M.A./ M. Sc. COURSE
IN
APPLIED OPERATIONAL RESEARCH

TWO-YEAR FULL-TIME PROGRAMME
SEMESTERS I to IV

SCHEME OF EXAMINATION AND COURSE CONTENTS

Department of Operational Research
Faculty of Mathematical Sciences
University of Delhi
Delhi-110007

M.A./ M. Sc. APPLIED OPERATIONAL RESEARCH
SCHEME OF EXAMINATION

Examination 2009 and onwards	**Duration (hrs.)**	**Sem. Exam Marks**	**Int. Ass. Marks**	**Total**	**Credits**
First Year: Semester I					
Course 101 : Mathematical Programming-I	3	70	30	100	4
Course 102 : Inventory Management-I	3	70	30	100	4
Course 103 : Queueing System-I	3	70	30	100	4
Course 104 : Statistics-I	3	70	30	100	4
Course 105: C++ & Unix					
(a) Theory	3	50	20	70	4
(b) Practical	3			30	

Examination 2010 and onwards	**Duration (hrs.)**	**Sem. Exam Marks**	**Int. Ass. Marks**	**Total**	**Credits**
First Year: Semester II					
Course 201 : Mathematical Programming-II	3	70	30	100	4
Course 202 : Scheduling Techniques	3	70	30	100	4
Course 203 : Marketing Management	3	70	30	100	4
Course 204 : Statistics-II	3	70	30	100	4
Course 205 : Java Programming					
(a) Theory	3	50	20	70	4
(b) Practical	3			30	

Examination 2010 and onwards	**Duration (hrs.)**	**Sem. Exam Marks**	**Int. Ass. Marks**	**Total**	**Credits**
Second Year: Semester III					
Course 301 : Mathematical Programming-III	3	70	30	100	4
Course 302 : Reliability & Maintenance Theory	3	70	30	100	4
Course 303 : Software Engineering	3	70	30	100	4
Course 304 : Database Management System & Visual Programming					
(a) Theory	3	50	20	70	4
(b) Practical	3			30	
Course 305 : Any course out of the following :					
(i) A course of equivalent credit offered by another department.					
(ii) Logistics & Supply Chain Management	3	70	30	100	4
(iii) Financial Management	3	70	30	100	4

Examination 2011 and onwards

		Duration (hrs.)	Sem. Exam Marks	Int. Ass. Marks	Total	Credits
Second Year: Semester IV						
Course 401-403 :	Any three of the following :					
(i)	Marketing Research	3	70	30	100	4
(ii)	Inventory Management-II	3	70	30	100	4
(iii)	Queueuing System-II	3	70	30	100	4
(iv)	Quality Management	3	70	30	100	4
(v)	Multicriteria Decision Models	3	70	30	100	4
(vi)	Data Warehousing and Data Mining	3	70	30	100	4
(vii)	A course of equivalent credit offered by another department.	3	70	30	100	4
Course 404 –405 :	**Project Work** The Project work will be taken under approved supervisors from amongst the members of the staff and the report is to be submitted for evaluation by April 30. It will carry 200 marks.					
	Project Report	100 marks				
	Viva-Voce	50 marks				
	Internal Assessment	50 marks			200	8

Note 1: **Each paper will carry 100 marks including 30 marks earmarked for Internal Assessment.**

Note 2: **Case Studies will be an integral part of teaching and evaluation in Courses 101-104, 201-205, 301-305 & 401-403. Semester Theory Examination in the said courses will include a compulsory part of 20 marks towards the Case Study.**

Note 3: **Students will be encouraged to use relevant software, viz. LINDO/LINGO/ MATLAB/SPSS/ Mathematica, etc. during their course of study.**

Note 4: **It is recommended that four lectures per week will be devoted to papers 101 to 104, 201 to 204, 301 to 303 & 305 and 401-403 and three lectures per week for the theory part of papers 105, 205 & 304. It is further recommended that each part of practical papers 105, 205 & 304 will be assigned two practical periods per week.**

Note 5 : **Each of papers 105, 205 & 304 consists of two parts (a and b) with the following subdivision of 30 marks for Part-b :**

Practical Examination	**: 20 marks**
Oral	**: 05 marks**
Record Book	**: 05 marks**

Note 6 : The format and modus operandi of Internal Assessments will be decided and announced by the Department at the beginning of a semester.

Pass Percentage, Promotion and Division Criteria and Span Period

PASS PERCENTAGE

Minimum marks for passing the examination in each semester shall be 40% in each paper and 45% in aggregate of a semester.

However, a candidate who has secured the minimum marks to pass in each paper but has not secured the minimum marks to pass in aggregate may reappear in any of the paper/s of his choice in the concerned semester in order to be able to secure the minimum marks prescribed to pass the semester in aggregate.

Note: Examination for courses shall be conducted only in the respective odd and even semesters as per the Scheme of Examinations. Regular as well as Ex-Students shall be permitted to appear/re-appear/improve in courses of odd semesters only at the end of odd semesters and courses of even semesters only at the end of even semesters.

No student would be allowed to avail of more than 3 chances to pass any paper inclusive of the first attempt.

PROMOTION CRITERIA

A. **Semester to Semester:** Students shall be required to fulfill the promotion criteria from the first year to the second year of the Course. Within the same year, students shall be allowed to be promoted from a semester to the next semester, provided he/she has passed at least half the papers of the current semester.

B. **First year to Second year:** Admission to the second year of the M.A./M. Sc. Course shall be open to only those students who have successfully passed at least 75% papers out of the papers offered for the first year of the M.A./M. Sc. Course comprising Semester I and Semester II taken together. However, he/she will have to clear the remaining papers while studying in the second year of the M.A./M. Sc. Course.

DIVISION CRITERIA

Successful candidates will be classified on the basis of the combined results of first year and second year examinations as follows:

Candidates securing 60% and above	:	I Division
Candidates securing 50% and above but less than 60%	:	II Division
Candidates securing 45% and above but less than 50%	:	Pass

SPAN PERIOD

No students shall be admitted as a candidate for the examination for any of the Years/Semesters after the lapse of 4 years from the date of admission to the first year of the M.A./M. Sc. Programme.

M.A./M. Sc. APPLIED OPERATIONAL RESEARCH

Semester I: Examination 2009 and onwards

Course -101: Mathematical Programming-I

Introduction to Linear Programming. Problem formulations. Linear independence and dependence of vectors. Convex sets. Extreme points. Hyperplanes and Halfspaces. Directions of a convex set. Convex cones. Polyhedral sets and cones. Theory of Simplex Method. Simplex Algorithm. Degeneracy. Bounded variable problem. Revised Simplex method. Duality theory. Dual-simplex method. Parametric linear programming. Sensitivity analysis. Transportation problem. Assignment problem.

Suggested Readings:

1. M. S. Bazara, J. J. Jarvis, H. D. Sherali: Linear Programming and Network Flows, Wiley, 3rd Edition, 2004.
2. P. R. Thie, G. E. Keough: An Introduction to Linear Programming and Game Theory, Wiley, New Jersey, 3rd edition, 2008.
3. S. I. Gass: Linear Programming- Methods and Applications, 5th Edition, McGraw Hill, New York, 1985 (Dover Publications, 2003 is also available).
4. G. Hadley: Linear Programming, Narosa, 1987 (2002 reprint available).
5. G. Hadley: Linear Algebra, Narosa, 1987 (2002 reprint available).
6. Wayne L. Winston and M. Venkataramanan: Introduction to Mathematical Programming: Applications and Algorithms, 4th edition, Duxbury Press, 2002.
7. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 8th Edition, 2007.
8. S. Chandra, Jayadeva, Aparna Mehra: Numerical Optimization with Applications, Narosa Publishing House, 2009
9. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
10. F.S. Hillier, G.J. Lieberman : Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill, 2010.

Course-102: Inventory Management-I

Analytical structure of Production and Inventory problems. Inventory related costs. Properties of Inventory systems. Factors influencing inventories. Inventory classification and its use in controlling inventory. Concept of Lead time, safety stock and service level.

Deterministic inventory models and extensions without and with lead time. Inventory models with partial backlogging and lost sales. Inventory models with constraints. Quantity discounts: All units and incremental. Models with continuous production and non-constant demand with known production capacity.

Stochastic Inventory Models and Extension without and with lead time. Power demand pattern Inventory Model.

Introduction to Just in Time (JIT) and Vendor Managed Inventory (VMI).

Suggested Readings:

1. Sven Axsater: Inventory Control,International Series in Operations Research & Management Science, Springer, 2nd Edition, 2006.

2. G. Hadley, T. M. Whitin: Analysis of Inventory Systems, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc., 1979.
3. Zipkin: Foundations of Inventory Management, Mc-Graw Hill Inc., 2000.
4. E. Naddor: Inventory System, John Wiley, 1966.
5. L. A. Johnson, D. C. Montogomery: Operations Research in Production Planning, Scheduling and Inventory Control, John Wiley, 1974.
6. Donald Waters: Inventory Control, John Wiley, 2003.
7. Edward A. Silver, David F. Pyke, Rein Peterson: Inventory Management and Production Planning and Scheduling, Wiley, 3rd Edition, 1998.

Course-103: Queueing System-I

Introduction of Basic Concepts in Stochastic Processes. Markov Chain and Markov Processes.
Queueing Systems. Probability Distribution of Arrival and Service Times.

Markovian Queueing Systems: M/M/1, M/M/C, Finite Source queues. Erlangian Queueing Systems : $M/E_k/1$ and $E_k/M/1$. Bulk Queueing Systems. Basic Idea of Priority Systems. Imbedded Markov Chain Models: M/G/1, G/M/1, M/D/C.

Design and Control Problems in Queueing Theory.

Simulation Procedures: Data Generation and Book-Keeping.

Suggested Readings:

1. R.B. Cooper: Introduction to Queueing Theory, 2nd Edition, North Holland, 1981.
2. L. Kleinrock: Queueing Systems, Volume I, John Wiley, 1975.
3. D. Gross, C. M.Harris: Fundamentals of Queueing Theory, 3rd Edition, John Wiley and Sons Inc. Pte. Ltd., 2002.
4. D. R. Cox, W. L. Smith: Queues, Mathuen, 1961.
5. J. Medhi: Stochastic Models in Queueing Theory, Academic Press, 1991.
6. T. L. Satty: Elements of Queueing Theory with Applications, Dover, NY, 1983.
7. U. N. Bhat: An introduction to Queueing Theory: Modelling and Analysis in Applications (Statistics for Industry and Technology), Birkhauser Boston, 2008.
8. U. N. Prabhu: Foundations of Queueing Theory, International Series in Operations Research & Management Science, Kluwer Academic Publishers, 2nd Edition, 2002.

Course-104: Statistics-I

Probability: Probability Axioms, Conditional Probability and Bayes' Theorem.

Random Variables and their Probability Distribution. Characteristic Function.

Multidimensional Random Variable: Joint, Marginal and Conditional Distributions, Independent Random Variables, Functions of Several Random Variables, Order Statistics.

Discrete and Continuous Distributions.

Weak Law of Large Numbers. Central Limit Theorem.
Concepts of Random Sampling. Sample Characteristics. Exact Sampling Distributions: Chi-Square, t, F Distributions.

Parametric Point Estimation. Testing of Hypotheses and Interval Estimation: Problem of Point Estimation, Maximum Likelihood Estimators, Simple and Composite Hypotheses, Neyman-Pearson Lemma, Likelihood Ratio Tests, Chi-Square tests, t-tests, F tests, Large Sample Tests, Construction of Confidence Intervals.

Suggested Readings:

1. V. K. Rohatgi, and Saleh, A.K. Md. Ehsanes: An Introduction to Probability and Statistics, 2nd Edition, John Wiley & Sons Inc., 2006.

2. A. M. Goon, A. K. Gupta, B. Dasgupta: An Outline of Statistical Theory, Vol. I, 2nd Edition,World Press Pvt. Ltd., 1987.
3. J. E. Fruend: Mathematical Statistics, 5th Edition, Eastern Economy Edition, 1999.
4. A. M. Mood, F. A. Graybill, D. C. Boes: Introduction to the Theory of Statistics, 3rd Edition, McGraw-Hill Book Co., 1974.
5. E. J. Dudewicz, S. N. Mishra: Modern Mathematical Statistics, John Wiley & Sons, 1988.
6. D. C. Montgomery, G. C. Runger: Applied Statistics and Probability for Engineers, 3rd Edition, Wiley India Pvt. Ltd. 2003.
7. A. D. Aczel, J. Sounderpandian: Complete Business Statistics, 6th Edition, McGraw Hill, 2006.

Course-105: C++ & Unix

Introduction to Computer Systems. Fundamental concepts of Operating system, networking.

Introduction to UNIX: UNIX commands, file system, shell features. Introduction to Structured Programming, Elementary Data Structure in C++, Control Structures: Sequence, Selection and Repetition. Functions, Arrays & Pointers.

Introduction to Object Oriented Programming, Object and Classes in C++. Functions, Structures, Operator Overloading, Inheritance, Polymorphism, Exceptions, Templates and Container Classes. Files and Streams.

Suggested Readings:

1. Afzal Amir: Unix Unbounded, Beginning Approach, 5th Edition, Prentice Hall, 2007.
2. B.W. Kernighan, W. R. Pike: The Unix Programming Environment, Prentice-Hall of India Pvt. Ltd, 1984 (Reprint 2007).
3. Graham Glass and King Ables: Unix for Programmers and Users, 3rd Edition, Prentice Hall, 2003.
4. S.C. Dewhurst, K.T. Stark: Programming with C++, Prentice Hall, 1995.
5. Scott Meyers: Effective C++, 55 Specific Ways to Improve Your Program and Designs, 3rd Edition, Addison-Wesley, 2005.
6. Bjarne Stroustrup: The C++ Programming Language, 3rd Edition, Addison-Wesley, 2000.
7. Peter Norton: Introduction to Computers, 6th Edition, Tata McGraw-Hill, 2005.

Course-(b): Practical based on C++ involving OR problems

Semester II: Examination 2010 and onwards

Course – 201: Mathematical Programming-II

Unconstrained and constrained optimization problems. Types of extrema and their necessary and sufficient conditions. Convex functions and their properties. Fritz-John optimality conditions. Karush-Kuhn-Tucker optimality conditions. Quadratic Programming: Wolfe's method, Complementary pivot algorithm, Duality in quadratic programming. Integer Linear Programming: Modeling using pure and mixed integer programming, Branch and Bound Technique, Gomory's Cutting Plane Algorithm, 0-1 programming problem, E-Bala's algorithm. Separable Programming. Dynamic Programming: Additive and Multiplicative Separable returns for objective as well as constraints functions.

Applications of Integer and Quadratic Programming.

Suggested Readings:

1. M. S. Bazara, H. D. Sherali, C. M. Shetty: Nonlinear Programming-Theory and Algorithms, Wiley, 3rd Edition, 2006.
2. A. Antoniou, Wu-Sheng Lu: Practical Optimization-Algorithms and Engineering Applications, Springer, 2007.
3. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 8th Edition, 2007.
4. Wayne L. Winston and M. Venkataramanan: Introduction to Mathematical Programming: Applications and Algorithms, 4th edition, Duxbury Press, 2002.
5. O. L. Mangesarian: Nonlinear Programming, McGraw Hill, New York, 1969. Reprint: SIAM Classics in Applied Mathematics 10, 1994, Philadelphia.
6. S. Chandra, Jayadeva, Aparna Mehra: Numerical Optimization with Applications, Narosa Publishing House, 2009
7. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
8. G. Hadley: Nonlinear and Dynamic Programming, Addison-Wesley, 1964.

Course-202: Scheduling Techniques

Flows in networks. Maximal flow. Distribution and general minimal cost flow problems. Shortest path and traveling salesman problem. Construction of minimal spanning tree and its applications.

Capacitated transshipment model. Facility location models.

PERT and CPM with activity times known and probabilistic. Various types of floats. Updating of PERT charts. Project crashing. Formulation of CPM as a linear programming problem. Resource leveling and resource scheduling.

Sequencing problem. Flow shop problem and general n/m job-shop problem.

Suggested Readings:

1. L. R. Ford, D. R. Fulkerson: Flows in Network, Princeton University Press, 1962.
2. M. S. Bazara, J. J. Jarvis, H. D. Sherali: Linear Programming and Network Flows, Wiley, 3rd Edition, 2004.
3. R. K. Ahuja, T. L. Magnanti, B. Orlin: Network Flows-Theory, Algorithm and Applications, Prentice Hall, NJ, 1993.
4. P. A. Jenson, W. J. Barnes: Network Flows Programming, John Wiley and Sons, 1980.
5. S. E. Elmaghraby: Activity Networks, Project Planning, and Control, John Wiley and Sons, 1977.
6. M.L. Pinedo: Scheduling-Theory, Algorithms, and Systems, 2nd Edition, Prentice Hall, 2002.
7. Cliff T. Ragsdale: Spreadsheet Modeling & Decision Analysis, 5th Edition, Mason, Thomson South-Western, 2008.
8. Ronald H. Ballou: Business Logistics / Supply Chain Management, 5th Edition, Prentice Hall, 2004.
9. J. D. Weist, F. K. Levy: A Management Guide to PERT/ CPM, 2nd Edition, PHI, 1967 (Reprint 2007).

Course-203: Marketing Management

Concept of Marketing and its role in Business and Public Organization, Marketing Decisions, Need for Scientific Marketing Analysis, Uses and Limitations of Mathematical Models in Marketing. Joint optimization of price, quality and promotional effort. Purchasing under fluctuating prices. Factors affecting Pricing decision, Pricing methods.

Promotional decisions in the presence of competition, Game theory models for Promotional Effort, Spatial Allocation of Promotional Effort, Media Allocation of Advertisement, Brand Switching Analysis.

Sales Response to Advertising in Presence of Competition.

Channels of distribution, Transportation decision, Locating company’s wholesale dealers and warehouses.

Suggested Readings:

1. Tony Curtis: Marketing for Engineers, Scientists and Technologists, John Wiley & Sons Inc. 2008.

2. B. Bass (ed): Mathematical Models and Methods in Marketing, Irwin Series, 1971
3. S. Murty, G. L. Lilien, P. Kotler: Marketing Models, Prentice Hall of India, 1998.
4. William R. King: Quantitative Analysis for Marketing Management, McGraw Hill Co., 1967.
5. J. M. Howard: Consumer behaviour in Marketing Strategies, Prentice Hall, 1989.
6. D.B. Montgomery, G.L.Urban: Management Science in Marketing, Prentice Hall, 1979.
7. Graham J. Hooley and Michael K. Hassey: Quantitative Methods in Marketing, 2nd Edition, International Thomson Business Press, 1999.
8. Grahame R. Dowling: The Art and Science of Marketing- Marketing for Marketing Managers, Oxford University Press, 2005.
9. Gary L. Lilien, Philip Kotler, K. Sridhar Moorthy: Marketing Models, Prentice Hall of India, 2003.

Course - 204 : Statistics-II

Introduction to Forecasting: The Nature and Uses of Forecasts, Explanatory versus Time Series Forecasting.

Econometric Models: The Basis of Econometric Modelling, Dynamic Econometric Models, Simultaneous Equation Models.

Time Series Methods: Decomposition, Exponential Smoothing Methods.

Time Series Econometrics : An Introduction to ARIMA Models, Box-Jenkin's Methodology, Basics of ARCH and GARCH Models, Non-Stationarity and Unit Root Test.

Suggested Readings:

1. J. Johnston: Econometric Methods , 3rd Edition, Mc-Graw Hill International Editions, 1984.
2. A. Koutsoyiannis: Theory of Econometrics, 2nd Edition, Palgrave Publications, 2001.
3. D. C. Montgomery, Elisabeth A. Peck, G. Geoffrey Vining: Introduction to Linear regression Analysis, 3rd Edition, John Wiley & Sons, 2003.
4. D. C. Montgomery, Cheryl L. Jennings, M. Kulahci: Introduction to Time Series Analysis and Forecasting, John Wiley & Sons Inc. 2008.
5. Peter J. Brockwell, Richard A. Davis: Introduction to Time Series Analysis and Forecasting, Springer International Editions, 2002.
6. S. Makridakis, Steven C. Wheelwright, Rob J. Hyndman: Forecasting-Methods and Applications, 3rd Edition, John Wiley & Sons Inc. 1998.

Course-205 : Java Programming

Introduction to Java Programming. Basic Syntax & Structures, Applets, Control Structures, Methods, Arrays, Strings, Object Oriented Programming Concepts (Objects, Classes, Inheritance), GUI Component (Panels and Frames), Multimedia (Sound, Graphics, Images and Animation), Error and Exception Handling, Multithreading and Input/Output Streams.

Software Packages for Operational Research Techniques.

Suggested Readings:

1. H. M. Deitel, P. J. Deitel : Java, How to Program, 7th Edition, Prentice Hall, 2007.
2. Bruce Eckel: Thinking in Java, 4th Edition, Prentice Hall 2006.
3. Mary Campione, Kathy Walrath: The Java Tutorial: Object Oriented Java Tutorial, The: Object-Oriented Programming for the Internet, 2nd Edition, Addison-Wesley, 1998.
4. Y Daniel Liang: Introduction to Java Programming: Comprehensive Version, 7th Edition, Prentice Hall, 2008.
5. Walter Savitch, Frank M. Carrano: Java- Introduction to Problem Solving and Programming, 5th Edition, Prentice Hall, 2009

Course- (b) Practical using Java and OR Software Packages

Semester III: Examination 2010 and onwards

Course-301 : Mathematical Programming-III

Generalized convex functions and their properties. Fritz John and Karush-Kuhn-Tucker optimality conditions. Lagrangian duality and saddle point optimality conditions. The concept of Penalty functions and Barrier functions. Methods of feasible directions: The method of reduced gradient, Generalized reduced gradient method. Geometric Programming. Multi-objective linear optimization: Efficiency and non-dominance, The weighted sum method. Goal programming: Modeling using goal programming, Archimedian goal programming, Preemptive goal programming, Lexicographic simplex method, Goal efficiency. Linear fractional programming: Simplex method, Charne's and Cooper method.

Suggested Readings:

1. M. S. Bazara, H. D. Sherali, C. M. Shetty: Nonlinear Programming-Theory and Algorithms, Wiley, 3rd Edition, 2006.
2. Ronald L. Rardin: Optimization in Operations Research, Prentice Hall, 1998.
3. E. Bajalinov: Linear-Fractional Programming-Theory, Methods, Applications, and Software, Kluwer Academic Publishers, 2003.
4. R. E. Steuer: Multiple Criteria Optimization-Theory, Computation, and Application, Wiley Series in Probability and Mathematical Statistics-Applied, Wiley, 1986.
5. O. L. Mangesarian: Nonlinear Programming, McGraw Hill, New York, 1969. Reprint: SIAM Classic in Applied Mathematics 10, 1994, Philadelphia.
6. S. Chandra, Jayadeva, Aparna Mehra: Numerical Optimization with Applications, Narosa Publishing House, 2009
7. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.

Course-302 : Reliability & Maintenance Theory

Basics of Reliability, Classes of life distributions based on Notions of Ageing.

System Reliability: Reliability of Series, Parallel, Standby, k-out-of-n, Series-Parallel, Parallel -Series configurations and Bridge Structure.

Reliability models of non-maintained & maintained systems, Availability theory and its modelling for various configurations.

Introduction to Renewal theory, Types of Renewal Processes and their Asymptotic Properties, Application of Renewal theory to One-Unit Repairable Systems with Different Maintenance Policies (Age, Block, Preventive & Corrective). Reward Renewal Processes, Minimal Repair Replacement Policies.

Suggested Readings:

1. R. E. Barlow, F. Proschan: Statistical Theory of Reliability and Life Testing, Holt, Rinehert &Winston Inc., 1975.
2. John G. Rau: Optimization and Probability in Systems Engineering, V.N. Reinhold Co., 1970**.**
3. P. K. Kapur, R. B. Garg, S. Kumar: Contributions to Hardware and Software Reliability, World Scientific, Singapore, 1999.
4. D. R. Cox: Renewal Theory, Mathew, London, 1962.
5. H. Pham: Handbook of Reliability Engineering, Springer-Verlag London Ltd., 2003.

6. A. Hoyland, M. Rausand: System Reliability Theory-Models and Statistical Methods, John Wiley & Sons Inc. 1994.
7. D. L. Grosh: A Primer of Reliability Theory, John Wiley & Sons Inc., 1989.
8. Way Kuo, Ming J. Zuo: Optimal Reliability Modeling- Principles and Applications, John Wiley & Sons Inc., 2003.

Course-303 : Software Engineering

A historical overview of software technology, Software production and its difficulties. Software life cycle models, Stepwise Refinement, CASE and Other Tools of the Trade.

Modularity and Objects, Requirements analysis, Requirements specification methods, Software planning and project management, Software design.

Software verification, validation, and testing, Introduction to Software Reliability, Importance of Software testing, Difference between hardware and software reliability, Software Reliability and Availability, Modelling Software Reliability and its uses, Markovian models, NHPP models, Parameter estimation, Reliability of Modular software, Introduction to COTS.

Release time problems, Release time problem based on cost criterion, Reliability criterion, Cost-reliability criterion, Penalty cost, Testing effort, Random life cycle, Warranty and risk cost, Bicriterion release policy.

Software implementation and integration, Software maintenance.

Case Studies.

Suggested Readings:

1. S. R. Schach: Classical and Object-Oriented Software Engineering, 4th Edition, WCB/McGraw-Hill, New York, NY 1998.
2. S. L. Pfleeger: Software Engineering : Theory and Practice, Prentice Hall, NJ, 1998.
3. I. Sommerville: Software Engineering, Fifth edition, Addison- Wesley, 1996.
4. M. L. Shooman: Software Engineering, McGraw Hill Book Co., 1983.
5. J. D. Musa, A. Iannino, K. Okumoto: Software Reliability- Measurement, Prediction and Application, McGraw Hill Book Co., 1987.
6. P. K. Kapur, R. B. Garg, S. Kumar: Contributions to Hardware and Software and Reliability, World Scientific, Singapore, 1999.
7. W. Kuo, V. R. Prasad, F. A. Tillman, C. L. Hwang: Optimal Reliability Design-Fundamentals and Applications, Cambridge University Press, 2001.

Course-304 : Database Management System & Visual Programming

Introduction to Database Systems, Data Models, Relational Model, The ER Methodology for Logical Design, Relational Algebra, SQL, Design Theory for Relational Databases.

Object Oriented Database Systems, Physical Level Organization, Query Processing & Optimization, Security and Integrity, Concurrency Control and Crash Recovery, Distributed Systems.

Introduction to Client Server Programming : Visual programming environment, iconic systems and their specifications including syntactic and semantic aspects. Messages and message passing, Programming with graphic devices, Implementation with visual systems, Introduction to Visual Basic.

Suggested Readings:

1. C. J. Date: An Introduction to Database Systems, 8th Edition, Addison Wesley, 2003.
2. H. F. Korth, A. Silberschatz, S. Sudarshan: Database System Concepts, McGraw Hill, 5th Edition, 2005.
3. Raghu Ramakrishnan: Database Management System, 3rd Edition, McGraw Hill, 2003.
4. B.C. Dasai: Database System, BPB, 1998.
5. Ramez Elmasri, Shamkant B. Navathe: Fundamentals of Database Systems, 4 Edition, Addison Wesley, 2003
6. David I. Schneider: Introduction to Programming Using Visual Basic 2008, 7 Edition, Prentice Hall, 2008.

Part – (b) Practical based on (a)

Course-305 : Any course out of the following

(i) : **A course of equivalent credit offered by another department.**

(ii) : Logistics & Supply Chain Management

Introduction to the Supply Chain. Customer driven strategies in production and distribution systems. Integrated production and distribution networks. Supply chain management in the context of JIT and MRP-II. Distributon Resource planning. Management of dealer networks. Total quality control and product innovation across the supply chain. Incoming logistics and supplier relationships. Value addition analysis.

Metrics for measurement of supply- chain performance. Mathematical models and computer assisted decision support for supply chain management. Mathematical programming models for supply chain decisions: Vendor buyer coordination, production-distribution coordination, inventory-distribution coordination.

Suggested Readings:

1. Martin Christopher: Logistics and Supply Chain Management, Richard Erwin, 1994.
2. F. W. Thomas: Customer Driven Strategies, Oliver White, 1992.
3. S. P. Bradley, A. Hax, T. L. Magnanti: Applied Mathematical Programming, Addison Wesley, 1977.
4. William A. Sandras (Jr): JIT: Making it happen, Oliver White, 1989.
5. M. G. Korgaonkar: Just-in-time manufacturing, Macmillan, 1992.
6. Sunil Chopra, Peter Meindl: Supply Chain Management-Strategy, Planning and Operation, 3rd Edition, Prentice-Hall Inc., 2007.
7. S. Tayur, Ram Ganeshan, Michael Magazine, Quantitative Models for Supply Chain Management, Kluwer Academic Publishers, Boston, 1998.
8. G. Raghuram, N. Rangaraj [Editors]: Logistics and Supply Chain Management-Cases and Concepts, Macmillan, New Delhi, 2000.
9. Journal Articles.

(iii) : **Financial Management**

Role of Financial Management. Financial Analysis and Planning. Working Capital Management. Cost of Capital. Capital Structure and Dividend Policies. Short term and Long term Financial Planning.

Analytical Approach to Finance. Application of Integer Programming & Goal Programming to Working Capital and Capital Budgeting Problems.

Financing Decision: Problems of determining optimal capital structure, Leasing, Debt Management, Analysis of commitment of funds and risk of cash insolvency; Receivables and Inventory Management Approaches.

Suggested Readings:

1. J. C. Van Horne, J. M. Wachowicz: Fundamentals of Financial management, 11th Edition, Prentice Hall of India, 2000.

2. E. F. Brigham, L. C. Gapenski, C.E. Michael: Financial Management-Theory and Practice, The Dryden Press, 11th Edition, 2004.
3. M. Y. Khan, P. K. Jain: Financial Management, Tata McGraw Hill Pub. Co., New Delhi, 5th Edition, 2008.
4. G. Cornuejols, R. Tutuncu: Optimization Methods in Finance, Cambridge University Press, 2007.
5. R. Brealey, S. Mgres, A. Franklin: Principle of Corporate Finance, 9th Edition, McGraw Hill, 2008.
6. J. Spronk: Interactive Multiple Goal Programming: An Application to Financial Planning, Martinus Nijhoff Publishing, 1981.

Semester IV: Examination 2011 and onwards

Any three courses out of the following

Course-401-403 (i) : Marketing Research

Marketing Research and its objectives; Applications of Marketing Research: Advertising Research, Product Research, Sales Research, Planning the research design, Exploratory descriptive research, experimental research.

Methods of collecting data, Sampling procedures in Marketing Research, Data Processing and Analysis, Advanced procedures of data analysis: Factor Analysis, Cluster Analysis and Discriminant Analysis. Research on Consumer behaviour, Group versus individual behaviour, Innovation Diffusion Model; Categorization of adopters, Estimation and Validation of Models.

Introduction of a new product, Utility measures for product search, Break even analysis for product evaluation, PERT and CPM in product development.

Suggested Readings:

1. P. E. Green, D. S. Tull, G. Album: Research for Marketing Decisions, Prentice hall of India, 1999.
2. D. J. Luck and R. S. Rubin: Marketing Research, Prentice Hall of India, 1998.
3. H. W. Boyd, R. Westfall, S. F. Starch: Marketing Research-Text and Cases, 7th Edition, Richard D. Irwin Inc., 1989.
4. Vijay Mahajan, Robart A. Peterson: Models for Innovation Diffusion and Related Research Papers, SAGE Publication, 1990.
5. David A. Aaker, V. Kumara, George S. Day: Marketing Research, 9th Edition, John Wiley & Sons Inc. 2007.
6. Scott M. Smith, Gerald S. Albaum: Fundamentals of Marketing Research, SAGE Publications Inc., 2005.

7. Carl McDaniel, Roger Gates: Marketing Research Essentials, John Wiley & Sons Inc. 2007.

Course-401-403 (ii): Inventory Management-II

Dynamic Inventory Models : Probabilistic Reorder Point Inventory Models without and with Lead Time. Two bin (S,s) Inventory Policy. Distribution Free Analysis. Minimax Solution of Inventory Models. Warehousing Problems. Capacity Expansion. Periodic and Continuous Review Models, Inventory Management of Items with Deterioration. Inventory Management of Items with inflation.

Material Requirement Planning: Dependent Demand, Bill of Materials, Determining net Requirement, Time Phased Order Point.

Material Management: Value Analysis, Store Control, Purchasing Function, Codification and Standardization.

Suggested Readings:

1. K. J. Arrow, Karlins, H. Scarff: Studies in the Mathematical theory of Inventory and Production, Stanford University Press, 1958.
2. G. Hadley, T. M. Whitin: Analysis of Inventory Systems, D.B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc., 1979.
3. G. W. Ploss: Production and Inventory Control-Principle and Teaching, 2nd Edition, Prentice Hall, 1985.
4. E. Naddor: Inventory Systems, John Wiley, 1966.
5. C. C. Sherbrooke: Optimal Inventory Modelling of System, Muller Echelon Techniques, Springer, 2nd Edition, 2004.
6. L. B. Schwarz: Multilevel Production Inventory Control System- Theory and Practice, North Holland Publishing Co., New York, 1981.
7. E. Porteus: Foundation of Stochastic Inventory Theory, Stanford Business Books, 2002.

Course-401-403 (iii): Queueing System -II

Probability Distribution of Phase Type, Quasi Birth and Death Processes, G/PH/I Queueing Models and their Algorithmic Solutions.

Combinatorial Method and Its Applications in Queueing Theory.

Introduction to Queueing Network Models, Open and Closed Queueing Networks, Computational Methods, Algorithms for Computing Normalizing Constant for Closed Network, Derivation of Performance Measures, Multi-Class Networks and their Solutions (BCMP Networks).

Queueing Networks with Blocking, Different Numerical Methods for their Solutions, Two Nodes Open Network with Blocking.

Suggested Readings:

1. H. Chen, David D. Yao: Fundamentals of Queueing Networks- Performance, Asymptotics and Optimization, Springer-Verlag, 2001.
2. J. Medhi: Stochastic Models in Queueing Theory, Academic Press Inc., 2nd Edition, 2003.
3. M. F. Neuts: Matrix Geometric Solutions in Stochastic Models, John Hopkins, University Press London, 1981.
4. L. Takacs: Combinatorial Methods in the Theory of Stochastic Processes, John Wiley, New York, 1967.
5. S. Balsomo, N.P. Vittoria De, R. Onvural: Analysis of Queueing networks with Blocking, Kluwer Academic Publishers, 2001.
6. T. G. Robertazzi: Computer Networks and systems- Queueing Theory and Performance Evaluation, 3rd Edition, 2000.
7. H. Kobayashi, Brian L. Mark: System Modelling and Analysis- Foundations of System Performance Evaluation, Prentice Hall, 2008.
8. H. G. Perros: Queueing networks with Blocking, Oxford University Press, 1994.

Course-401-403 (iv): Quality Management

Overview of quality, history of quality, competitive advantage, industrial perspective, total quality system, Taguchi "Loss Function" concept.

Meaning and significance of statistical process control (SPC)-construction of control charts for variables and attributes. Acceptance sampling plans. Process capability-meaning, significance and measurement-Six sigma concepts of process capability, DMAIC and DMADV.

Pareto Analysis, Ishikawa (Cause/Effect) Diagrams, Failure Modes and Effects Analysis, Program for Quality Improving.

Introduction to ISO 9000- quality management systems-guidelines for performance improvements. Quality Audits.

Introduction to Total Quality Management (TQM).

Suggested Readings:

1. J.R. Evans, W.M. Lindsay: The Management and Control of Quality, West Publishing Company, 1996.
2. Kaoru Ishikawa: Introduction to Quality Control, Chapman and Hall, 1992.
3. Dale H. Besterfield et al, Total Quality Management, 3rd Edition, Pearson Education, 2004.
4. Shridhara Bhat K: Total Quality Management- Text and Cases, First Edition, Himalaya Publishing House, 2002.
5. Amitava Mitra: Fundamentals of Quality Control and Improvement, 2nd Edition, Prentice-Hall Inc., 1998
6. William J. Kolarii: Creating quality, McGraw Hill, 1995.
7. Poornima M.Charantimath: Total quality management, Pearson Education, 2003.
8. Indian standard – quality management systems – Guidelines for performance improvement, Bureau of Indian standards, New Delhi.

Course-401-403 (v): **Multicriteria Decision Models**

Multi-objective linear optimization: Lexicographic optimality, Interactive procedures. Multi-objective nonlinear optimization: efficient and properly efficient solutions, Karush-Kuhn-Tucker optimality conditions. Vehicle routing problem. Bottleneck assignment problem. Multi-objective fractional programming. Data Envelopment Analysis: Charnes, Cooper and Rhodes (CCR) model, Banker, Charnes and Cooper (BCC) model. Analytic Hierarchy Process: Ranking and weighting information using Eigen Vector Method (EVM) and Approximation Methods.

Suggested Readings:

1. R. E. Steuer: Multiple Criteria Optimization-Theory, Computation, and Application, Wiley Series in Probability and Mathematical Statistics-Applied, Wiley, 1986.
2. M. Ehrgott: Multicriteria Optimization, Springer, Second Edition, 2005.
3. Ronald L. Rardin: Optimization in Operations Research, Prentice Hall, 1998.
4. W. W. Cooper, L. M. Seiford, K. Tone: Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software, Springer, 2007.
5. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 8th Edition, 2007.

6. K. Miettinen: Nonlinear Multiobjective Optimization, Kluwer Academic Publishers, 1999.
7. K. Deb: Multi-objective Optimization using Evolutionary Algorithms, Wiley, 2001.
8. T.L. Saaty: Fundamentals of the Analytic Hierarchy Process, RWS Publications, Pittsburgh, PA, 2000.

Course-401-403 (vi) : Data Warehousing and Data Mining

Overview of Data Warehouse, Online Analytical Processing (OLAP). Introduction to Data Mining, The Knowledge in Databases (KDD) process, Limitation of traditional query tools. Association rules, Classification, Clustering, Regression, Patterns, Time series. Measuring predictive performance, Efficiency, Data preparation, Data Reduction, Mathematical Solutions, Statistical Methods, Distance Solutions. Decision Trees, Decision Rules, Neural Networks, Genetic Algorithms. Text mining, Text categorization.

Mining Web Logs.

Suggested Readings:

1. U. M. Fayaad, G. Piatetsky-Shapiro, P. Smyth, R. Uthurusamy: Advances in Knowledge Discovery and Data Mining, MIT Press, 1996.
2. M. J. A. Berry, G. Linoff: Data Mining Techniques for Marketing- Sales and Costumer Support, John Wiley, 1997.
3. A. Berson, J. S. Stephen: Data Warehousing, Data Mining and OLAP, McGraw Hill, 1997.
4. P. Adriaans, D. Zantinge: Data Mining, Addison Wesley, 1996.
5. Tan Pang-Ning, Michael Steinbach, Vipin Kumar: Introduction to Data Mining, Addison Wesley, 2005.

Course-401-403 (vii): A Course of equivalent credit offered by another department.

Course 404 –405 : Project Work