

## **INDIAN ECONOMIC SERVICE/INDIAN STATISTICAL SERVICE EXAMINATION**

**Age Limits:** A candidate must have attained the age of 21 years

Upper Age limit: 30 years

Upper age-limit prescribed above will be relaxable

3 years - Other Backward Classes

3 years - Defence Services Personnel disabled in operations during hostilities with any foreign country or in a disturbed area

5 years - a Scheduled Caste or a Scheduled Tribe and ex-servicemen including Commissioned Officers and ECOs/SSCOs who have rendered at least five years Military Service.

### **Educational Qualifications:**

A candidate for the **Indian Economic Service** must have obtained a Post-Graduate Degree in Economics/Applied Economics/Business Economics/Econometrics from a University.

A candidate for the **Indian Statistical Service** must have obtained a Bachelor's Degree with Statistics/Mathematical Statistics/Applied Statistics as one of the subject or a Master's degree in Statistics/Mathematical Statistics/Applied Statistics from a University.

### **SCHEME OF EXAMINATION**

The examination shall be conducted according to the following plan— Part I-Written examination carrying a maximum of 1000 marks in the subjects as shown below. Part II-Viva voce of such candidates as may be called by the Commission carrying a maximum of 200 marks.

## **PART-I**

### **A. Indian Economic Service**

<b>SI.No</b>	<b>Subject</b>	<b>Maximum Marks</b>	<b>Time Allowed</b>
1.	General English	100	3 hrs.
2.	General Studies	100	3 hrs.
3.	General Economics-I	200	3 hrs.
4.	General Economics-II	200	3 hrs.
5.	General Economics-III	200	3 hrs.
6.	Indian Economics	200	3 hrs.

### **B. Indian Statistical Service**

<b>SI.No</b>	<b>Subject</b>	<b>Maximum Marks</b>	<b>Time Allowed</b>
1.	General English	100	3 hrs.
2.	General Studies	100	3 hrs.
3.	Statistics-I (Objective)	200	2 hrs.
4.	Statistics-II (Objective)	200	2 hrs.
5.	Statistics-III (Descriptive)	200	3 hrs.
6.	Statistics-IV (Descriptive)	200	3 hrs.

**Note-1:** Statistics I & II will be of Objective Type Questions (80 questions with maximum marks of 200 in each paper) to be attempted in 120 minutes.

**Note-2:** Statistics III and IV will be of Descriptive Type having Short Answer/ Small Problems Questions (50%) and Long Answer and Comprehension problem questions (50%). At least one Short Answer and One Long Answer Question from each section is compulsory. In Statistics-IV, there will be SEVEN Sections in the paper. Candidates have to choose any TWO Sections out of them. All Sections will carry equal marks.

**Note-3:** The papers on General English and General Studies, common to both Indian Economic Service and Indian Statistical Service will be of subjective type.

**Note-4:** All other papers of Indian Economic Service will be of subjective type.

## **STANDARD AND SYLLABI**

The standard of papers in General English and General Studies will be such as may be expected of a graduate of an Indian University. The standard of papers in the other subjects will be that of the Master's degree examination of an Indian University in the relevant disciplines. The candidates will be expected to illustrate theory by facts, and to analyse problems with the help of theory. They will be expected to be particularly conversant with Indian problems in the field(s) of Economics/Statistics.

**GENERAL ENGLISH (COMMON TO BOTH IES/ISS)** Candidates will be required to write an essay in English. Other questions will be designed to test their understanding of English and workman like use of words. Passages will usually be set for summary or precis.

**GENERAL STUDIES (COMMON TO BOTH IES/ISS)** General knowledge including knowledge of current events and of such matters of everyday observation and experience in their scientific aspects as may be expected of an educated person who has not made a special study of any scientific subject. The paper will also include questions on Indian Polity including the political system and the Constitution of India, History of India and Geography of a nature which a candidate should be able to answer without special study.

## **GENERAL ECONOMICS – I (For IES only)**

### **PART A :**

1. Theory of Consumer's Demand—Cardinal utility Analysis: Marginal utility and demand, Consumer's surplus, Indifference curve, Analysis and utility function, Price income and substitution effects, Slutsky theorem and derivation of demand curve, Revealed preference theory. Duality and indirect utility function and expenditure function, Choice under risk and uncertainty. Simple games of complete information, Concept of Nash equilibrium.

2. Theory of Production: Factors of production and production function. Forms of Production Functions: Cobb Douglas, CES and Fixed coefficient type, Translog production function. Laws of return, Returns to scale and Return to factors of production. Duality and cost function, Measures of productive efficiency of firms, technical and allocative efficiency. Partial Equilibrium versus General Equilibrium approach. Equilibrium of the firm and industry.

3. Theory of Value: Pricing under different market structures, public sector pricing, marginal cost pricing, peak load pricing, cross-subsidy free pricing and average cost pricing. Marshallian and Walrasian stability analysis. Pricing with incomplete information and moral hazard problems.

4. Theory of Distribution: Neo classical distribution theories; Marginal productivity theory of determination of factor prices, Factor shares and adding up problems. Euler's theorem, Pricing of factors under imperfect competition, monopoly and bilateral monopoly. Macro- distribution theories of Ricardo, Marx, Kaldor, Kalecki. 5. Welfare Economics: Inter-personal comparison and aggression problem, Public goods and externalities, Divergence between social and private welfare, compensation principle. Pareto optimality. Social choice and other recent schools, including Coase and Sen.

## **PART B : Quantitative Methods in Economics**

1. Mathematical Methods in Economics: Differentiation and Integration and their application in economics. Optimisation techniques, Sets, Matrices and their application in economics. Linear algebra and Linear programming in economics and Input-output model of Leontief.

2. Statistical and Econometric Methods: Measures of central tendency and dispersions, Correlation and Regression. Time series. Index numbers. Sampling of curves based on various linear and non-linear function. Least square methods and other multivariate analysis (only concepts and interpretation of results). Analysis of Variance, Factor analysis, Principle component analysis, Discriminant analysis. Income distribution: Pareto law of Distribution, longnormal distribution, measurement of income inequality. Lorenz curve and Gini coefficient. Univariate and multivariate regression analysis. Problems and remedies of Heteroscedasticity, Autocorrelation and Multicollinearity.

## **GENERAL ECONOMICS – II (For IES only)**

1. Economic Thought: Mercantilism Physiocrats, Classical, Marxist, Neo-classical, Keynesian and Monetarist schools of thought.

2. Concept of National Income and Social Accounting: Measurement of National Income, Inter relationship between three measures of national income in the presence of Government sector and International transactions. Environmental considerations, Green national income.

3. Theory of employment, Output, Inflation, Money and Finance: The Classical theory of Employment and Output and Neo classical approaches. Equilibrium, analysis under classical

and neo classical analysis. Keynesian theory of Employment and output. Post Keynesian developments. The inflationary gap; Demand pull versus cost push inflation, the Philip's curve and its policy implication. Classical theory of Money, Quantity theory of Money. Friedman's restatement of the quantity theory, the neutrality of money. The supply and demand for loanable funds and equilibrium in financial markets, Keynes' theory on demand for money. IS-LM Model and AD-AS Model in Keynesian Theory.

4. Financial and Capital Market: Finance and economic development, financial markets, stock market, gift market, banking and insurance. Equity markets, Role of primary and secondary markets and efficiency, Derivatives markets; Future and options.

5. Economic Growth and Development: concepts of Economic Growth and Development and their measurement: characteristics of less developed countries and obstacles to their development – growth, poverty and income distribution. Theories of growth: Classical Approach: Adam Smith, Marx and Schumpeter- Neo classical approach; Robinson, Solow, Kaldor and Harrod Domar. Theories of Economic Development, Rostow, Rosenstein-Roden, Nurske, Hirschman, Leibenstein and Arthur Lewis, Amin and Frank (Dependency school) respective role of state and the market. Utilitarian and Welfarist approach to social development and A.K. Sen's critique. Sen's capability approach to economic development. The Human Development Index. Physical quality of Life Index and Human Poverty Index. Basics of Endogenous Growth Theory.

6. International Economics: Gains from International Trade, Terms of Trade, policy, international trade and economic development- Theories of International Trade; Ricardo, Haberler, Heckscher- Ohlin and Stopler- Samuelson- Theory of Tariffs- Regional Trade Arrangements. Asian Financial Crisis of 1997, Global Financial Crisis of 2008 and Euro Zone Crisis- Causes and Impact.

7. Balance of Payments: Disequilibrium in Balance of Payments, Mechanism of Adjustments, Foreign Trade Multiplier, Exchange Rates, Import and Exchange Controls and Multiple Exchange Rates. IS-LM Model and Mundell- Fleming Model of Balance of Payments.

8. Global Institutions: UN agencies dealing with economic aspects, role of Multilateral Development Bodies (MDBs), such as World Bank, IMF and WTO, Multinational Corporations. G-20.

**GENERAL ECONOMICS – III (For IES only)**

1. Public Finance—Theories of taxation: Optimal taxes and tax reforms, incidence of taxation. Theories of public expenditure: objectives and effects of public expenditure, public expenditure policy and social cost benefit analysis, criteria of public investment decisions, social rate of discount, shadow prices of investment, unskilled labour and foreign exchange. Budgetary deficits. Theory of public debt management.

2. Environmental Economics—Environmentally sustainable development, Rio process 1992 to 2012, Green GDP, UN Methodology of Integrated Environmental and Economic Accounting. Environmental Values: Users and non-users values, option value. Valuation Methods : Stated and revealed preference methods. Design of Environmental Policy Instruments: Pollution taxes and pollution permits, collective action and informal regulation by local communities. Theories of exhaustible and renewable resources. International environmental agreements, RIO Conventions. Climatic change problems. Kyoto protocol, UNFCCC, Bali Action Plan, Agreements up to 2017, tradable permits and carbon taxes. Carbon Markets and Market Mechanisms. Climate Change Finance and Green Climate Fund.

3. Industrial Economics—Market structure, conduct and performance of firms, product differentiation and market concentration, monopolistic price theory and oligopolistic interdependence and pricing, entry preventing pricing, micro level investment decisions and the behaviour of firms, research and development and innovation, market structure and profitability, public policy and development of firms.

4. State, Market and Planning—Planning in a developing economy. Planning regulation and market. Indicative planning. Decentralised planning.

### **INDIAN ECONOMICS (For IES only)**

1. History of development and planning— Alternative development strategies—goal of self-reliance based on import substitution and protection, the post-1991 globalisation strategies based on stabilization and structural adjustment packages: fiscal reforms, financial sector reforms and trade reforms.

2. Federal Finance—Constitutional provisions relating to fiscal and financial powers of the States, Finance Commissions and their formulae for sharing taxes, Financial aspect of Sarkaria Commission Report, financial aspects of 73rd and 74th Constitutional Amendments.

3. Budgeting and Fiscal Policy—Tax, expenditure, budgetary deficits, pension and fiscal reforms, Public debt management and reforms, Fiscal Responsibility and Budget Management (FRBM) Act, Black money and Parallel economy in India—definition, estimates, genesis, consequences and remedies.

4. Poverty, Unemployment and Human Development—Estimates of inequality and poverty measures for India, appraisal of Government measures, India's human development record in global perspective. India's population policy and development.

5. Agriculture and Rural Development Strategies— Technologies and institutions, land relations and land reforms, rural credit, modern farm inputs and marketing— price policy and subsidies; commercialisation and diversification. Rural development programmes including poverty alleviation programmes, development of economic and social infrastructure and New Rural Employment Guarantee Scheme.

6. India's experience with Urbanisation and Migration—Different types of migratory flows and their impact on the economies of their origin and destination, the process of growth of urban settlements; urban development strategies.

7. Industry: Strategy of industrial development— Industrial Policy Reform; Reservation Policy relating to small scale industries. Competition policy, Sources of industrial finances. Bank, share market, insurance companies, pension funds, non-banking sources and foreign direct investment, role of foreign capital for direct investment and portfolio investment, Public sector reform, privatisation and disinvestment.

8. Labour—Employment, unemployment and underemployment, industrial relations and labour welfare— strategies for employment generation—Urban labour market and informal sector employment, Report of National Commission on Labour, Social issues relating to labour e.g. Child Labour, Bonded Labour International Labour Standard and its impact.

9. Foreign trade—Salient features of India's foreign trade, composition, direction and organisation of trade, recent changes in trade, balance of payments, tariff policy, exchange rate, India and WTO requirements. Bilateral Trade Agreements and their implications.

10. Money and Banking—Financial sector reforms, Organisation of India's money market, changing roles of the Reserve Bank of India, commercial banks, development finance institutions, foreign banks and non-banking financial institutions, Indian capital market and SEBI,

Development in Global Financial Market and its relationship with Indian Financial Sector.  
Commodity Market in India-Spot and Futures Market, Role of FMC.

11. Inflation—Definition, trends, estimates, consequences and remedies (control): Wholesale Price Index. Consumer Price Index: components and trends.

### **STATISTICS-I (OBJECTIVE TYPE) (For ISS only)**

1. Probability: Classical and axiomatic definitions of Probability and consequences. Law of total probability, Conditional probability, Bayes' theorem and applications. Discrete and continuous random variables. Distribution functions and their properties. Standard discrete and continuous probability distributions - Bernoulli, Uniform, Binomial, Poisson, Geometric, Rectangular, Exponential, Normal, Cauchy, Hyper geometric, Multinomial, Laplace, Negative binomial, Beta, Gamma, Lognormal. Random vectors, Joint and marginal distributions, conditional distributions, Distributions of functions of random variables. Modes of convergences of sequences of random variables - in distribution, in probability, with probability one and in mean square. Mathematical expectation and conditional expectation. Characteristic function, moment and probability generating functions, Inversion, uniqueness and continuity theorems. Borel 0-1 law, Kolmogorov's 0-1 law. Tchebycheff's and Kolmogorov's inequalities. Laws of large numbers and central limit theorems for independent variables.

2. Statistical Methods: Collection, compilation and presentation of data, charts, diagrams and histogram. Frequency distribution. Measures of location, dispersion, skewness and kurtosis. Bivariate and multivariate data. Association and contingency. Curve fitting and orthogonal polynomials. Bivariate normal distribution. Regression-linear, polynomial. Distribution of the correlation coefficient, Partial and multiple correlation, Intraclass correlation, Correlation ratio. Standard errors and large sample test. Sampling distributions of sample mean, sample variance, t, chi-square and F; tests of significance based on them, Small sample tests. Non-parametric tests-Goodness of fit, sign, median, run, Wilcoxon, Mann-Whitney, WaldWolfowitz and Kolmogorov-Smirnov. Order statistics-minimum, maximum, range and median. Concept of Asymptotic relative efficiency.

3. Numerical Analysis: Finite differences of different orders:  $\Delta$ , E and D operators, factorial representation of a polynomial, separation of symbols, sub-division of intervals, differences of zero. Concept of interpolation and extrapolation: Newton Gregory's forward and backward



interpolation formulae for equal intervals, divided differences and their properties, Newton's formula for divided difference, Lagrange's formula for unequal intervals, central difference formula due to Gauss, Sterling and Bessel, concept of error terms in interpolation formula. Inverse interpolation: Different methods of inverse interpolation. Numerical differentiation: Trapezoidal, Simpson's one-third and three-eighth rule and Waddles rule. Summation of Series: Whose general term (i) is the first difference of a function (ii) is in geometric progression. Numerical solutions of differential equations: Euler's Method, Milne's Method, Picard's Method and Runge-Kutta Method.

4. Computer application and Data Processing: Basics of Computer: Operations of a computer, Different units of a computer system like central processing unit, memory unit, arithmetic and logical unit, input unit, output unit etc., Hardware including different types of input, output and peripheral devices, Software, system and application software, number systems, Operating systems, packages and utilities, Low and High level languages, Compiler, Assembler, Memory – RAM, ROM, unit of computer memory (bits, bytes etc.), Network – LAN, WAN, internet, intranet, basics of computer security, virus, antivirus, firewall, spyware, malware etc. Basics of Programming: Algorithm, Flowchart, Data, Information, Database, overview of different programming languages, frontend and backend of a project, variables, control structures, arrays and their usages, functions, modules, loops, conditional statements, exceptions, debugging and related concepts.

## **STATISTICS- II (OBJECTIVE TYPE) (For ISS only)**

(i) Linear Models: Theory of linear estimation, Gauss-Markov linear models, estimable functions, error and estimation space, normal equations and least square estimators, estimation of error variance, estimation with correlated observations, properties of least square estimators, generalized inverse of a matrix and solution of normal equations, variances and covariances of least square estimators. One way and two-way classifications, fixed, random and mixed effects models. Analysis of variance (two-way classification only), multiple comparison tests due to Tukey, Scheffe and Student-Newmann-Keul-Duncan.

(ii) Statistical Inference and Hypothesis Testing: Characteristics of good estimator. Estimation methods of maximum likelihood, minimum chi-square, moments and least squares. Optimal properties of maximum likelihood estimators. Minimum variance unbiased estimators. Minimum

variance bound estimators. Cramer-Rao inequality. Bhattacharya bounds. Sufficient estimator. factorization theorem. Complete statistics. Rao-Blackwell theorem. Confidence interval estimation. Optimum confidence bounds. Resampling, Bootstrap and Jackknife. Hypothesis testing: Simple and composite hypotheses. Two kinds of error. Critical region. Different types of critical regions and similar regions. Power function. Most powerful and uniformly most powerful tests. Neyman-Pearson fundamental lemma. Unbiased test. Randomized test. Likelihood ratio test. Wald's SPRT, OC and ASN functions. Elements of decision theory.

(iii) Official Statistics: National and International official statistical system Official Statistics: (a) Need, Uses, Users, Reliability, Relevance, Limitations, Transparency, its visibility (b) Compilation, Collection, Processing, Analysis and Dissemination, Agencies Involved, Methods National Statistical Organization: Vision and Mission, NSSO and CSO; roles and responsibilities; Important activities, Publications etc. National Statistical Commission: Need, Constitution, its role, functions etc; Legal Acts/ Provisions/ Support for Official Statistics; Important Acts Index Numbers: Different Types, Need, Data Collection Mechanism, Periodicity, Agencies Involved, Uses Sector Wise Statistics: Agriculture, Health, Education, Women and Child etc. Important Surveys & Census, Indicators, Agencies and Usages etc. National Accounts: Definition, Basic Concepts; issues; the Strategy, Collection of Data and Release. Population Census: Need, Data Collected, Periodicity, Methods of data collection, dissemination, Agencies involved. Misc: Socio Economic Indicators, Gender Awareness/Statistics, Important Surveys and Censuses.

**STATISTICS- III (DESCRIPTIVE TYPE) (For ISS only) (i) Sampling Techniques:** Concept of population and sample, need for sampling, complete enumeration versus sampling, basic concepts in sampling, sampling and Non-sampling error, Methodologies in sample surveys (questionnaires, sampling design and methods followed in field investigation) by NSSO. Subjective or purposive sampling, probability sampling or random sampling, simple random sampling with and without replacement, estimation of population mean, population proportions and their standard errors. Stratified random sampling, proportional and optimum allocation, comparison with simple random sampling for fixed sample size. Covariance and Variance Function. Ratio, product and regression methods of estimation, estimation of population mean, evaluation of Bias and Variance to the first order of approximation, comparison with simple random sampling. Systematic sampling (when population size (N) is an integer multiple of sampling size (n)). Estimation of population mean and standard error of this estimate, comparison with simple random sampling. Sampling with probability proportional to size (with

and without replacement method), Des Raj and Das estimators for  $n=2$ , Horvitz-Thomson's estimator Equal size cluster sampling: estimators of population mean and total and their standard errors, comparison of cluster sampling with SRS in terms of intra-class correlation coefficient. Concept of multistage sampling and its application, two-stage sampling with equal number of second stage units, estimation of population mean and total. Double sampling in ratio and regression methods of estimation. Concept of Interpenetrating sub-sampling.

(ii) Econometrics: Nature of econometrics, the general linear model (GLM) and its extensions, ordinary least squares (OLS) estimation and prediction, generalized least squares (GLS) estimation and prediction, heteroscedastic disturbances, pure and mixed estimation. Auto correlation, its consequences and tests. Theil BLUS procedure, estimation and prediction, multicollinearity problem, its implications and tools for handling the problem, ridge regression. Linear regression and stochastic regression, instrumental variable estimation, errors in variables, autoregressive linear regression, lagged variables, distributed lag models, estimation of lags by OLS method, Koyck's geometric lag model. Simultaneous linear equations model and its generalization, identification problem, restrictions on structural parameters, rank and order conditions. Estimation in simultaneous equations model, recursive systems, 2 SLS estimators, limited information estimators, k-class estimators, 3 SLS estimator, full information maximum likelihood method, prediction and simultaneous confidence intervals.

(iii) Applied Statistics: Index Numbers: Price relatives and quantity or volume relatives, Link and chain relatives composition of index numbers; Laspeyre's, Paasches', Marshal Edgeworth and Fisher index numbers; chain base index number, tests for index number, Construction of index numbers of wholesale and consumer prices, Income distribution-Pareto and Engel curves, Concentration curve, Methods of estimating national income, Inter-sectoral flows, Interindustry table, Role of CSO. Demand Analysis Time Series Analysis: Economic time series, different components, illustration, additive and multiplicative models, determination of trend, seasonal and cyclical fluctuations. Time-series as discrete parameter stochastic process, auto covariance and autocorrelation functions and their properties. Exploratory time Series analysis, tests for trend and seasonality, exponential and moving average smoothing. Holt and Winters smoothing, forecasting based on smoothing. Detailed study of the stationary processes: (1) moving average (MA), (2) auto regressive (AR), (3) ARMA and (4) AR integrated MA (ARIMA) models. Box-Jenkins models, choice of AR and MA periods. Discussion (without proof) of estimation of mean, auto covariance and autocorrelation functions under large sample theory, estimation of

ARIMA model parameters. Spectral analysis of weakly stationary process, periodogram and correlogram analyses, computations based on Fourier transform.

#### **STATISTICS-IV (DESCRIPTIVE TYPE) (For ISS only)**

(Equal number of questions i.e. 50% weightage from all the subsections below and candidates have to choose any two subsections and answer)

- (i) Operations Research and Reliability: Definition and Scope of Operations Research: phases in Operation Research, models and their solutions, decision-making under uncertainty and risk, use of different criteria, sensitivity analysis. Transportation and assignment problems. Bellman's principle of optimality, general formulation, computational methods and application of dynamic programming to LPP. Decision-making in the face of competition, two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in  $2 \times 2$ ,  $2 \times m$  and  $m \times n$  games. Analytical structure of inventory problems, EOQ formula of Harris, its sensitivity analysis and extensions allowing quantity discounts and shortages. Multi-item inventory subject to constraints. Models with random demand, the static risk model. P and Q- systems with constant and random lead times. Queuing models – specification and effectiveness measures. Steady-state solutions of M/M/1 and M/M/c models with associated distributions of queue-length and waiting time. M/G/1 queue and Pollaczek-Khinchine result. Sequencing and scheduling problems. 2-machine n-job and 3-machine n-job problems with identical machine sequence for all jobs Branch and Bound method for solving travelling salesman problem. Replacement problems – Block and age replacement policies. PERT and CPM – basic concepts. Probability of project completion. Reliability concepts and measures, components and systems, coherent systems, reliability of coherent systems. Life-distributions, reliability function, hazard rate, common univariate life distributions – exponential, weibull, gamma, etc. Bivariate exponential distributions. Estimation of parameters and tests in these models. Notions of aging – IFR, IFRA, NBU, DMRL and NBUE classes and their duals. Loss of memory property of the exponential distribution. Reliability estimation based on failure times in variously censored life-tests and in tests with replacement of failed items. Stress-strength reliability and its estimation.

- (ii) Demography and Vital Statistics: Sources of demographic data, census, registration, ad-hoc surveys, Hospital records, Demographic profiles of the Indian Census. Complete life table and its main features, Uses of life table. Makehams and Gompertz curves. National life tables. UN model life tables. Abridged life tables. Stable and stationary populations. Measurement of Fertility: Crude birth rate, General fertility rate, Age specific birth rate, Total fertility rate, Gross reproduction rate, Net reproduction rate. Measurement of Mortality: Crude death rate, Standardized death rates, Age-specific death rates, Infant Mortality rate, Death rate by cause. Internal migration and its measurement, migration models, concept of international migration. Net migration. International and postcensal estimates. Projection method including logistic curve fitting. Decennial population census in India.
- (iii) Survival Analysis and Clinical Trial: Concept of time, order and random censoring, likelihood in the distributions – exponential, gamma, Weibull, lognormal, Pareto, Linear failure rate, inference for these distribution. Life tables, failure rate, mean residual life and their elementary classes and their properties. Estimation of survival function – actuarial estimator, Kaplan – Meier estimator, estimation under the assumption of IFR/DFR, tests of exponentiality against non-parametric classes, total time on test. Two sample problem – Gehan test, log rank test. Semi-parametric regression for failure rate – Cox’s proportional hazards model with one and several covariates, rank test for the regression coefficient. Competing risk model, parametric and non-parametric inference for this model. Introduction to clinical trials: the need and ethics of clinical trials, bias and random error in clinical studies, conduct of clinical trials, overview of Phase I – IV trials, multicenter trials. Data management: data definitions, case report forms, database design, data collection systems for good clinical practice. Design of clinical trials: parallel vs. cross-over designs, cross-sectional vs. longitudinal designs, review of factorial designs, objectives and endpoints of clinical trials, design of Phase I trials, design of single-stage and multi-stage Phase II trials, design and monitoring of phase III trials with sequential stopping, Reporting and analysis: analysis of categorical outcomes from Phase I – III trials, analysis of survival data from clinical trials.
- (iv) Quality Control: Statistical process and product control: Quality of a product, need for quality control, basic concept of process control, process capability and product control,

general theory of control charts, causes of variation in quality, control limits, sub grouping summary of out of control criteria, charts for attributes p chart, np chart, c-chart, V chart, charts for variables:  $\bar{X}$ ,  $(\bar{X}, R)$ ,  $(\bar{X}, \sigma)$  charts. Basic concepts of process monitoring and control; process capability and process optimization. General theory and review of control charts for attribute and variable data; O.C. and A.R.L. of control charts; control by gauging; moving average and exponentially weighted moving average charts; Cu-Sum charts using V-masks and decision intervals; Economic design of  $\bar{X}$ -bar chart. Acceptance sampling plans for attributes inspection; single and double sampling plans and their properties; plans for inspection by variables for one-sided and two sided specification.

(iv) Multivariate Analysis: Multivariate normal distribution and its properties. Random sampling from multivariate normal distribution. Maximum likelihood estimators of parameters, distribution of sample mean vector. Wishart matrix – its distribution and properties, distribution of sample generalized variance, null and non-null distribution of multiple correlation coefficients. Hotelling's  $T^2$  and its sampling distribution, application in test on mean vector for one and more multivariate normal population and also on equality of components of a mean vector in multivariate normal population. Classification problem: Standards of good classification, procedure of classification based on multivariate normal distributions. Principal components, dimension reduction, canonical variates and canonical correlation — definition, use, estimation and computation.

(vi) Design and Analysis of Experiments: Analysis of variance for one way and two way classifications, Need for design of experiments, basic principle of experimental design (randomization, replication and local control), complete analysis and layout of completely randomized design, randomized block design and Latin square design, Missing plot technique. Split Plot Design and Strip Plot Design. Factorial experiments and confounding in  $2^n$  and  $3^n$  experiments. Analysis of covariance. Analysis of non-orthogonal data. Analysis of missing data. (vii) Computing with C and R : Basics of C: Components of C language, structure of a C program, Data type, basic data types, Enumerated data types, Derived data types, variable declaration, Local, Global, Parametric variables, Assignment of Variables, Numeric, Character, Real and String constants, Arithmetic, Relation and Logical operators, Assignment operators, Increment and decrement operators, conditional operators, Bitwise operators, Type modifiers and expressions, writing and interpreting expressions, using expressions in statements. Basic input/output. Control statements: conditional statements, if

- else, nesting of if - else, else if ladder, switch statements, loops in c, for, while, do - while loops, break, continue, exit ( ), goto and label declarations, One dimensional two dimensional and multidimensional arrays. Storage classes: Automatic variables, External variables, Static variables, Scope and lifetime of declarations. Functions: classification of functions, functions definition and declaration, assessing a function, return statement, parameter passing in functions. Pointers (concept only). Structure: Definition and declaration; structure (initialization) comparison of structure variable; Array of structures : array within structures, structures within structures, passing structures to functions; Unions accessing a union member, union of structure, initialization of a union variable, uses of union. Introduction to linked list, linear linked list, insertion of a node in list, removal of a node from list. Files in C: Defining and opening a file, input – output operation on a file, creating a file, reading a file. Statistics Methods and techniques in R.