Part-I Sem-II
Biostatistics Paper: HCT2.2
Title: Stochastic Processes
<u>Question Bank</u>

Short Answers

1. Define and illustrate Markov chain. Show that initial distribution and TPM specifies the Markov chain completely.
2. State and prove Chapman-Kolmogorov equations.
3. Give classification of Stochastic processes according to state space and time domain.
4. Let {Xn} be a stochastic process with state space= {1,2,3} and initial distribution [1/2,1/4,1/4]' and tpm P as

$$P = \begin{bmatrix} 1/2 & 1/4 & 1/4 \\ 1/6 & 5/6 & 0 \\ 1/3 & 1/3 & 1/3 \end{bmatrix}$$

   Then find : i) $P(X_3 = 2 / X_1 = 1)$ ii) $P(X_2=1)$ iii) $P(X_1=2)$
5. State and illustrate : i) State space ii) Stochastic Process iii) TPM
6. Define and explain Markov property.
7. Explain the concept of first return and probability of ultimate return to a state i.
8. Define and illustrate Persistent and transient state.
9. For a Markov chain $\{X_n\}$, tpm is as given below. Classify the states as persistent or transient.

$$\begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/7 & 2/7 & 4/7 \\ 1/6 & 1/3 & 1/2 \end{bmatrix}$$

10. What is transition probability matrix?
11. Write a note on Gambler's ruin problem
12. Simulation of Possion process
13. State and prove first entrance theorem

14. Define processes with independent increments. Give an example whereassumption of processes with independent increment is not suitable withjustification.
15. Explain Yule-Furry process.
16. State key renewal theorem.
17. Prove that, Markov chain is completely specified by one step t.p.m. and initial distribution
18. Let $\{N(t),\ t \geq 0\}$ be a Poisson process with rate λ and s, t be two points such that $s < t$ then find the conditional distribution of $N(s)$given $N(t) = n$.
19. Write an algorithm for simulation of Markov chain.
20. Write a note on Poisson Process.
21. Write a short note on Mean recurrent time of a state.
22. Discuss probability of first return for a state.
23. Discuss stationary distribution of a Markov chain.
24. Write a note on counting process.
25. Describe Poisson Process. State postulates of this process.
26. Define periodicity of Markov chain and give an example of Markov chain which is periodic. Also give example of aperiodic Markov chain.
27. State Markov properly for stochastic process. State and prove Chapman-Kolmogorov equation for Markov chain.
28. Suppose, for a branching process, the offspring distribution is geometric distribution with probability of success 0.2. Find probability of extinction.
29. Write a short note on Delayed renewal process.

Long Answers

1. Prove that, Markov chain is completely specified by one step t.p.m. and initial Distribution
2. Describe gambler's game. If a gambler starts the game with initial amount 'i', find his winning probability.

3. Classify the states of random walk model.

4. Give two definitions of Poisson Process. Show that addition of two Poison processes is a Poisson process.

5. Establish the equivalence between two definitions of Poisson process.

6. Define stationary distribution of a Markov chain. Find the same for a Markov chain with state space {1,2,3}, whose tpm is

$$\begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/3 & 1/3 & 1/3 \\ 2/5 & 1/5 & 2/5 \end{bmatrix}$$

7. Define branching process. Derive expression for the mean of the population sizeat n^{th} generation.

8. Define pure birth process and obtain its probability distribution.

9. Describe M/M/S queuing model.

10. Describe birth and death process and obtain its Kolmogorov differentialequations.

11. Define branching process. With usual notations, obtain its mean and variance.

12. Stating the postulates, derive the probability distribution of a Poisson process with rate λ.

13. A professor continually gives exams to her students. She can give three possible types of exams, and her class is graded as either having done well or badly. Let p_i denote theprobability that the class does well on a type i exam, and suppose that $p_1 = 0.3$, $p_2 = 0.6$, and $p_3 = 0.9$. If the class does well on an exam, then the next exam is equally likely to be any of the three types. If the class does badly, then the next exam is always type 1. What proportion of exams are type i, i = 1, 2, 3?

14. Describe M/M/1 queuing model.

15. Discuss the classification of stochastic processes according to state space and index set.

16. Let $\{X_n, n \geq 0\}$ be a Markov chain with state space S={0, 1, 2 },t.p.m$P = \begin{bmatrix} 0.6 & 0 & 0.4 \\ 0 & 0.6 & 0.4 \\ 0.4 & 0 & 0.6 \end{bmatrix}$ and initial distribution (0.5, 0.5, 0).

Compute

i. $P(X_2 = 1,\ X_0 = 1)$

ii. $E(X_2)$

17. Consider that a store stocks a certain items, the demand for which is given by given by $\mathrm{p_k = P(k\ demands\ of\ the\ item\ in\ a\ week)}$, $\mathrm{p_0} = 0.2, \mathrm{p_1} = 0.7, \mathrm{p_2} = 0.1$. Stocks are replenished at weekends according to the policy: not to replenish if there is any stock in store and to obtain 2 new items if there is no stock. Let $\mathrm{X_n}$ be the number of items at the end of the $\mathrm{n^{th}}$ week, just before weeks replenishment, if any and $\mathrm{P(X_0 = 3) = 1}$. Here $\{\mathrm{X_n}, \mathrm{n} \geq 0\}$ be a Markov chain. Then

    i. Write down the transition probability matrix

    ii. What is the probability that at the end of second week, just before weeks replenishment, if any, there are 3 items in store?

    If at the end of second week, just before weeks replenishment, if any, there is 1 item in store, what is the probability that at the end of fourth week, just before weeks replenishment, if any, there will be 0 items in store?

18. Describe birth and death process and obtain its Kolmogorov differential equations.

19. Verify the states of random walk model for persistency as well as for periodicity

20. Consider the problem of sending a binary message, 0 or 1, through a signal channel consisting of several stages, where transmission through each stage is subject to a fixed probability of error α. Suppose that $X_0 = 0$ is the signal that is sent and let X_n be the signal that is received at the $\mathrm{n^{th}}$ stage. Assume that $\{X_n\}$ is a Markov chain.

    i) Determine the transition probability matrix of $\{X_1\}$

    ii) Determine the probability that no error occurs up to stages $n = 2$

    iii) Determine the probability that a correct signal is received at stage 2.

21. Prove that persistency is a class property

22. Discuss Gambler's ruin problem in detail.

23. Calculate the extinction probability for branching process.

24. Explain Gamblers ruin problem. Obtain the probability that starting with i units the Gamblers fortune will reach N before reaching zero.

25. If {N(t)} is a Poisson process, then for s < t, obtain the distribution of N(s),

if it is already known that N(t)=k.

26. Show that recurrence is a class property.

27. A Markov chain with state space S={1,2,3} has tpm $\begin{bmatrix} 0.2 & 0.4 & 0.4 \\ 0.3 & 0.4 & 0.3 \\ 0.1 & 0.8 & 0.1 \end{bmatrix}$. It is known that the process has started with the state $X_0=2$

i) $P(X_1 = 2)$

ii) $P(X_2 = 3)$

iii) $P(X_0=1)$

iv) $P(X_3=2/X_1=1)$

28. Prove that a state j of a Markov chain is recurrent if and only if $\sum p_{jj}{}^{(n)} = \infty$.

29. State and prove class property of periodicity.

30. Write down the algorithm for the simulation of Poisson process and branching process.

Punyashlok Ahilyadevi Holkar Solapur University, Solapur
Department of Statistics

M.Sc. (Biostatistics) Part-II Sem-IV

Biostatistics Paper SCT4.2

Title: Data Mining

Question Bank

Short answers

1. Write a short note on Imbalanced data.
2. Describe CRISP process in brief.
3. Describe SEMMA process in brief.
4. Distinguish between training data and testing data.
5. Describe supervised learning.
6. Describe Gini’s method to obtain information gain in decision tree.
7. Discuss loss functions used in SVM.
8. Discuss unsupervised learning. Also give illustrations.
9. What is market basket analysis?
10. Discuss association rules and prediction.
11. Write a note on problem of classification.
12. Why kNN classifier is also called as lazy classifier?
13. Explain the steps Involved in Supervised Learning.
14. What are the advantages and disadvantages of supervised learning?
15. What are the advantages and disadvantages of unsupervised learning?
16. Write a short note on clustering.
17. Write a short note on association rules.

18. Discuss the drawbacks of kNN classifier.
19. Explain how to deal with missing values in kNN classifiers.
20. Write a short note on confusion matrix.
21. Discuss sensitivity and specificity of a model.
22. Discuss accuracy and precision of a classifier.

Long answers

1. Describe k-nearest neighbor classifier in detail.
2. Describe decision tree classifier in detail.
3. Describe naive Bayesian classifier in detail.
4. Describe logistic regression classifier in detail.
5. Describe Artificial Neural Network (ANN).
6. Distinguish between single layer and multi-layer neural network.
7. Describe how regression is used in ANN?
8. Discuss Support Vector Machine (SVM) in detail.
9. Discuss density based methods for unsupervised learning.
10. Discuss McCulloch-Pitts AN model in detail.
11 Write down the algorithm for decision tree classifier.
12. Write down the algorithm for Bayesian classifier.
13. Write down the algorithm for kNN classifier.
14. What are the different metrics for Evaluating Classifier Performance?
15. Discuss information gain in decision tree.
16. Write a note on confusion matrix. Also explain different metrics for evaluating classifier performance.
17. Discuss accuracy and precision of a classifier. Describe how accuracy can mislead with respect to performance of the data.

18. Discuss the prominent characteristics of ANN.
19. Discuss deep learning.
20. Describe maximum margin hyperplane in support vector machine.
21. Discuss characteristics of logistic regression.
22. Describe logistic regression. Also discuss its characteristic.
23. Describe logistic regression. Also discuss the scenarios in which logistic regression is used.
24. Discuss characteristics of naive Bayesian classifier.
25. Describe naive Bayesian classifier in detail. Also discuss its characteristics.
26. Describe naive Bayesian classifier in detail. Also explain why it is called naïve.
27. Discuss kNN classifier. Explain how to deal with missing values in kNN classifiers.
28. Describe unsupervised learning. Also discuss association rules and prediction.
29. Describe supervised learning. Describe naive Bayesian classifier in detail.
30. Describe supervised learning. Describe kNN classifier in detail.

Punyashlok Ahilyadevi Holkar Solapur University, Solapur
Department of Statistics
M.Sc. (Biostatistics) Part-II (Sem-IV)
Biostatistics Paper: HCT-4.3
Title of Paper: Survival Analysis
<u>Question Bank</u>

Short Answers

1. Define:
   i) Reliability of a component ii) Failure rate function iii) Coherent structure
2. Define reliability of component. Obtain the reliability of series system of n independent components.
3. Define reliability of a system. Obtain the reliability of parallel system of n independent components.
4. Define dual of a system. Obtain dual of a 2-out-of-3 system.
5. Define: i) Structure function ii) Coherent structure. Illustrate giving one example each.
6. Define k out of n system. Obtain the reliability function of this system.
7. Define minimal path sets and minimal cut sets. Illustrate the same by example.
8. Define dual of a structure function. Show that dual of dual is primal.
9. Define coherent system. Give an illustration of a system which is not coherent.
10. Define irrelevant component. Give an illustration.
11. Define associated random variables. Show that ordered statistics are associated.
12. Define IFR and DFR class of life distributions.
13. Define IFRA and DFRA classes of distributions.
14. Give two definitions of star shaped function and prove their equivalence.
15. Define Polya function of order 2.
16. Define the following terms: i) survival function ii) Random censoring
17. Define the following terms: i) Type-II censoring ii) Cumulative hazard function
18. Define TTT transform and show that it is concave if F is IFR.
19. Explain the concept of random censoring giving one example.
20. Describe type-I censoring and type-II censoring.
21. Describe situations where random censoring occurs naturally.
22. State the properties of order statistics from an exponential distribution.
23. Show that for exponential distribution normalized spacings are independently distributed.

24 Give two real life examples where both left and right censoring occurs.

Short Notes

1 Pivotal decomposition of structure function
2 Cumulative hazard function
3 Mean residual life function
4 Hazard transform.
5 Graphical estimation technique for Weibull distribution
6 Polya function of order 2.
7 Relevant and irrelevant component.
8 Star shaped function.
9 Birnbaum's measure of structural importance.
10 Path and cut sets of the dual of the system.
11 Log-rank test
12 Proportional Hazard model
13 Random censoring
14 Estimation of survival function under uncensored data.
15 Type-I censoring
16 Type-II censoring
17 Empirical survival function and its properties.
18 Graphical estimation technique for Weibull distribution
19 Generalized maximum likelihood estimator
20 Tarone-Ware Tests

Long Answers

1 Define reliability of a component and reliability of a system. Obtain the reliability of series and parallel systems of n independent components.
2 Define reliability of the system. Obtain expression for reliability of a coherent system in terms of reliabilities of components. Also obtain reliability of series system if each component has reliability p.
3 Define dual of a structure function. Obtain the dual of k-out-of- n system.
4 Define k-out-of-n system. Obtain reliability of this system.
5 Define coherent system. Show that k-out-of-n system is coherent system.
6 Define associated random variables. If $X_1, X_2, \ldots, X_n$ are binary associated random variables then prove that $1-X_1, 1-X_2, \ldots, 1-X_n$ are also binary associated.
7 Obtain a structure function of system in terms of i) minimal path ii) minimal cut.
8 Obtain structure function of a coherent system using minimal cut sets. Illustrate the same by an example.

9 Obtain the structure function by using minimal path sets. Illustrate the same by an example.

10 Show that minimal path vector is a minimal cut vector of its dual.

11 A system consists of 4 components. System functions when both components 1 and 4 functions and at least one of the remaining two functions. Find the reliability of system.

12 For a coherent system with n components prove that:

i) $\phi(0) = 0$ and $\phi(1) = 1$ ii) $\prod_{i=1}^{n} X_i \le \phi(X) \le \coprod_{i=1}^{n} X_i$

13 If $X_1, X_2, ..., X_n$ are associated binary random variables then prove that

i) $P\left(\prod_{j=1}^{n} X_j = 1\right) \ge \prod_{j=1}^{n} P(X_j = 1)$ ii) $P\left(\coprod_{j=1}^{n} X_j = 1\right) \le \coprod_{j=1}^{n} P(X_j = 1)$

14 If $X_1, X_2, ..., X_n$ are associated state variables of coherent system then prove that

$$\prod_{i=1}^{n} P(X_i = 1) \le P(\phi(X) = 1) \le \coprod_{i=1}^{n} P(X_i = 1)$$

15 Define associated random variables. If $X_1, X_2, ..., X_n$ are binary associated random variables then prove that $E\left[\prod_{i=1}^{n} X_i\right] \ge \prod_{i=1}^{n} E(X_i)$.

16 Define associated random variables. If $X_1, X_2, ..., X_n$ are binary associated random variables then prove that $P\left[\coprod_{j=1}^{n} X_j = 1\right] \le \coprod_{j=1}^{n} P(X_j = 1)$.

17 Define mean time to failure (MTTF) and mean residual life (MRL) function. Obtain the same for exponential distribution.

18 If failure time of an item has gamma distribution obtain the failure rate function

19 Define mean residual life function and obtain the same for exponential distribution.

20 Define IFR and IFRA class of distributions. If $F \in IFR$ then show that $F \in IFRA$.

21 Define IFR and IFRA classes of distributions. Prove that $\mathrm{IFR} \subset \mathrm{IFRA}$.

22 State and prove IFR closure property under convolution.

23 Show that IFRA class of life distribution is closed under convolution.

24 State and prove IFRA closure theorem.

25 Define NBU and NBUE classes of distributions. Prove that $F \in IFRA \Rightarrow F \in NBU$.

26 Define NWU and NWUE class of distributions. Prove that if $F \in DFRA$ then $F \in NWU$.

27 Define NBU and NBUE class of distributions. Prove or disprove: $\text{NBUE} \Rightarrow \text{NBU}$.

28 Give two definitions of star shaped function and prove their equivalence.

29 Define star shaped function. Prove that $F \in IFRA$ if and only if $-\log R(t)$ is star shaped.

30 State three equivalent definitions of a PF_2 function and describe how this concept is useful in examining whether a given distribution is IFR.

31 Define Poly function of order 2 (PF_2). Prove that if $f \in PF_2$ then $F \in IFR$.

32 Define PF_2 function and describe how it is useful in examining whether a given distribution is IFR.

33 Define totally positive function of order n. Give an example.

34 Let $F(x) = \int_\alpha F_\alpha(x)\, d\, G(\alpha)$ be a mixture of $\{F_\alpha\}$ with mixing distribution $G(\alpha)$. Prove that if each F_α is DFR then F is DFR.

35 Let $F(x) = \int_\alpha F_\alpha(x)\, d\, G(\alpha)$ be a mixture of $\{F_\alpha\}$ with mixing distribution $G(\alpha)$. Prove that if each F_α is DFRA then F is DFRA.

36 If failure time of item has Weibull distribution with distribution function

$$F(t) = \begin{cases} 1 - e^{-(\lambda t)^\alpha} & , t > 0 \\ 0, otherwise \end{cases}.$$

Examine whether it belongs to IFR or DFR.

37 If failure time of an item has the distribution

$$f(t) = \frac{\lambda^\alpha}{\Gamma\alpha} t^{\alpha-1} e^{-\lambda t} \quad , t > 0, \quad \lambda, \alpha > 0.$$

Examine whether it belongs to IFR or DFR.

38 Obtain the reliability function and hazard function for the Weibull distribution.

39 Define gamma distribution as failure time model. Discuss the monotonicity property of its hazard rate.

40 If f(t), F(t) and h(t) are the density, distribution and hazard functions of a random variable T, then show that $\text{h}(\text{t}) = \frac{\text{f}(\text{t})}{\bar{\text{F}}(\text{t})}$, $\bar{\text{F}}(\text{t}) = 1 - \text{F}(\text{t})$. Also establish a suitable relationship between h(t) and reliability function.

41 Define Hazard function and survival function. Obtain the same for an exponential distribution.

42 Describe the need of censoring experiment. Describe Type-I and Type-II censoring with suitable examples.

43 Define type-I censoring and obtain the likelihood corresponding to a parametric model for lifetime distribution.

44 Describe various censoring schemes.

45 Describe each of the following with one illustration:

a) Type-I censoring

b) Type-II censoring

c) Random censoring

46 Describe situations where random censoring occurs naturally. Obtain actuarial estimate of survival function and derive Greenwood's formula for the estimate of variance of the estimator,

47 Under time censoring with replacement obtain likelihood function. When the observations are taken from exponential distribution with mean θ, does MLE for θ exist? Justify.

48 Discuss maximum likelihood estimation of parameters of a gamma distribution under uncensored data.

49 Discuss maximum likelihood estimation of parameters of a Weibull distribution based on uncensored data.

50 Describe graphical method of estimating the parameters of Weibull distribution based on complete data.

51 Obtain moment estimator of the parameters of lognormal distribution based on random sample of size n.

52 Derive the likelihood function of observed data under type I censoring.

53 Obtain the likelihood function under random censoring set up when observations come from a distribution F with density F.

54 Describe Type-I censoring. Obtain MLE of mean of exponential distribution under Type I censoring.

55 Obtain maximum likelihood estimator of the mean of exponential distribution under type I censoring.

56 Obtain maximum likelihood estimate of mean of the exponential distribution under type II censoring.

57 Obtain MLE of the mean (θ) of an exponential distribution based on complete sample and type I censoring.

58 Obtain MLE of the mean (θ) of an exponential distribution based on type I and type II censoring.

59 Obtain the nonparametric estimator of survival function based on complete data. Also obtain confidence band for the same using Kolmogorov-Smirnov statistic.

60 Describe actuarial method of estimation of survival function, with suitable illustration.

61 Derive Greenwood's formula for an estimate of variance of actuarial estimator of survival function.

62 Obtain the actuarial estimator of the survival function. Clearly state the assumption that you need to make. State Greenwood's formula for the variance of the estimator.

63 Describe Kaplan-Meier estimator and derive an expression for the same.

64 Show that Kaplan-Meier estimator of survival function is the generalized likelihood estimator of the survival function.

65 Describe two sample problem under randomly censored set up and develop Gehan's test for the same.

66 Describe Gehan's test for two sample testing problem in presence of censoring.

67 Describe Mantel-Haenzel test. Indicate the null distribution of test statistic.

68 Describe Mantel's technique of computing Gehan's statistics for a two-sample problem for testing equality of two life distributions.

69 Describe Deshpande's test for exponentiality against IFRA.

70 Develop Hollander-Proschan test for exponentiality against NBU.

71 Develop a test for exponentiality against NBU.

72 Define TTT transform. Obtain relation between TTT transform and failure rate function of a survival distribution.

73 Define TTT transform. Show that for an IFR distribution TTT transform is a convex function.

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Punyashlok Ahilyadevi Holkar Solapur University, Solapur

M. Sc. Biostatistics Part II Semester – IV

HCT 4.1 Demography and Health Statistics

<u>Question Bank</u>

Short Answer Questions:

1) What is Demography?

2) What is difference between Population studies and Demography?

3) What is Subject matter of Demography?

4) What are different aspects of Demography?

5) Define macro demography and micro demography.

6) Explain Demography as a science.

7) Write the relation between Demography and Sociology.

8) Write importance of Demography.

9) How Demography and Geography are related?

10) Define two measures of fertility rates.

11) Define two measures of mortality rates.

12) Explain Direct method of obtaining standardized death rate.

13) Explain two factors affecting mortality.

14) Define two methods of census.

15) What are primary sources of demographic data? Explain any one.

16) Explain objectives of first and second NFHS.

17) What are criticism on Malthusian theory?

18) What are population projection methods? Explain one.

19) Write about India's population policies.

20) What is Lewis model of rural urban migration?

Short notes

1) Standardized death rate

2) Life tables

3) Mortality

4) Fertility

5) Migration

6) Population projection

7) Population estimates

8) Population policies

9) Sample Registration System

10) National Sample Survey Organization

11) National Family Health survey

12) National Rural Health Mission

13) Vital Registration System

14) Longitudinal Ageing Study of India

15) Components of Population change

Long Answer Questions

1) Write method of projection of mortality, fertility and migration components.

2) Describe cohort component method of population projection.

3) Write in detail Optimum theory of population.

4) Describe Longitudinal Ageing Study in India (LASI).

5) Describe Fei-Ranis model or rural urban migration.

6) Discuss Karl Marx theory of surplus population.

7) Explain in detail migration and their types.

8) Explain in detail any one source of demography.

9) Explain method of rural-urban and sub-national population projection.

10) Describe Leibenstein's motivation theory of population growth.

11) Explain Indian census 2011in detail.

12) Explain in detail National Rural Health Mission (NRHM).

13) Describe Sample Registration method of collection of demographic data.

14) Explain in detail method of estimation of net internal migration.

15) Explain in detail measures of fertility.

16) Write a note on nature and scope of Demography.

17) How Demography is related to Economics? Discuss.

18) What are the factors that determine population growth?

19) Analyze the relationship between education of women and fertility.

20) What are factors that determine migration.

21) What are silent features of Census 2011 India? Discuss.

22) Write a note on the growth of Indian population in recent decades.

23) Explain ASFR and TFR. Discuss their relative merits and demerits. Why is TFR a better measure of fertility than ASFR.

24) Explain Crude and Standardized death rates. In what way is STDR superior to CDR? Explain the Direct method of standardization along with its merits and demerits.

25) Discuss in detail Dumont's theory or Population.

26) Discuss different survey conduction by National Sample Survey Organization, India.

27) Explain criticism on Malthusian theory

28) What was Neo-Malthusian theory? Explain in detail.

29) Explain the methods of rural-urban and sub-national population projection.

30) Discuss in detail Population theories.

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

Department of Statistics

M.Sc. (Biostatistics) Part-I Sem-II

Biostatistics Paper SCT2.1: Statistical Genetics

Question Bank

Short answers

1. Discuss Mendel's first law of inheritance in brief.
2. Discuss Mendel's second law of inheritance in brief.
3. Discuss Mendel's third law of inheritance in brief.
4. Discuss Hardy Weinberg equilibrium.
5. Discuss law of natural selection.
6. Describe in detail the idea of phenotype and genotype.
7. Write a short note on DNA.
8. What do you mean by allele frequency?
9. What is Punnet's square?
10. Write a short note on mutation.
11. Write a short note on genetic drift.
12. What is meant by genetic variance?
13. What is meant by genetic correlation?
14. State the law of natural selection.
15. Describe the factors affecting natural selection.

16 Describe allele structure with reference to dominant and recessive alleles.

17. What is meant by inbreeding?

18. State the law of dominance with respect to inheritance.

19. State the law of segregation with respect to inheritance.

20. State the law of independent assortment with respect to inheritance.

Long answers

1. Describe non-random mating in detail. Also illustrate with examples.
2. Distinguish between random mating and non-random mating.
3. Discuss Mendel's laws of inheritance.
4. Discuss Mendel's first law of inheritance in detail.
5. Discuss Mendel's second law of inheritance in detail.
6. Discuss Mendel's third law of inheritance in detail.
7. Derive Hardy Weinberg equilibrium with the help of mating table.
8. What are the assumptions in Hardy Weinberg equilibrium.
9. Discuss assortative mating.
10. Discuss the idea of Identical by Descent (IBD).
11. Explain genetical variance and correlations.
12. Discuss Mendel's laws of inheritance in detail.
13. Describe the following:
    - i) Law of dominance with respect to inheritance.
    - ii) Law of segregation with respect to inheritance.
14. Describe the following:
    - i) Law of segregation with respect to inheritance.

ii) Law of independent assortment with respect to inheritance.

15. Write a note on inheritance of quantitative traits

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

Department of Statistics

M.Sc. (Biostatistics) Part-II Sem-IV

Biostatistics Paper HCT4.2: Clinical Trials

<u>Question Bank</u>

Short answers

1. Explain the concept of Stratified randomization.
2. Write advantages and disadvantages of crossover design.
3. Pharmacokinetic parameters used in bioequivalence.
4. Endpoints in clinical trials.
5. Explain the following terms:
   i) Full analysis set/cohort.
   ii) Completers set/cohort.
   iii) Per-protocols set/cohort
6. Explain the role of Bio-statistician in the planning and execution of CTs. Also state some sources of bias in CTs.
7. Write any two definitions of clinical trials. Explain the terms in it.
8. Write notes on run in and washout period.
9. Describe Balanced Incomplete Block Design (BIBD).
10. Explain Cox's proportional hazard model for assessment of test drug based on censored data.
11. Explain the difference between: Statistically significant difference and clinically significant difference.
12. Explain the difference between: Interaction and confounding.
13. Explain the four phases involve in development of clinical trials.
14. Write the note on: Investigation New Drug Application (INDA).
15. Write the note on: Abbreviated New Drug Application (ANDA).
16. What are the major objectives behind conduction of the clinical trials (CTs)
17. Explain the following terms related with CTs
    i) Subject
    ii) Treatment
    iii) Clinical Endpoints.
    iv) Placebo
18. Write notes on: Superiority trials
19. Write notes on: Equivalence or non-inferiority trials

Long answers

1. Explain the overall clinical drug development process.
2. Define Blinding. Explain the various types of blinding methods used in clinical trials.
3. Discuss role of ethics in clinical trials.
4. What are clinical trials? Explain the why clinical trials are essential in the development of new interventions.
5. Explain the permuted randomization and its advantages over complete randomization.
6. Explain the concept of sample size. Discuss are the factors necessary to calculate the appropriate sample size.
7. Explain the role of Good clinical practice in clinical trials.
8. Explain the Cox's proportional hazard model for assessment of test drug based on censored data.
9. Explain the concept hypothesis of superiority and hypothesis of non-inferiority
10. What is patient compliance? What is difference between missing value and drop outs?
11. Classify the clinical trials depending upon their functioning. Explain their respective functions in brief.
12. Explain the role of sampling distribution for the valid and unbiased assessment of true efficiency and safety of the study medication.
13. Explain the patient selection process for clinical trials.
14. What is randomization? Why randomization is needed? What are the types of randomizations involved in clinical trials?
15. For the selection of appropriate design for clinical trials, which issues must be considered?
16. a) Define:

    i) Clinical Trials

    ii) Experimental unit

    iii) Treatment

    iv) Evaluation.
17. Write a note on

i) Active control and Equivalence trials.

ii) Combination trials.

18. Explain the assumption for using the placebo control and No treatment control.
19. Explain the dose response concurrent control.
20. Write the short note on Washout period and Carryover effect in crossover design.
21. Discuss the parallel design useful in clinical trials and its advantages over the crossover designs.
22. Explain the method of block randomization and its advantages over complete randomization.
23. What is meaning of blinding? Way it is used in Clinical trials? Explain the type of bindings.
24. A pharmaceutical company is interested in conducting a clinical trial to compare two cholesterol lowering agents. Suppose that a difference of 8% in the percent change of LDL-cholesterol is considered a clinically meaningful difference and that standard deviation is assumed to be 15%. Find the required sample size for having an 80% power and $\alpha = 0.05$.
25. Explain the difference between the Multicenter trails and Meta analysis.
26. Explain concept of protocol and process of protocol developments in clinical trials.
27. Discuss the concept of bioequivalence study.
28. Write note on Protocol in Clinical Trials (CTs).
29. What is safety report in CT? Explain Treatment IND and termination of IND.
30. Explain the method of Permuted block randomization and its advantages over complete randomization.
31. What are controls? Explain active concurrent control.
32. what are crossover designs? In which situations crossover designs are useful?
33. Write a note on interim analysis and data monitoring.
34. List out the different kinds of CTs. Also discuss brief objectives of each of them.
35. Give two examples of response variables where categorical data are generated.
36. List out the kinds of uncertainty in CTs.