GRADUATE PROGRAMME IN OPERATIONAL RESEARCH

EXAMINATIONS CONDUCTED BY THE
OPERATIONAL RESEARCH SOCIETY OF INDIA

General Information

The Concept of O.R.

The application of Operational Research Technique of complex problems of an organization involves taking into account the total system which influences the decision making process. The Operational Research not only considers all the factors in the environment and their interrelationships, but tries to present these in a quantified form so that the implications of the change in any of the factors can be easily assessed. Operational Research is an integral part of the multidisciplinary area of Management Philosophy.

The origin of Operational Research may be traced to the various scientific studies on military operations and logistic problems which were undertaken by teams of scientists and specialists in U.K. and U.S.A. during the Second World War. It was only after the war that this type of activity was extended beyond military context and has been known as 'Operational Research' or 'Operations Research'.

Recent developments in the field of computer technology have enabled Operational Research to integrate their models into information systems and thus make O.R. a part of decision making procedures of many organizations. Apart from application in military contexts, Operational Research provides techniques for decision making in various industries, business organization, government, social service organizations and public utilities for dealing with such problems as production planning and scheduling, finance and investment planning under risk, materials management, marketing and distribution, planning and manpower, traffic and transportation planning for national economy, health planning and hospital management, educational system and national integration.

The Operational Research Society of India.

The Operational Research Society of India was established in 1957 with the objective of promoting Operational Research and associated activities in our country. Today, it has the membership strength of more than 1000 with branches operating in various parts of the country. The Secretariat of the Operational Research Society of India is located at 39, Mahanirvan Road, Kolkata 700029. The Society is affiliated to the International Federation of O.R. Societies (a World Organization).

The members of the Society have been actively participating in conferences, seminars, conventions etc. in Operational Research and in other allied subjects held in India and abroad, assisting other organizations in training course in O.R. and conducting courses for various levels of executives.

The first Annual Convention of the Society held in Kolkata in 1968 was a step forward in the growth of Operational Research in India. This along with the subsequent conventions, has served a very useful purpose in the exchange of views and generation of new ideas among Operational Research scientist and practitioners both in theory and in practice.

Following are the categories of membership of the Society for which fees payable are as under:

Sl. No.	Type of Membership	Subscription (₹)
1	Student Member	300/- per calendar year
2	Annual Member	600/- per calendar year
3	Life Member	6000/- lump sum

The fees for Annual and Life members include the subscription to the quarterly journal "OPSEARCH". Student members may receive the journal by paying requisite charges. Issues already published in a year prior to the date of payment of publication are not guaranteed. The fees are subject to revision. The annual fees cover a calendar year.

The demand from persons specially Mathematicians, Statisticians, Engineers, Economists and Accountants engaged in such diverse fields as Industry, business, administration, space research, universities, and other institution for participation in the rapidly growing field of scientific endeavour continues to increase steadily. To provide for such participation on a large scale, the Society introduced its Graduate Programme Examination in Operational Research in 1973 and feels expansion of O.R. knowledge in this country. The examination has been recognized by the Government of India, Ministry of Human Resource Development in memo No. F. 1843/78/T-7 dated 15th October 1980.

Graduate Programme in Operational Research: Nature of Examination

This examination will have two parts (i) Part I subjects and (ii) Part II subjects. Part I will have basic subjects, namely, Mathematics; Statistics; Economics; Industrial Engineering and Computer Programming; Cost Accountancy and Introduction to Operational Research. Part II will have four compulsory papers involving O.R techniques, such as Linear and Non Linear Programming; Inventory Theory; Queuing Theory, Reliability and Simulation; Network Analysis, Investment and Replacement Theory and two ELECTIVEs from a set of subjects namely Advanced Mathematics and Statistics; Theory of Games and Statistical Decision Theory; Dynamic Programming; Control Processes; O.R. in Marketing; Cybernetics and Econometrics.

Rules for the Examination System

1. A candidate can appear in as many new subjects as he/she may chose in Part I at any examination.
2. After qualifying in any three subjects in Part I, a candidate can appear in Part II in addition to part I subjects, if any, skipping one examination following the first examination he/she has appeared in Part I, with the limitation that he/she will be

allowed to appear in three new Part II subjects at a time. This latter limitation will cease after two years of his/her registration for the examination.

3. There will be no limit to the number of back subjects in which one could appear in any examination in any part.
4. A candidate who falls to clear both parts I and II in three years after registration, will have to register afresh, with all formalities and fees. On re-registration the credit for the subjects passed will be carried forward.
5. The diploma conferred on completion of the two parts is recognized by the Ministry of Human Resource Development, Government of India, Department of Education as equivalent to Degree.

Programme of Examinations

Examinations in both Part I and II subjects will be held in the month of November on an all India basis in Kolkata and in other cities, on the basis of enrolment. Announcement of the dates and programmes of these Examinations will be made sufficiently in advance. The dates are subject to change to meet exigencies, but will be duly intimated.

The candidate intending to appear in November in a particular year should complete the formalities for registration and examination latest by 31 July of the year in which the candidate opts to appear at the examination. A candidate may also pay all the fees and submit all the forms at the same time together.

THE COURSE STRUCTURE AND SUBJECTS

Part I

Candidates will be required to qualify as under in the following subjects:

Subjects	Subject Code	Total Marks	Qualifying Marks	Time
1. Mathematics	GDOR101C	100	40	3 hours
2. Statistics	GDOR102C	100	40	-Do-
3. Economics	GDOR103C	100	40	-Do-
4. Industrial Engineering & Computer Programming.	GDOR104C GDOR105C	50 50	15 15 Total =40	-Do-
5. Cost Accountancy	GDOR106C	100	40	-Do-
6. Introduction to O.R.	GDOR107C	100	40	-Do-
7. Qualifying Maths.*	GDOR108X	100	40	-Do-

* To be taken by those Graduates who have not passed mathematics at the B.Sc. level (pass degree course).

Part II

Candidates will be required to qualify as under in the following subjects:

Four Compulsory Subjects:

Subjects	Subject Code	Total Marks	Qualifying Marks	Time
1. Linear and Non-Linear Programming	GDOR201C	100	40	3 hours
2. Inventory Theory	GDOR202C	100	40	-Do-
3. Queuing Theory, Reliability and Simulation	GDOR203C	100	40	-Do-
4. Network Analysis, investment and Replacement Theory	GDOR204C	100	40	-Do-

Electives

Any two from the following seven subjects:

Subjects	Subject Code	Total Marks	Qualifying Marks	Time
i) Advanced Mathematics and Statistics	GDOR205E	100	40	3 hours
ii) Theory of Games and statistical Decision Theory	GDOR206E	100	40	-Do-
iii) Dynamic Programming	GDOR207E	100	40	-Do-
iv) Control Processes	GDOR208E	100	40	-Do-
v) Operational Research in Marketing	GDOR209E	100	40	-Do-
vi) Cybernetics	GDOR210E	100	40	-Do-
vii) Econometrics	GDOR211E	100	40	-Do-

No exemption, whatsoever, is given and a candidate is required to qualify in all the papers as prescribed.

Distinction will be awarded to candidates securing 60% or above in aggregate.

EXAMINATION FEE

Registration : Rs.1,000.00

Part I- one subject : Rs.500.00

Part II- one subject : Rs.500.00

For back papers same fee for each paper as for first appearance.

Part III : Rs.5,000.00

ASSESSMENT AND AWARD

Examination results will normally be announced within two months from the commencement of an examination. Candidates passing all the subjects of both Part-I & Part II will be awarded appropriate Diploma as recognized by the Ministry of Human Resource Development, Government of India.

A graduate of any recognized University passing with Mathematics as one of the subjects and an Engineering Graduate and of not less than 18 years of age is eligible to appear in the Graduate Programme Examination of the Society. Those Graduates who have not passed mathematics atthe B.Sc. level (pass degree course) will have to appear for a qualifying examination in Mathematics along with the Part I subjects.

PROCEDURE FOR ENROLLMENT

A candidate desirous of appearing in the Society's Graduate Examination has to register his/her name with the society for the Examination he/she would be required to –

1) apply for registrations for the examination with the society in the enclosed form with a fee of Rs.1,000/- only
2) send attested copies of University certificates/mark sheets as evidence of eligibility of appear.
3) Send attested copies of Higher Secondary Examination or its equivalent examination certificates or other certificates as evidence of age.
4) Apply for permission after or along with registration to appear in part I subjects in the printed form enclosed, with the requisite examination fees. (Rs.500/- for each part I paper) before the last dates specified.

All the fees are non-refundable and non-transferable. The examination fees are good only for the specific examination on specific dates and will otherwise lapse automatically.

Payment will be accepted by demand draft drawn in favour of "Operational Research Society of India"payable in Kolkata.

For these examinations the last date for receiving applications for registration and for permission to appear is 31 July for the November examination.

DESCRIPTION OF THE SUBJECTS
(Syllabus)
Part – I

1. Mathematics (Subject Code**:** GDOR101C**)**

Linear Algebra: Vector space, Subspaces of R^n, linear dependence and dimension, Matrices, Rank of a Matrix, Systems of linear equations, Cayley-Hamilton theorem, Eigen Values and Eigen Vectors, Diagonalisation of a Matrix, Quadratic Forms.

Ordinary Differential Equation (ODE): Formation of a differential equation, Equation of First order and First Degree, Exact differential equation, Equations of first order and higher degree, Linear equations of Higher Order, Homogeneous Linear Equations, Simultaneous Linear Differential equations, Method of Variation of Parameters.

Partial differential equation (PDE): Formation of PDEs, Types of solutions, PDEs of the first order, Lagrange's solution, PDEs of second and higher order, Classification of linear PDEs of second order. Homogeneous and non-homogeneous equations with constant coefficients.

Numerical Analysis: Finite Differences, Interpolation, Method of Least squares, Numerical Differentiation and Integration.

Reference Books:

1. ***K. Hoffman & Ray Kunze****, Linear Algebra, Prentice Hall, India (1972).*
2. ***Das & Mukherjee****, Differential and Integral Calculus, U. N. Dhar*
3. ***Shepley L. Ross,*** *Differential Equations, Wiley, 1984.*
4. ***Ghosh & Maiti,*** *Differential Equations, U. N. Dhar*
5. ***S. K. Mapa,*** *Higher Algebra Abstract and linear, Sarat Book House.*
6. ***M. K. Jain, S. R. K. Iyengar, R. K. Jain,*** *Numerical Methods, New Age International Publishers.*

2. Statistics (Subject Code**:** GDOR102C**)**

Probability Theory: Elementary set theory, Event, Meaning of Probability, Classical definition of Probability, Conditional Probability, Baye's Rule and Independence of events, Random Variable and its expectation and variance, Joint distribution of two random variables, Cumulative distribution function, Probability mass and probability density function. Discrete distributions- Binomial, Poisson, Negative Binomial and Geometric. Continuous distributions- Exponential, Normal, Gamma, Beta, Weibull, Bivariate Normal, Bivariate Exponential.

Statistical Methods: Collection and summarization of data, Frequency distribution, Graphical presentations- bar diagram, Pie chart, histogram, Stem and leaf plot, Box plot, Moments of frequency distribution, Central tendency, Dispersion, Skewness and kurtosis, Bivariate data- Correlation and regression, Logistic regression, Categorical data analysis.

Statistical Inference: Random Sampling, parameter, statistic and sampling distribution, Expectation and standard error of sample mean and sample proportion, Chi-square, t and F

distributions, Point and interval estimation, Maximum likelihood method of estimation, Testing of hypothesis - test for mean and variance of a normal distribution, Analysis of variance - one and two way classified data.

Simulation: Random numbers, Generation of sample from Binomial, Poisson, Exponential and Normal distributions,
Use of R-program.

Reference books:

1. Fundamental of Statistics (Vol. I) - Goon, Gupta & Dasgupta, World Press Pvt. Ltd.1968.
2. Probability, Statistics and Queuing Theory with Computer Science Applications (2nd Edition)- Arnold O. Allen, Elsevier.
3. Foundations of Theory of Probability - Andrey Kolmogrov, Chelsea Publishing Company. (June 1956).
4. Probability and Statistics - Schaum's on line series. (Schaum's outlines; 4th edition (01Jan2013)).

3. Economics (Subject Code**:** GDOR103C**)**

Group A: Microeconomics

• Market equilibrium: Supply, demand, elasticities – short and long run.
• Consumer behaviour: the indifference curve, MRS, substitutes and complements, utility maximization, price/income – consumption curves, Engel curves, income and substitution effects, inferior and Giffen goods.
• The firm: Isoquants, MRTS, diminishing returns and returns to scale; fixed and variable costs,
average and marginal costs – related concepts and diagrams; short and long run, cost minimization and output maximization subject to relevant constraints.
• Market structure: perfect competition and monopoly – concepts and illustration of equilibrium;
industry supply curve under perfect competition – long and short run, broad concepts of monopolistic competition and oligopoly (details of equilibrium not required).
• General equilibrium: Edgeworth box diagram, contract curve, utility possibility frontier and production possibility frontier, three conditions of economic efficiency, gains from free trade, efficient allocation under perfect competition, Pareto optimality and the First Fundamental Theorem of welfare economics.
• Market failure – causes; merit goods and public goods – the role of government.

Group B: Macroeconomics

• Circular flow of income and expenditure, three equivalent ways of measuring GDP, concept of national income; the Keynesian consumption function, expenditure on GDP and equilibrium in the goods market, autonomous spending and the multiplier, the IS curve - shifts, the balanced budget multiplier.
• The Central Bank and money supply, deposit multiplier, instruments of control of money supply; demand for money and equilibrium in the money market (LM curve and its shifts).
• IS-LM and aggregate demand, concept of natural rate of unemployment and output; money supply and price level – neutrality of money in the medium run.

• Open economy – expenditure on GDP and equilibrium in the goods market, saving-investment and net exports, nominal and real exchange rates (concepts only).
• Bond prices as present discounted values, bond yields and the yield curve, stock prices as present discounted values, the efficient market hypothesis and random walk.
• Growth economics – aggregate production function under CRS, steady state capital and output in the Solow model, saving rate and the steady state.

References books:

General:
• *Samuelson and Nordhaus – Economics. Tata McGrew Hill Education Pvt. Ltd.*
Microeconomics:
• *Pindyck, R.S. and Rubinfeld, D.L. – Microeconomics, Prentice Hall.*
• *Anindya Sen – Microeconomics: Theory and Applications, Oxford University Press.*
• *Joseph E. Stiglitz, Jay K. Rosengard – Economics of the Public Sector, W W Norton & Co.*
Macroeconomics:
• *N. Gregory Mankiw – Brief Principles of Macroeconomics, Cengage Learning.*
• *Olivier Blanchard – Macroeconomics, Pearson Education (2010).*
• *S. Sikdar – Principles of Macroeconomics, Oxford University Press (U. S. A.)*

4. Industrial Engineering & Computer Programming.

A. Industrial Engineering(Subject Code**:** GDOR104C**)**

1. **Genesis and Development of Industrial Engineering**.
2. **Management:** Introduction, Management and Administration, Functions of management.
3. **Plant Location and Facility Layout**.
4. **Productivity:** Introduction, Importance, Tools of productivity
5. **Work Methods Design:** Introduction, Process Analysis, Activity Charts, Fundamental Hand Motions
6. **Time Study:** Introduction, Time Study Equipment, Rating Factor, Determining Allowances, Time Standards, Therbligs, SIMO – chart.
7. **Value analysis**.
8. **Material handling:** Introduction, Need, Function, Basic equipments.
9. **Quality Control and Improvement:** Definition of Quality, Quality Control, Quality Circle, PDCA Cycle, Control Chart - $\bar{X}$ and R– chart, p- chart, c– chart.
10. **Maintenance Management:** Difference between preventive and breakdown maintenance.

Reference books:

1. *Motion and Time Study: Design and Measurement of Work by Ralph M. Barnes, John Wiley & Sons*
2. *Introduction to Work Study, George Kanawaty, International Labour Organization*
3. *Fundamentals of Quality Control and Improvement, AmitavaMitra, John Wiley & Sons*
4. *Industrial Engineering and Organization Management, S K Sharma and Savita Sharma, S K Kataria& Sons*
5. *Principles and Practice of Management, L M Prasad, Sultan Chand & Sons*

B. Computer Programming.(Subject Code**:** GDOR105C**)**

Computer Fundamentals: Generations of Computers , A simple model of a Digital computer, Von Neumann architecture, Representation of Characters, Integers, Fractions in computers, Binary, Octal, Hexadecimal representations and their inter conversions, Binary arithmetic, Memory, Processors Input / Output units.

Programming Concepts: Need for a Programming Language, Introduction to High level Language Programming Paradigm, ***Introduction to C Programming:*** Basic of storage class, Functions, Preprocessor, Structure and Union, Pointers, Function Pointers, Introduction to bit wise operators.
Data Structures & Algorithms: Abstract Data Types, Arrays, Stack and Queue, ***Searching Algorithms:*** Linear search, Binary search, ***Sorting Algorithms:*** Bubble sort, Selection sort, Quick sort, Merge Sort.

Reference Books:

1. ***V. Rajaraman,*** *Computer Programming in C, Prentice Hall India, 1994.*
2. ***B. Kernighan and D. Ritchie,*** *The C Programming Language, Prentice Hall India, 1995.*
3. ***E. Balagurusamy,*** *Introduction to Computing, TMH.*
4. ***F. S. Schied,*** *Theory and Problems of Computers and Programming.*

5. Cost Accountancy (Subject Code**:** GDOR106C**)**

Material control; Purchasing and accounting; Stores keeping and material recording; Stores ledger; Fixation of stores levels; Pricing stores issues; Physical inventory, Materials issuance and accounting, Scrap, wastage and spoilage.

Pay-roll accounting, Time keeping, Recording attendance, Elapsed, time, preparation of factory pay-roll; labour time pricing; Employee remuneration and incentive, labour turnover.

Overheads;Manufacturing, overhead accumulation distribution and absorption, administrative overhead selling and distribution overheads.

Cost Control accounts and subsidiary ledgers; Reconciliation of Cost and financial Accounts; Integrated systems of Cost Accounting.

Methods of costing, Job Costing system; and Batch Costing, Process Cost System, Normal and Abnormal Loss, Equivalent Product and by-product Costing.

Budget and budgetary control, Capital Expenditure Budgeting.

Marginal Costing and Cost – Volume Profit Analysis.

Service Costing.

Standard cost; Direct materials cost variables; Direct Wages; variances, Manufacturing overhead cost variances; Cost variance Reports; Administrative overhead variances, Distribution cost variance;.

Uniform cost accounting and inter firm comparison.

Working Capital Management, Accounting Ratio Analysis, Sources and Application of Funds, Make or Buy Decision.

Reference books:

1. *Cost Accounting by Basu & Das.*
2. *Cost Accounting Problems & Solutions by V. K. Saxena& C. D. Vashist published by Sultan Chand & Sons.*
3. *An Introduction to Financial Management by Mazumdar, Ali &Nesha published by ABS Publishing House.(2005)*

6. Introduction to Operational Research. (Subject Code**:** GDOR107C**)**

1. **Introduction:** Significance of O.R. for decision making problems, formulation of models in O.R.

2. **Linear Programming:**

    i. Introduction – Convex set, Extreme points, Spheres and Hyperplanes, Convex and Concave functions and their properties, Pseudo-convex, Quasi-convex function, dual simplex sensitivity.
    ii. Model Formulation.
    iii. Solution procedures - Graphical method, Algebraic method, Simplex algorithm.
    iv. Duality Theory - Primal and dual problems, Dual simplex algorithm.

3. **Transportation Problem:** Formulation of transportation problems, Balanced and unbalanced problems, Minimization and maximization problems, North-West Corner rule, Vogel's approximation method, MODI Method, Degeneracy.

4. **Assignment Problem:** Mathematical formulation, Hungarian method, Balanced and unbalanced problems, Travelling Salesman problem as an assignment problem.

5. **Game Theory:**

    i. Definition and terminology - Payoff matrix, Saddle point, Two-person zero sum game, Pure and mixed strategy, Value of the game.
    ii. Max–min and Min–max principle, Dominance principle.

iii. Solution procedure - Graphical method, Algebraic method, Simplex method.

6. **Queuing Theory:**

   i. Introduction – Queuing discipline, Queuing strategy, Kendal's notation.
   ii. Models – Single and multi-channel.

7. **Inventory Problems:**

   i. Definition and terminology - Inventory costs (set up, holding, storage), Demand, Replenishment, Time horizon, Lead time, Safety stock, EOQ.
   ii. Deterministic Inventory models – Infinite replenishment without shortage, Finite replenishment without shortage, Infinite replenishment with shortage, Finite replenishment with shortage, Multi-item inventory models.
   iii. Probabilistic inventory models – Discrete and Continuous.

Reference books:

1. Management Science Modeling – Albright and Winston (Cengage Learning).
2. Operations Research - J.K. Sharma (Macmillan India Ltd.).
3. Introduction to Management Science – F.S. Hillier and M.S. Hillier (Tata McGraw Hill).
4. Principals of Operation Research – H.M. Wagner (Prentice Hall).
5. Operations Research - Principles and Practice - Ravindran, Phillips and Solberg (Wiley).
6. Operational Research - An Introduction, H.A. Taha (Macmillan).
7. Introduction to Operations Research – Hillier and Lieberman (McGraw Hill).

Part II

COMPULSORY SUBJECTS

1. Linear and Non-linear Programming (Subject Code**:** GDOR201C **)**

Classical optimization techniques:

Single and multi-variable problems – Types of constraints
Advanced Linear Optimization Algorithms; Revised simplex method; Dual simplex method; Bounded variables; Integer Programming; Parameter Programming

Non-linear Programming:

Minimization and Maximization of convex functions; Local and global optimum; convergence analysis;
Unconstrained optimization: Fibonacci search; Golden section search; Newton's Method;

Constrained optimization: Lagrangian method, sufficiency conditions; KKT optimality conditions; Quadratic programming problems; Convex programming problems; Interior point method; Geometric programming;

Stochastic programming.

References:

1. S. M. Sinha, Mathematical Programming: Theory and Methods, Elsevier, 2006
2. Bazarra M.S., Sherali H.D. & Shetty C. M., Nonlinear Programming Theory and Algorithms, John Wiley, New York, 1979.
3. Kalyanmoy Deb, Optimization for Engineering: Design-Algorithms and Examples, Prentice Hall (India), 1998
4. S. S. Rao – Engineering Optimization
5. J. K. Sharma – Operations Research, Macmillon

2. Inventory Theory (Subject Code**:** GDOR202C **)**

Introduction, Deterministic Inventory Models, Concept of Inventory and Various Parameter, EOQ Models with and without Shortages, EOQ with Quality Discount, Multi Items Inventory Models, Math-Constraints Inventory Models, Concept of Lead Time, Safety Stock and Service Level; Probabilistic Inventory Models, Single Period Inventory Models, Newsboy Problems with or without Salvage Value, Periodic and Continuous Review Models; Concept of Simulation in Inventory Control.

References:

1. Principles of O.R. with Application to Managerial Decisions: H. M. Wagner, Prentice Hall
2. Introduction to operations Research: F. S. Hiller and G.J. Liberman, Addison Wesley
3. Operations Research: An Introduction: H. A. Taha, Macmillan, N. Y.
4. Operations Research – Kanti Swarup, P. K. Gupta and man Mohan, 1977
5. Inventory Control: Models and Methods – Bartmann Dieter, 1992
6. Production Control and inventory control practices and problems as evidenced by a survey of eleven American companies – Culbertson R. W. 1953

3. Queuing Theory, Reliability and Simulation (Subject Code**:** GDOR203C **)**

1. **Queuing Theory**: General Introduction of Queuing Systems; Arrival and Service Processes; Queuing Characteristics and Queuing Terminology; Pure Birth and Pure Death Models; Simple Markovian Birth-Death Queue Models; Steady State Solution for the M/M/1 Queue Model; Queues with Parallel Channels (M/M/C); Erlang Formula; (M/Ek/1) Steady State Measures of Performance (Ls, Lq, Ws, Wq,etc.); Balk Queuing System; Imbedded Markov Chain Models.

2. **Reliability**: Definition of Reliability and its Measure; Concept of Failure; System Reliability and its Mathematical Model; Time Dependent Reliability of Components and Systems; Reliability Based Optimum Design; Fault Tree Analysis – System Safety Analysis; Failure Modes and Effect Analysis; Event Tree Analysis; Minimal Cut Sets.

3. **Simulation**: Role of Simulation in System Analysis; Monte Carlo Simulation; Definition and Types of Simulation; Generation of Random Number; Applications of Simulation (Inventory, Queue, Capital Budgeting and Financial Planning).

References:

1. Taha, Hamdy A., "Operations Research: An Introduction", Pearson Education, Asia, 2002
2. Gross, Donald, Harris, Car M., "Fundamentals of Queuing Theory". John Wiley and Sons, New York,1985.
3. Srinatyh, L. S., "Reliability Engineering", East West Press Pvt. Ltd., New Delhi, 1991
4. Sharma, S. D. "Operations Research", Kedar Nath Ram Nath & Co., Meerut, 2003.
5. Ravindran, Phillips and Solberg: Operations Research – Principles & Practice.

4. Network Analysis, Investment and Replacement Theory. (Subject Code**:** GDOR204C **)**

1. **Network Analysis:** Introduction to Theory of Graphs; Directed Networks; Shortest Path Problems; Minimal Spanning Tree Problem; Maximal Flow Problems; Max Flow – Mincut Theorem; Decision Tree Analysis.

Project Network: Construction of Networks; Critical Path Methods; PERT; Cost Analysis and Crashing the Network; Linear Programming Formulation.

2. **Investment Theory**: Introduction to Investment Analysis; Methods of Investment Analysis; Break-Even Analysis; Payback Period Method; Average (Accounting) Rate of Return Method; Time-Adjusted or Discounted Cash Flow (DCF) Method; Internal Rate of Return (IRR) Method; Discounted Payback Period Method; Probabilistic Models; Risk Adjusted Discount Rate; Expected Monetary Value (EMV); Hiller And Hertz's Models.

3. **Replacement Theory**: Replacement of Items that Deteriorate; Equipment Replacement Policies in Deterministic and Stochastic Cases; Chain of Improving Equipments Assuming (i) Same Life for Each Member in the Chain and (ii) Increasing Life; Replacement in Anticipation of Failure; Group Replacement Policy; Markovian Decision Models in Replacement Theory.

References:

1. OPERATIONS RESEARCH by ER. Prem Kumar Gupta and Dr. D. S. Hira, S. Chand Publications
2. OPERATIONS RESEARCH: An Introduction by Hamdy A. Taha, Prentice Hall of India Publication
3. Introduction to Operations Research by Billye and Gillett, Tata Mc-Graw Hill Publications, New Edition
4. Operations Research: Application and Algorithms by Waynel Winston, fourth edition
5. Operations Research: Methods and Problems by M. Sasieni, A. Yaspan, L. Friedman, J. Wiley & Sons, U.S.A.
6. Operations Research by S. Kalavathy, Vikash Publication, Second Edition.

ELECTIVE SUBJECTS

1. Advanced Mathematics and Statistics (Subject Code**:** GDOR205E**)**

Selected topics of matrix algebra, linear partial differential equations of first and second order, simultaneous and partial difference equations differential-difference equations, topological spaces, metric spaces, normed spaces, linear functional, linear operators, simple types of functional equations.

Analysis of variance, partial and multiple correlation, design and analysis of experiments, introduction to stochastic process, stationary and ergodic process. Markov process, prediction theory, stochastic allocation and control problems, selected applications in traffic flow, inventory, dam and storage, engineering design and optimal control problems.

2. Theory of Games and Statistical Decision Theory (Subject Code**:** GDOR206E**)**

Mathematical formulation of conflict decision problems as a game, extensive and normal forms of a game, finite games and linear programming, the mini-max theorem and the value of game, optimal strategies, finite games of perfect information, games with an infinite number of moves, games of timing, games of sequence generation and prediction, differential games, management games for decision-making under conditions of competition and uncertainty.

Games against nature, theory of utility functions, complete class theorems for decision function, Bayesian decision functions, Optimality criterion, multiple decision rules – sequential decision problems – Applications to statistical inference, acceptance sampling, control theory and problems in economics.

3. Dynamic Programming (Subject Code**:** GDOR207E)

Introduction; Multistage Decision; Dynamic Programming Terminology; Concept of Suboptimization and Principle of Optimality; Bellman's Principle of Optimality; Solution of Problems Using Dynamic Programming Approach; Serial Multistage Model; Solution of Multistage Optimization Problems; Backward and Forward Recursion; Recursive Relationship of Dynamic Programming for Various Problems; Linear and Non-Linear Programming as a Case of Dynamic Programming; Problem of Dimensionality in Dynamic Programming; Computational Economy in Dynamic Programming; Application of Dynamic Programming to Continuous System; Applications to Investment; Inventory and Production; Advertisement and Queuing Problems.

References:

1. Sono, Nonlinear and Dynamic Programming (An Introduction), Springer – Verlag. 1975

2. Rao. S. S., Engineering Optimization-Theory and Practice, New Age International Private Ltd., New Delhi,Third Edition, 1996.

3. Rao. S. S. Optimization - Theory and Applications, Wiley Eastern, 1977.

4. Swarup, Kanti, Gupta, P. K. and Man Mohan, Operations Research, Sultan Chand and Sons, New Delhi,2004

5. Taha, H. A. Operations Research- An Introduction, Prentice-Hall of India, New Delhi , 7th Edition 2006

6. White, D. J. Dynamic Programming, Oliver-Boyd: Day, 1969.

4. **Control Processes (**Subject Code**:** GDOR208E**)**

The control processes approach to system analysis, types of control processes-finite, and infinite discrete and continuous, scalar and multidimensional, categorization of control process-optimal control, stochastic control and adaptive controls, solution of problems in control process by methods of calculus of variation, Pontryagins maximum principle, dynamic programming and functional analysis, applications to problems in engineering, operations research and economics.

5. **O. R. in Marketing (**Subject Code**:** GDOR209E**)**

1. The Complexity of Marketing; Operations Research Approach to Marketing Decisions; Modelling Methodology; Theoretical Modelling in Marketing.

2. Foundations and Nature of Consumer Behaviour Models; Stochastic Models-Purchase Incidence Models, Stochastic Models of Brand Choice; Process-Oriented Models of Consumer Choice Process; Integration- Examples of Combining Models to Solve Management Problems in this area.

3. Organizational Buying Models: Webstar-Wind Model, Howard-Sheth Model, Choffray-Lilien Model, Group Choice, Bargaining Models, Negotiation Models

4. Pricing Decision Models: Simple Monopoly in a Static Environment, Dobson and Kalish Model,

5. Advertising Decision Models: ADPULS Model, Nerlove-Arrow Model, BRANDAID Model, Mills Model, Friedman Model

6. Promotion Decision Models: Types and Effects, Rao-Lilien Model, Narasimhan's Model, Blattberg and Levin's Model

7. Sales Force Decision Models: Assignment Problem, Travelling Salesman Problem

8. Distribution Models: Distribution Strategy, Distribution Location, SHARP Model, Distribution Logistics

9. New Product Planning Models: Pure Innovative Model(Fourt and Woodlock), Fisher and Pry Model, Bass's Model, Kalish Model, Repeat Purchase Model

10. Marketing Planning and Strategy Decisions: Market Definition and Market Structure, Cost Dynamics, Marketing Mix Analysis and Models

11. Decision Support and Implementation: Decision Support Systems, Intelligent Marketing Systems, IMS/MDSS: Bridge to Successful Implementation for Marketing Models

References:

1. Lilien, Gary L., Kotler, Philip, and Moorthy, K. Sridhar; "Marketing Models"; PHI Learning Private Ltd., New Delhi-110001, 2011.

2. Robert D. Buzzell; "Mathematical Models and Marketing Management"; December, 1964

3. Charles A. Ingene, and Mark E. Parry; "Mathematical Models of Distribution Channels" (International Series in Quantitative Marketing); 23 Nov 2004

4. Frank Myron Bass ; "Mathematical Models and Methods in Marketing", R.D. Irwin, 1961.

6. Cybernetics (Subject Code**:** GDOR210E**)**

(The emphasis will be primarily on the application aspect of cybernetics in operational research).

Cybernetic approach: Definition of Cybernetic system varieties- meaning of isomorphism and homomorphism-meta-system, subsystem, black-boxes etc; concept of feedback, stability-sensitivity-conflict between stability and sensitivity-stochastic and determinate systems.

(Through emphasis will be on the physical concept, elements of algebraic structure will be introduced).

Elements of information Theory: Shannon's theory measurement of information, concept of entropy, concept of ergodicity (Birkhoff), information transfer-statistics of the communication problems-application in industrial process.

Elements of Network theory: graph theory-simple applications of network problems.

Applications in Economics: Forecasting models (with applications)- Marketing Models (with applications)-use of simple differential equations- Planning Models (including appraisal of input model of leontief).

A few problems in Social Cybernetics: Analysis of conflicts (with game theoretic approach), problem of adaptivization vis-à-vis optimization-hierarchy (Mesarovics models).

7. Econometrics (Subject Code**:** GDOR211E**)**

Regression Methods; Classical least squares-refiew of theory, computational procedure, multi-co linearity, curvillinearity, regressions, use of drummy variables.

No spherical Disturbance and generalized least squares; heteroseedastivity and auto correlated disturbances; estimation methods, tests of non-sphericalness-the Durbir-Waston statistic.

Qualitative and limited dependent variables, use of extraneous information.

Stochastic regressors; independent stochastic linear regressions; autoregressive linear regression-distributed lag models; errors in variables, grouping methods.

Simultaneous equation systems; least squares bias; the problems of identification-order and rank conditions for identify-ability: indirect least squares, structural estimation single-equation methods (two-stage squares, limited information, K-class estimators) and system methods (three-stage least squares, full information); recursive models; comparison of various estimators-asymptotic properties, Monte-Carlo Studies; forecasting; the multipliers; final forms; direct estimation of reduced forms.

Applications; Analysis of size distribution; the Lorenz Curve; Pareto, lognormal and log logistic distribution; (probability models leading to pareto and lognormal distribution; concentration in business or industry). Statistical demand analysis, the demand function; elasticity of demand, Engel Curve analysis form household budgets-algebraic forms, effect of household size and composition; the specific concentration curve, demand projections based on Engel Curve; estimation of demand functions from time series data-the problems of identification etc.; pooling of cross-section and time series data: the Cob-Web models; the linear expenditure system.

Syllabus for the Qualifying Examination in Mathematics
(Subject Code**:** GDOR108X**)**

[To be taken by Graduates without Mathematics of B.Sc. standard who intend to appear in the Graduate Programme in Operational Research Examination]

Differential and Integral Calculus

Functions of single variable, limits and continuity of functions, inverse functions, differential coefficients-interpretation as rate measurer, techniques of differentiation for products and quotients, functions, trigonometric functions, logarithmic and exponential functions etc.; successive differentiation, Roles and mean value theorems, differentials taylor's and Maclurin's theorems with different forms of remainders, maxima and minima-conditions for existence and applications to simple cases.

Integration as a sum and as the reverse process of differentiation, standard forms, methods of integration-integration by substitution, integration by parts, integration of rational fractions, elementary properties of definite integrals, evaluation of standard definite integrals involving trigonometric functions, calculation of volume, surface, moment of inertia of simple bodies.

Elementary Differential Equation

Family of curves represented by differential equations, degree and order of equation, solution of first order differential equations of different type-variables separable, homogenous, linear and exact, solution of second order differential equations with constant coefficients, use of the method of operators in finding the particular integral of second order equation of form f (D)y = h(x), where h(x) – constant, x^n, e^{nx}cos bx. etc. applications to problems in different areas.

<u>Algebra</u>

Determinants and their properties, minors and cofactors, addition and multiplication of determinants, adjoint of a determinant, Laplace's developments of determinants, symmetric and skew symmetric determinants, solution of linear equations by cramer's rule.

Matrices-definitions, different types of matrices, equality of matrices, addition, multiplication and transportation of matrices.

Part-III

Only candidates who are diploma holders in Operational Research of this Society are eligible to pursue the Part-III offered by the Society (This Part is yet to be recognized).

A candidate who has registered for the Part-III programme of the Society is to complete the Part III programme of the Society in one year by writing a dissertation on a topic duly approved by the O.R. Society of India. The intending candidate (a graduate diploma holder of the society) is to submit a synopsis (three copies) of the project to be undertaken together

with the name and the Bio-data of the guide under whom the candidate proposes to write the dissertation along with a letter of consent of the proposed guide. The O.R. Society of India after a review by a panel of experts decides whether the proposed project could be undertaken or not. Once the Society permits the candidate to carry out the project work he is supposed to submit three copies of the dissertation for adjudication by the panel of experts appointed by the Society. On unanimous recommendation for approval of the dissertation, the candidate is supposed to appear for a viva-voce before an expert. On his satisfactory performance at the viva-voce, the Society considers that its Part III programme has been completed and the candidate is offered the Post-Graduate Diploma in O.R.

The project could be on applied or theoretical problems a part of which should be on real life problems.

The decisions to approve or reject a dissertation lies with the Society. The examination fees for the Part III Programme is Rs.5000/- to be paid by a Bank Draft in favour of 'Operational Research Society of India' payable in Kolkata along with the duly completed form.

INSTRUCTION FOR CANDIDATES

Please read the following instructions before filling in the Examination Registration form for the Graduate Programme in Operational Research Examination.

1. Persons willing to appear in Part I and Part II Examinations conducted by the Society should at least be either engineering graduates of graduates in other disciplines with Mathematics as one of the subject at B.A or B.Sc. level from any recognized university/ Institution.

2. Other graduates will have to take the qualifying examination in mathematics.

3. The candidate~~s~~ has to become a member of the Society. The candidate can enroll either as 'Student Member' of as 'Member'. This membership will have to be continued.

4. In case the person is already a member of the Society he/she has to mention the name of the branch attached to in the space provided in the examination registration form and enclose the receipt of membership subscription paid for the current year. If the receipt is missing, a letter from the Hon. Secretary or the Branch concerned needed. Membership fee covers a calendar year.

5. A candidate who is not already a member of the society and is willing to register his/her name with the Society for the examination, will have to fill in two forms namely

(i) membership form and (ii) examination registration form available in the website. The candidate will have to enclose the photocopy of his/her graduation certificate and mark sheets with the examination registration form:

The candidate will have to pay the following membership fee:

Either

Student Member – Annual Subscription Rs.300/- (a student member is not entitled to get the quarterly journal OPSEARCH)

or

Member – Annual Subscription : Rs.600/-

or

Life Member : Rs.6000/- (one time)

6. The examination fee (for Graduate Programme) may be paid along with the registration or thereafter within the due dates enclosing the prescribed form properly filled in.
7. Payment in all cases will be crossed bank draft drawn in favour of 'Operational Research Society of India' payable in Kolkata. The total amount of fees may be sent in a consolidated bank draft instead of multiple drafts for different items.

Some Information and Rules

1. The examination system is recognized by the Ministry of Human Resource Development, Government of India.
2. Two Grades are offered: **Distinction & Pass**
   Those who will qualify in all the six subjects in one go at the first attempt in Part I and get 60% marks in aggregate will be awarded **Distinction**. In case of Part II, if completed in two first attempts without back subjects, obtaining 60% in aggregate, will qualify for Distinction.

   Pass on obtaining a minimum of 40% in each subject.
3. Details about dissertation is available on application.
4. Once a candidate obtains pass marks in a paper (40% with 15/50 in case of half paper), the credit is stored for future.
5. The Society organizes no correspondence course.
6. A list of text and reference books will be supplied on registration.

7. A candidate can appear in as many new subjects as he may choose in Part I at any examination.
8. After qualifying in any three subjects in Part I, a candidate can appear in Part II in addition to Part I subjects, If any.
9. There will be no limit to the number of back subjects in which one could appear in any-examination in any part.
10. A candidate who fails to clear both parts I and II in three years after registration, will have to register afresh, with all formalities and fees.
11. The examinations on both Part I and Part II subjects will be held in the month of May every year.