CURRICULUM OF

INDUSTRIAL ENGINEERING

BSc/BE
&
ME/MS

(Revised 2017)

HIGHER EDUCATION COMMISSION
ISLAMABAD

CURRICULUM DIVISION, HEC

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PREFACE

The curriculum, with varying definitions, is said to be a plan of the teaching-learning process that students of an academic programme are required to undergo to achieve some specific objectives. It includes scheme of studies, objectives & learning outcomes, course contents, teaching methodologies and assessment/ evaluation. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled "Supervision of Curricula and Textbooks and Maintenance of Standard of Education". With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula regularly through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society by seeking nominations from their organizations.

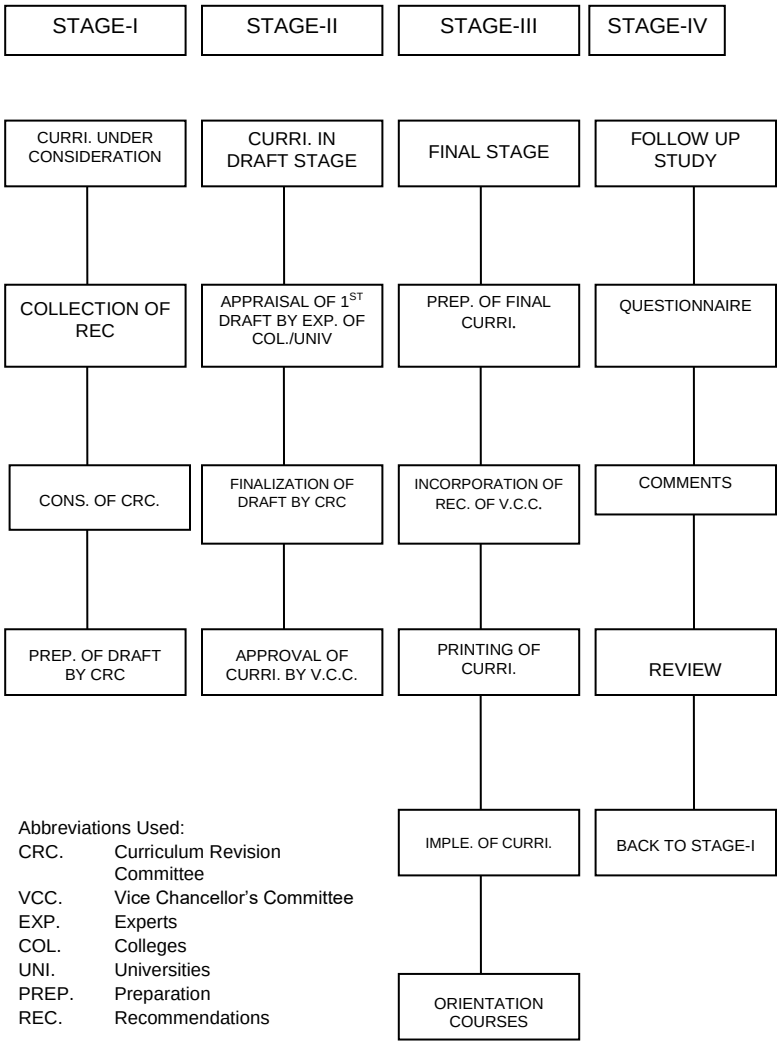
In order to impart quality education which is at par with indigenous needs and international standards, HEC NCRCs have developed unified framework/ templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering.

It is hoped that this curriculum document, prepared by the respective NCRC's, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC

http://hec.gov.pk/english/services/universities/RevisedCurricula/Pages/default.aspx

(Muhammad Raza Chohan)
Director General (Academics)

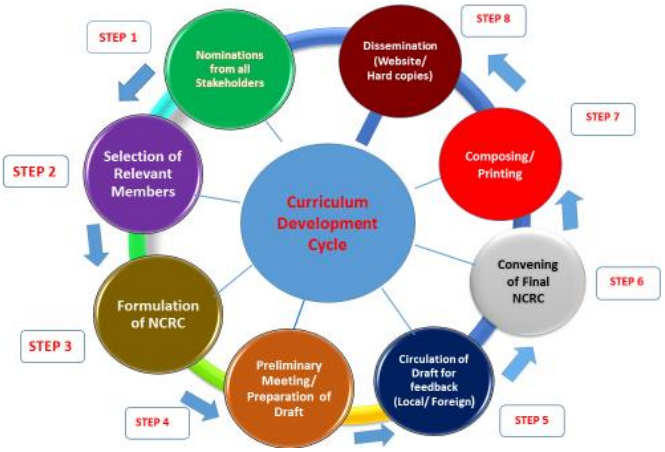
CURRICULUM DEVELOPMENT PROCESS



Abbreviations Used:

CRC.	Curriculum Revision Committee
VCC.	Vice Chancellor's Committee
EXP.	Experts
COL.	Colleges
UNI.	Universities
PREP.	Preparation
REC.	Recommendations

CURRICULUM DEVELOPMENT CYCLE



INTRODUCTION

The preliminary meeting of National Curriculum Revision Committee for Industrial Engineering was held at HEC Regional Centre, Lahore from February 13-15, 2017 to review the BE/BSc and ME/MS Curriculum of Industrial Engineering revised in the year 2012. The following members attended the meeting:

Sr.No.	Name & Address	Status
1.	Dr. Salim ur Rahman, Professor / Vice Chancellor Sarhad University of Science & Information Technology, Landi Akhun Ahmad, Ring Road, Peshawar.	**Convener**
2.	Dr. Sahar Noor, Professor / Chairman, Department of Industrial Engineering, University of Engineering and Technology, Peshawar.	**Secretary**
3.	Dr. Ijaz Ahmad Chaudhry, Professor/ Dean School of Engineering, Department of Industrial Engineering, University of Management & Technology, C-II, Johar Town, Lahore.	**Member**
4.	Dr. Muhammad Tahir Nawaz Professor / HoD, Engineering Management NUST College of Electrical & Mechanical Engineering, Peshawar Road, Rawalpindi.	**Member**
5.	Dr. Mirza Jahanzaib Professor / Chairman, Department of Industrial Engineering, University of Engg & Technology, Taxila.	**Member**
6.	Dr. Syed Amir Iqbal, Professor / Chairman, Department of Industrial and Manufacturing Engineering, NED University of Engineering & Tech, University Road, Karachi.	**Member**
7.	Dr. Hussain Bux Marri, Professor / Chairman, Department of Industrial Engineering & Management, Mehran University of Engineering & Technology, Jamshoro	**Member**
8.	Dr. Nadeem Ahmad Mufti. Professor / Dean Faculty of Mech Engg	**Member**

	Department of Industrial & Manufacturing Engineering, University of Engineering & Technology, Lahore.	
9.	Dr. Muhammad Saleh Jumani Professor Department of Industrial Engineering and Management, Mehran University of Engineering and Technology, Jamshoro.	**Member**
10.	Dr. Wasim Ahmad Associate Professor, Department of Industrial Engineering, University of Engineering & Technology, Taxila.	**Member**
11.	Dr. Shakeel Ahmed Shaikh, Associate Professor, Department of Industrial Engineering & Management, Mehran University of Engineering & Technology, Jamshoro.	**Member**
12.	Dr. Muhammad Wasif, Assistant Professor, Department of Industrial & Manufacturing Engineering, NED University of Engineering & Tech, University Road, Karachi.	**Member**
13.	Dr. Syed Waheed-ul-Haq MD, Advance Research, Development & Information Centre (ARDIC), Heavy Industries, Taxila.	**Member**
14.	Mr. Riaz-ul-Haque, Assistant Director, Higher Education Commission, Sector H-8, Islamabad.	**Coordinator**

2. The meeting started with recitation of verses from the Quran Majeed by Mr. Riaz-ul-Haque, Assistant Director, HEC, followed by welcome on behalf of the Chairman, Executive Director and the Director General Academics, HEC Islamabad. Mr. Riaz-ul- Haque briefed the participants about the aims and objectives of the meeting with a particular focus on OBE (Outcome Based Education) laid down by HEC/PEC in accordance with the Washington Accord. Horizontal & vertical alignment of course contents, learning outcomes according to Blooms Taxonomy, in order to make the curriculum compatible with international standards, satisfying indigenous demands as well as ensuring the uniformity of academic standards within the country.

3. The members of the Committee unanimously selected Dr. Salim ur Rahman, Vice Chancellor, Sarhad University of Science & Information Technology, Peshawar and Dr. Sahar Noor, Chairman / Professor, Department of Industrial Engineering, University of Engineering and Technology, Peshawar as **Convener** and **Secretary** of the NCRC, respectively. The Convener thanked the participants for his selection and started proceedings of the meeting in accordance with the agenda. The Committee, during the proceedings of the meeting, considered the inputs given by the members of the Committee, and incorporated their suggestions where necessary in the curriculum.

4. After thorough discussion and having three days deliberations, the committee achieved the following objectives:-

i. Revised the draft curriculum in the discipline of Industrial Engineering to bring it at par with international standards.
ii. Revised Vision, Mission, and Scope of the discipline.
iii. Revised /developed objectives / learning outcomes, list of contents and assessment criteria (formative & summative) aligned with undergraduate programmes (vertical approach) and other graduate level programmes (horizontal approach).
iv. Incorporated/suggested latest reading materials/references (local & international) against each course.
v. Developed contents keeping in view the uniformity across other disciplines and avoiding overlapping.
vi. Made recommendations for promotion/development of the discipline, keeping in view the futuristic needs of the society and revival of our values and culture.
vii. Finalized the intake criteria for BE/BSc & ME/MS programmes.

5. The Convener of the NCRC thanked the members for their inputs in revising the preliminary draft curriculum of Industrial Engineering by keeping in view the requirement of the country and to make it more practical, competitive and effective.

6. The committee highly appreciated the efforts by the officials of HEC Regional Centre, Lahore and Assistant Director, Curriculum, HEC Islamabad for making proper arrangements to facilitate the members of committee.

7. The meeting ended with the vote of thanks to and from the chair.

Vision / Mission (by committee)
Vision and Mission
To produce Industrial Engineers of global competitiveness having professional knowledge, skills, research capability and entrepreneurial approach enabling them to play a leading role for continuous improvement, safety, enhanced productivity and sustainability for the benefit of society.

Scope of Industrial Engineering
The Bachelors program in Industrial Engineering can be offered under the following titles:

- Bachelor of Industrial Engineering
- Bachelor of Manufacturing Engineering
- Bachelor of Industrial and Manufacturing Engineering
- Bachelor of Industrial Engineering and Management

The Masters in Industrial Engineering Program will cover but not restricted to the degrees issued under the following nomenclatures:

- Master of Industrial Engineering
- Master of Manufacturing Engineering
- Master of Industrial and Manufacturing Engineering
- Master of Manufacturing Systems Engineering
- Master of Industrial Engineering and Management
- Master of Engineering Management
- Master of Quality Management
- Master of Logistics Supply Chain Management

An organization can run effectively and efficiently if all of its subsystems work in an integrated manner for its main objective. Operations management of any industry/organization plays a very important role in the improvement of productivity which leads to improved living standards. However, there is a need for further improvement in the productivity of Pakistan's organizations for which focus should be on policy, creativity, innovation and sustainability.

The industrial engineers play a significant role for the enhancement of productivity and efficiency. They are equipped with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from the integrated systems of people, materials, information, equipment, and energy. Industrial Engineers having a diversified knowledge and skills in the field of manufacturing systems, total quality management, enterprise resource planning, ergonomics and computers are most suitable for the optimum operation of any organization including manufacturing industry, services sector

(banking, shipping and transportation, healthcare, entertainment, hospitality etc), agricultural, operations management/research and the like.

The main areas of improvements in our industries are related to risk assessment, product development, Material Requirement Planning (MRP), capacity planning, work in process management and inventory management, operations management, quality control, process control, facility planning and design, manufacturing techniques, human factors engineering and working within multi-echelon environments. These necessitate integrated solutions which can only be provided by Industrial Engineers because these areas fall in their domain. The focus is on developing processes and systems, improving quality productivity, lean methodologies, complex problem solving and sustainability.

The Educational Institutions offering Engineering Programs are being required by the HEC/PEC to adopt OBE (Outcome based Education) approach. The Committee recommends adoption of the same. While complete guidelines can be acquired from the PEC accreditation Manual 2014, some guidelines are provided below for the beginners.

Program Educational Objectives (PEOs)

1. To produce Industrial Engineering graduates having capabilities to assume challenging roles in Manufacturing and Service sectors in global environment;
2. To provide employers with graduates who are technically competent and possess decision making and problem solving abilities to enhance effectiveness;
3. To produce professionals who recognize that engineering is a global service profession that must be practiced ethically.

Program Learning Outcomes (PLOs)

(a) Engineering Knowledge: An ability to apply knowledge of mathematics, science, engineering fundamentals and the engineering specialization to the solution of complex engineering problems.

(b) Problem Analysis: An ability to identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

(c) Design/Development of Solutions: An ability to design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

(d) **Investigation:** An ability to investigate complex engineering problems in a methodical way including literature survey, design and conduct of experiments, analysis and interpretation of experimental data, and synthesis of information to derive valid conclusions.

(e) **Modern Tool Usage:** An ability to create, select and apply appropriate techniques, resources, and modern engineering and ICT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.

(f) **The Engineer and Society:** An ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solution to complex engineering problems.

(g) **Environment and Sustainability:** An ability to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.

(h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

(i) **Individual and Team Work:** An ability to work effectively, as an individual or in a team, on multifaceted and /or multidisciplinary settings.

(j) **Communication:** An ability to communicate effectively, orally as well as in writing, on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

(k) **Project Management:** An ability to demonstrate management skills and apply engineering principles to one's own work, as a member and/or leader in a team, to manage projects in a multidisciplinary environment.

(l) **Lifelong Learning:** An ability to recognize importance of, and pursue lifelong learning in the broader context of innovation and technological developments.

COURSE LEARNING OUTCOMES (CLOs)

Faculty members should be required to define/ specify and map with PLOs the relevant course learning outcomes from the following three domains depending upon scope of the course(s):

1. Cognitive
2. Psychomotor
3. Affective

Assessment

Formative Assessment

The goal of formative assessment is to monitor *students' learning* thus providing feedback that can be used by faculty to improve their teaching and by students to improve their learning. Objective is to:

- help students identify their strengths and weaknesses and target areas that need work,
- help faculty recognize where students are struggling and address problems immediately.

Examples of formative assessments include asking students to:

- draw a concept map in class to represent their understanding of a topic,
- submit one or two sentences identifying the main point of a lecture,
- turn-in a research proposal for early feedback.

Summative Assessment

The goal of summative assessment is to *evaluate students' learning* at the end of an instructional unit by comparing it against some standard or benchmark.

Summative assessments are often *high stakes*, which means that they have a high point value. Examples of summative assessments include:

- a midterm exam,
- a final project,
- a paper,
- a senior recital.

Information from summative assessments can be used formatively when students or faculty use it to guide their efforts and activities in subsequent courses.

Universities may map/relate their Vision and Mission with the Program Educational Objectives (PEOs), the PEOs with the Course Learning Outcomes (CLOs) using tables or graphs. A sample table is provided below:

Mapping of the PEOs developed with the PLOs adopted from PEC Manual.

Sr. No.	PLO	PEO 1	PEO 2	PEO 3	PEO 4
1	Engineering Knowledge				
2	Problem Analysis				
3	Design/Development of Solutions				
4	Investigation				
5	Modern Tool Usage				
6	The Engineer and Society				

7	Environment and Sustainability				
8	Ethics				
9	Individual and Team Work				
10	Communication				
11	Project Management				
12	Lifelong Learning				

Unified Framework for BS									
Non-Engineering Domain									
Knowledge Area	**Subject Area**	**Name of Course**	**Lec CH**	**Lab CH**	**CR**	**Total Courses**	**Total Credits**	**% Area**	**% Overall**
Humanities	English	English I (Functional English)	3	0	3	3	9	20.5	6.6
		English II (Communication Skills)	3	0	3				
		English III (Technical Report Writing & Presentation Skills)	3	0	3				
	Culture	Pakistan Studies	2	0	2	2	4	9.1	2.9
		Islamic Studies/Ethics	2	0	2				
	Social Sciences	Social Sciences-I (Logic & Critical Thinking)	3	0	3	2	6	13.6	4.4
		Social Sciences-II (Engg. Economics)	3	0	3				

Management Sciences		Intro to Engineering Management	3	0	3	2	7	15.9	5.1
		Project Management	3	1	4				
Natural Sciences	Physics	Engineering Mechanics	2	1	3	1	3	6.8	2.2
	Mathematics	Calculus	3	0	3	3	9	20.5	6.6
		Differential Equations	3	0	3				
		Applied Linear Algebra	3	0	3				
	Electives	Elective-I (Numerical Analysis and Computer Applications)	2	1	3	2	6	13.6	4.4
		Elective-II (Probability & Statistics)	3	0	3				
TOTAL						**15**	**44**	**100.0**	**32.4**

Engineering Domain									
Knowledge Area	**Subject Area**	**Name of Course**	**Lec CH**	**Lab CH**	**CR**	**Total Courses**	**Total Credits**	**% Area**	**% Overall**
Computing	Fundamentals	Introduction to Computing	2	1	3	3	9	9.8	6.6
	Programming	Computer Simulation	2	1	3				
	Design	Computer Aided Manufacturing	2	1	3				
Engineering Foundation	Engineering Foundation	Operations Research	3	1	4	10	31	33.7	22.8
		Metrology & Statistical Quality Control	3	1	4				
		Mechanics of Materials	3	1	4				
		Basic Industrial Electronics	2	1	3				

		Engineering Drawing & Graphics	0	1	1				
		Machine Design & CAD	2	1	3				
		Workshop Practice	0	2	2				
		Production Planning & Control	2	1	3				
		Work Study & Methods Engineering	2	1	3				
		Materials Engineering	3	1	4				
Major Based Core (Breadth)	Major Based Core (Breadth)	Environment, Maintenance & Safety	3	0	3	6	20	21.7	14.7
		Human Factor Engg.	2	1	3				
		Elective I	3	1	4				
		Elective II	3	1	4				

		Elective III	3	0	3				
		Elective IV	3	0	3				
Major Based Core (Depth)	Major Based Core (Depth)	Industrial Facilities Design	2	1	3	5	19	20.7	14.0
		Manufacturing Processes	3	1	4				
		Instrumentation & Control	3	1	4				
		Production Systems Design	3	1	4				
		Operations of Manufacturing Systems	3	1	4				
Inter-disciplinary Engineering Breadth (Electives)	Inter Disciplinary Engg. Breadth Electives	IDEE-I (Intro to Thermo Fluids)	3	1	4	2	7	7.6	5.1
		IDEE-II (Design of experiments)	3	0	3				
Senior Design Project		Senior Design Project -I	0	3	3	2	6	6.5	4.4

		Senior Design Project -II	0	3	3				
TOTAL						**28**	**92**	**100.0**	**67.6**
Industrial Training									
Grand Total						**43**	**136**		

Legend:

The following notation is used to define credit and contact hours.
T (a,b) where
T - Total Credit Hours = a+b
a - Theory Credit Hours (one contact hour equal to one credit hour)
b - Lab /Tutorial Credit Hours (three contact hours equal one credit hour)

Duration: 4 years
Number of semesters: 8
Number of weeks per semester: 16 - 18 (16 for teaching and 2 for examinations)
Total number of credit hours: 130 - 136
Number of credit hours per semester: 15 - 18
Engineering Courses (Minimum):65 - 70 per cent
Non-Engineering Courses (Maximum):30 - 35 per cent

Domain	Knowledge Area	Total Courses	Total Credits	% Overall
Non-Engineering	Humanities	7	19	32.4
	Management Sciences	2	7	
	Natural Sciences	6	18	
	Sub Total	**15**	**44**	
Engineering	Computing	3	9	67.6
	Engineering Foundation	10	31	
	Major Based Core (Breadth)	6	20	
	Major Based Core (Depth)	5	19	
	Inter-Disciplinary Engineering Breadth (Electives)	2	7	
	Senior Design Project	2	6	
	Industrial Training	0	0	
	Sub Total	**28**	**92**	
Grand Total		**43**	**136**	**100**

SCHEME OF STUDIES & FLOW CHART (BE/BSc)

Course Title	Lec	Lab	Tot	Course Title	Lec	Lab	Tot
First Year (Sem 1)				**Sem 2**			
English I (Functional English)	3	0	3	English II (Communication Skills)	3	0	3
Basic Industrial Electronics	2	1	3	Differential Equations	3	0	3
Pakistan Studies	2	0	2	Workshop Practice	0	2	2
Engineering Drawing and Graphics	0	1	1	Machine Design & CAD	2	1	3
Introduction to Computing	2	1	3	Islamic Studies /Ethics	2	0	2
Engineering Mechanics	2	1	3	Applied Linear Algebra	3	0	3
Calculus	3	0	3				
Total	**14**	**4**	**18**	**Total**	**13**	**3**	**16**
First Year Credit Hours	**34**						
Second Year (Sem 3)				**Sem 4**			
Intro to Engineering Management	3	0	3	Engineering Economics *	3	0	3
Probability & Statistics	3	0	3	Mechanics of Materials	3	1	4
Manufacturing Processes	3	1	4	Metrology & Statistical Quality Control	3	1	4
Intro to Thermo-fluids **	3	1	4	Production Systems Design	3	1	4
Materials Engineering	3	1	4	English III (Technical Report Writing & Presentation)	3	0	3
Total	**15**	**3**	**18**	**Total**	**15**	**3**	**18**
Second Year Credit Hours	**36**						

Third Year (Sem 5)				**Sem 6**			
Operations of Manufacturing Systems	3	1	4	Computer Simulations	2	1	3
Numerical Analysis and Computer Applications	2	1	3	Human Factors Engg	2	1	3
Logic & Critical Thinking *	3	0	3	Project Management	3	1	4
Operations Research	3	1	4	Production Planning & Control	2	1	3
Work Study & Methods Engg	2	1	3	Computer Aided Manufacturing	2	1	3
Total	**13**	**4**	**17**	**Total**	**11**	**5**	**16**
Third Year Credit Hours	**33**						

Final Year (Sem 7)				**Sem 8**			
Design of Experiments **	3	0	3	Environment, Maintenance and Safety	3	0	3
Industrial Facilities Design	2	1	3	Elective II	3	1	4
Instrumentation & Control **	3	1	4	Elective III	3	0	3
Elective I	3	0	3	Elective IV	3	1	4
Project Phase I	0	3	3	Project Phase II	0	3	3
Total	**11**	**5**	**16**	**Total**	**12**	**5**	**17**
Final Year Credit Hours	**33**						
Total Credit Hours	**136**						

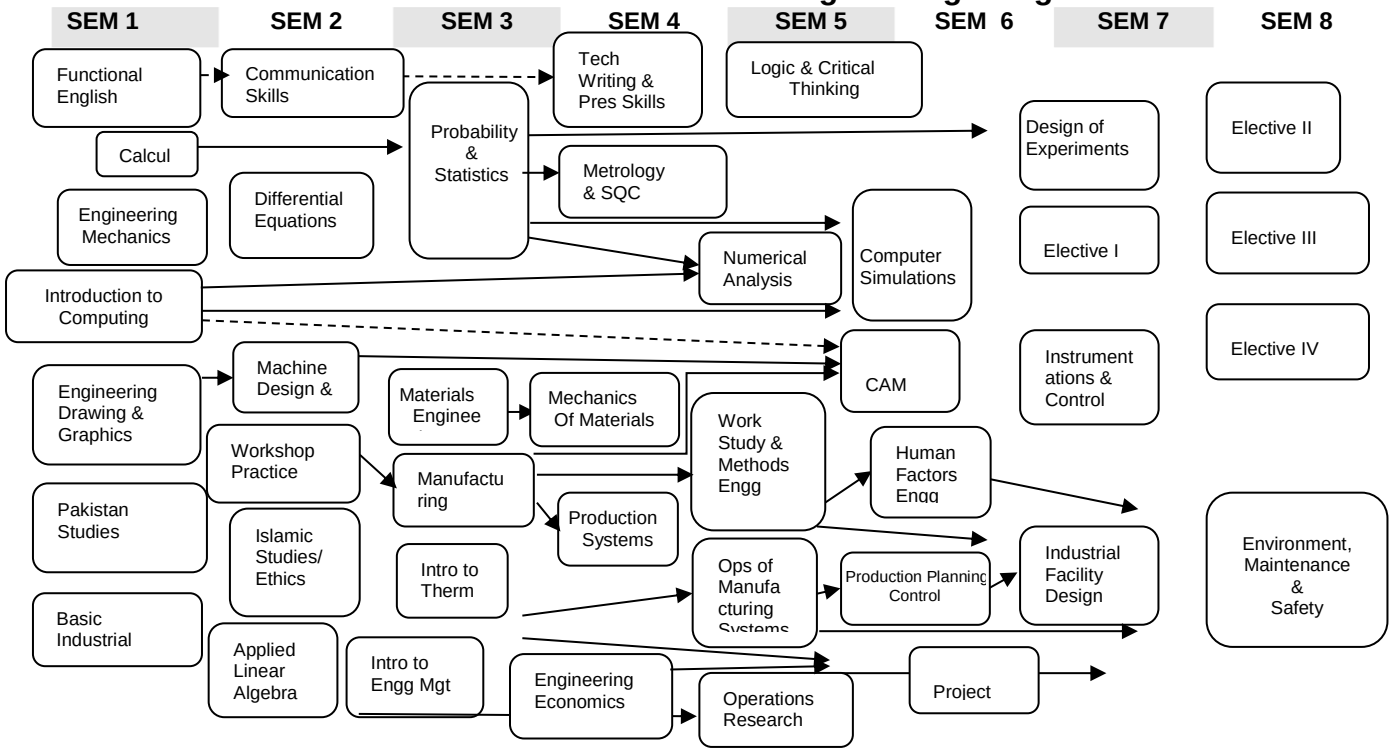
* Can be replaced by some other courses of Social Sciences

** Can be replaced by courses from other disciplines of Engineering

List of Elective Courses

Manufacturing Track				**Management Track**			
Human Resource Management	3	0	3	Marketing Management	3	0	3
Computer Integrated Manufacturing	3	1	4	Human Resource Management	3	0	3
Metal Forming & Cutting Analysis	3	1	4	Financial Management	3	0	3
Tool & Die Design	3	1	4	Managerial Accounting	3	0	3
Automation & Robotics	3	1	4	Total Quality Management	3	0	3
Total Quality Management	3	0	3	Management Information System	3	1	4
Management Information System	3	1	4	Organizational Behaviour	3	0	3
Reliability Analysis	3	0	3	Computer Integrated Manufacturing	3	1	4
Special Topics	3	0	3	Logistics Management	3	0	3
Logistics Management	3	0	3	Special Topics	3	0	3
Lean Manufacturing	3	0	3	Business Forecasting	3	0	3
Virtual Reality	3	0	3	Business Communications	3	0	3
Contracts and Claims	3	0	3	Contracts and Claims	3	0	3
Entrepreneurship	3	0	3	Entrepreneurship	3	0	3

Flow Chart of BE / BSc Industrial Engineering Program



Legend: Solid Arrow shows pre-requisite course, dotted arrow shows preferred knowledge

DETAIL OF COURSES

A) ENGINEERING DOMAIN

COMPUTING

Introduction to Computing **3 (2, 1)**

Objective:
To give working knowledge & skills of coding (C++ / Fortran/ VB / Matlab etc), how to avoid common coding pitfalls, to use and create own functions and classes. The course will enable students to recognize the advantages of using pointers and references & to understand the fundamental ideas of object oriented design (OOD).

Contents:
Introduction to computer hardware and software, Introduction to programming languages, Equation solvers and procedural computations, Communication and networking. Constants and variables, Arithmetic operations, Intrinsic functions, Algorithm design, Flowcharts, and Pseudo codes, IF statements, Do loop, While loop, Data files, Formatted Input and Output, Logical and character data type, Arrays: One-dimensional, Two-dimensional; Subprograms: Functions and subroutines, Numerical applications,

Recommended Books:
1. C++ How to Program by Paul Deitel and Harvey Deitel, 10th Edition
2. Microsoft Visual Basic .NET Programmers cookbook by Mathew McDonald, 2003.
3. Microsoft Visual Basic 2013 Step by Step by Michael Halvorson.
4. Fortran 90/95 for Scientists & Engineers by Stephan J. Chapman, 2003.
5. MATLAB for Engineers by Holly Moore, 5th Edition, 2017.
6. An Engineers guide to MATLAB, 3rd Edition by Edward B. Magrab, 2011.

Suggested Lab:
Hands on Experience using software.

Computer Simulations **3 (1, 2)**

Prerequisites: Introduction to Computing, Probability and Statistics

Objective:
The course enables the students to become proficient in simulation model building and use of computer simulation as problem solving technique.

Hands-on experience on computer simulation using software like ARENA, SIMIO, FLEXSIM, WITNESS etc.

Contents:
Introduction and simulation concepts, fundamental concepts (entities, attributes, resources, queues, statistical accumulators, events), simulation with hand, modules (create, entity data, process flow chart, resource data, queue data, dispose flow chart and connecting flow chart modules), Building model (electronic assembly and test system, enhanced electronic assembly and test system), Input analyser, Output module, animation, intermediate modelling, small manufacturing system model (building model of data and logic modules) and statistical analysis of output from steady state simulation of small manufacturing systems, entity transfer, variables and expressions and call centre model.

Recommended Books:
1. Simulation with ARENA by W. David Kelton, R. Sadowski, N. Zupick, 6th Edition. 2015.
2. Discrete Event System Simulation by Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol, 5th Edition, 2009.
3. Simulation Modelling and Analysis with ARENA, Altiok, T. and Melamed, 2011.
4. System Simulations by Geoffrey Gordon, 2nd Edition, 2015.

Suggested Lab:
Hands on Experience using software.

Computer Aided Manufacturing **3 (2, 1)**
Prerequisites: Machine Design and CAD, Manufacturing Processes

Objective:
To objective is to expose the students to the use of computer software and hardware in the translation of computer aided design models into manufacturing instructions for numerically controlled machine tools.

Contents:
Conventional Numerical Control, NC Part Programming, Computer Controls in NC, Group Technology and Process Planning, Programmable Logic Controllers, Design for Manufacturing.

Suggested Labs:
Process planning, programming machine tools using G&M codes and simulation of machining operations.

Recommended Books:

1. Computer Aided Manufacturing by T C Cheng, Richard A, Wysk and H P Weng, 3rd Edition, 2005.
2. Principles of CAD/CAM/CAE systems by Kunwoo Lee, 1999.
3. CAD/CAM Theory and Practice by Zeid Ibrahim, 2nd Edition, 2009.

B) ENGINEERING FOUNDATION

Operations Research **4(3, 1)**

Prerequisites: Applied Linear Algebra

Objectives:

The primary emphasis is on linear programming and its applications, covering modeling, fairly complex problems & solving those using computers, understand transportation and assignment problems, determining optimum solution of constrained resource allocation problems.

Contents:

Application of Linear Algebra to Industrial Problems, Introduction to Linear Programming, Graphical method of solving L.P. problems, Simplex method, Duality and Sensitivity Analysis, Solving large scale problems using computer, Transportation and Assignment Problems, Network problems, shortest path, minimum spanning tree, maximum flow problems, Queuing theory.

Recommended Books:

1. Operations Research by H. A. Taha, 8th Edition, 2009.
2. Quantitative Analysis for Management, by Barry Render, Ralph M. Stair, Michael E. Hanna, Trevor, S. Hale, 12th Edition, 2014.
3. Operation Management-Strategy and analysis by Krajewsky and Ritzman, 6th Edition.
4. Operation Management: Processes and Supply Chain by Krajewsky, Manoj K, Malhotra, Larry P. Ritzman, 11th Edition, 2015.
5. Operations Research by S. Kalavathy, 4th Edition, 2016.
6. Operations Research: Applications and Algorithms by Wayne L. Winston, 4th Edition, 2003.

Suggested Labs:

1. Familiarization with software like LINDO, TORA , LPEra, etc.
2. Mathematical modeling of real life problems.
3. Solving an LP problem using graphical method.
4. Solving a given LP problem and finding the relationship between solutions of Primal and Dual formulations.

5. Performing sensitivity analysis.
6. Solving assignment and transportation problems using Simplex Method.
7. Studying the effect of problem formulation on the number of iterations.
8. Comparison of actual number of iterations with the maximum possible iterations for a given formulation.

Metrology & Statistical Quality Control **4 (3, 1)**

Prerequisites: *Probability and Statistics*

Objective:
The course exposes the students to the principles of measurement, gauges and modern quality concepts and their practical use, the basic statistical & probability techniques and their usages in quality applications.

Contents:
General principles of measurement, Geometric dimensioning and tolerances, Gauges and comparators, Interferometers and associated devices, Surface texture measurement, Study of frequency distributions and probability models in quality control, Sources of variation, Preparation and use of various control charts, Process Capability Indices, Construction of different sampling plans, Methods to quality improvement and analysis of quality costs, Computer applications in SQC.

Recommended Books:
1. Quality Control by D. H. Besterfield, 9th Edition, 2009.
2. Introduction to Statistical Quality Control by Douglas C. Montgomery, 7th Edition, 2012.
3. Engineering Metrology and Measurements, by N V Raghavendra and L, Krishna Murthi, 1st Edition, 2013.
4. Statistical Methods for quality improvement by Thomas P. Ryan, 3rd Edition, 2011.

Suggested Labs:
Use of gauges and measuring instruments such as Vernier callipers, micro meters, gauge blocks, slip gauges, Go, No-Go gauges etc.
Applications of comparators and surface measuring instruments, Coordinate Measuring Machines, Data collection, tally sheets, Pareto analysis, fishbone diagrams. Control charts for variables and attributes using Minitab.

Mechanics of Materials **4 (3, 1)**

Prerequisites: ***Materials Engineering***

Objective:
This course allows engineers to predict failures and understand the physical and mechanical properties of materials. Students are exposed to basic engineering design concepts.

Contents:
Mechanics of Deformable Bodies, Deformation, Strain, General stress-strain relationships, Elastic load-deformation behaviour of materials, Lateral strain, Thermal strain, Bending: Pure bending, Moment-curvature Relationship, Beam Deflection; Torsion and Twisting, Energy Methods, Stress and strain transformations, Mohr's stress/strain circle, Stress and strain transformation in composites, Yield and failure criteria of materials.

Recommended Books:
1. Mechanics of Materials, by Beer, Johnston and Dewolf, 7th Edition, 2014.
2. Mechanics of Materials, by Hibbeler, R. C. 10th Edition, 2016.
3. An Introduction to the Mechanics of Solids, by Lardner, T. J., Archer, R.R., Crandall S. H., and Dahl N.C, 3rd Edition, 2012.
4. Mechanical Behavior of Materials, by Dowling, N. E., 4th Edition, 2012.

Suggested Labs:
1. To study the Universal testing machine.
2. To determine the shear strength (single and double) of metallic and non metallic (wood etc.) specimen.
3. To determine the hardness of different metallic specimens using a) Brinell b) Rockwell c) any other testing equipment.
4. To determine Modulus of Elasticity of a) rectangular section b) I-section beam using bending test.
5. To determine the Modulus of Elasticity of a metallic specimen using tensile test.
6. To determine the stiffness of a) leaf b) helical coil spring by plotting load vs deflection graph.

Basic Industrial Electronics **3 (2, 1)**

Objective:
This course will provide an overview of basic industrial electronics.

Basics and Applications of Circuit Analysis, Semiconductor devices such as diodes, transistors, power transistors with reference to their terminal

characteristics, Switches, Transducers, Operational amplifier principles and applications, Digital logic , Digital systems and microprocessors, Modulation and Demodulation.

Books Recommended:

1. Modern Industrial Electronics by Timothy J. Maloney, 5th Edition, 2003.
2. Industrial Electronics by Colin D. Simpson,, 1st Edition, 1996.
3. Electronics Devices by Thomas L Floyd, 9th Edition, 2011

Engineering Drawing and Graphics **1 (0, 1)**

Objective:

To familiarize the students with the basic concepts of engineering drawing and graphics.

Contents:

Introduction. Types of lines, lettering, dimensioning, drawing instruments, planning of drawing sheet. Orthographic projections, plane of projections, projection of straight lines, traces of a line, true length of a line, inclination to both the planes, projection of oblique and auxiliary planes. Loci of Points and Generated Curves. Development of Solids. Intersection of Surfaces. Intersection of solids. Axonometric Projections. Types, Isometric projections of solids, planes, typical examples. Projection in Auxiliary Planes. Auxiliary planes and views, projection of points, line, plane. Projection of Solids, development of surfaces.

Recommended Books:

1. Engineering Drawing and Graphics by T. E. French, C. J. Vierck, R. J. Foster, 1993.
2. Practical Geometry & Engineering Graphics by Abbot, 1989.
3. Technical Drawing with Engineering Graphics, by Giesecke F. E., Mitchell A, Spencer, H C, 15th Edition, 2016.
4. Engineering Drawing, by N D Bhatt, 53rd Edition, 2014.
3. Engineering Graphics by Craft, Meyers & Boyer, 1989.

Machine Design & CAD **3 (2, 1)**

Pre requisites: Engineering Drawing and Graphics

Objectives:

The course equips the students by providing strong inter-relationship with machines, their system of operations and the types of material used for any particular work, keeping in view the component design/manufactured

should be durable and economical in cost and also meet the other requirements.

Contents:

Introduction: Design methodology, design standards, design and safety, Stress concentrations
Design of Shafts, pulleys, belts, keys, cotters, couplings, Welded and riveted joints. Design of various bearing

Fundamentals of CAD:
Introduction, the design process, application of computers for design, creating the manufacturing data base, benefits of CAD.

Recommended Books:
1. Shigley's Mechanical Engineering Design, by Richard Budynas, Keith Nisbett, 10th Edition, 2014.
2. Design of Machine Elements, by Spotts, M.F. Shoup, T.E., Hornberger, L.E., Jayram, S.R. and Venkatesh, C.V.,", Pearson Education, 8th Edition, 2003.
3. Machine Design, by R L Norton, 2013.

Suggested Lab:
Use of AutoCad/ Solidworks/ProE.

Workshop Practice **2 (0, 2)**

Objective:
The main focus is to be hands-on training of Workshop practice namely Machine shop including CNC, Wood working, fitting shop, fabrication & foundry etc.

Contents:
Basic Processes in Fitter Shop, Bench-fitting practice; Exercise in marking and fittings, Basic Processes in Wood Work Shop, Use of carpenter's tools; Exercises in preparing simple joints; Use of measuring instruments.

Basics of Electric Shop, Functions of Forge & Foundry Shop, Machine Shop, Soldering, Brazing and Welding. Smith's forge; Exercise in bending, upsetting and swage. Heat treatment, Moulding and casting. Simple machine shop processes, such as turning, shaping, milling, Introduction to CNC Machines.

Recommended Books:
1. Workshop Technology Part 1-6 by W. A. J. Chapman, 5th Edition, 1985

2. Workshop processes, Practices and Materials by Bruce J. Black, 3rd Edition, 2004

Production Planning and Control **3(2, 1)**

Prerequisites: ***Operations of Manufacturing Systems***

Objective:
The course enables the students to use various forecasting methods & their applications, different production planning models & capacity requirement planning.

Contents:
Forecasting methods and their applications to various industrial and management problems, Analysis and design of production and scheduling control systems, machine sequencing, Flow shop, Job shop, Open shop, Algorithms for production planning and re-planning, Stochastic inventory models, Aggregate planning, Capacity requirements planning, Introduction to mixed production models.

Recommended Books:
1. Operations Management: Sustainability and Supply Chain Management by Heizer, Render and Munson, 12th Edition, 2017.
2. Principle of Production Control by J. L. Burbige, 2nd Edition,1978.
3. Manufacturing Planning & Control by Vollmann, William Berry & Whybark, 4th Edition, 1997.
4. Factory Physics by Hopp & Spearman, 3rd Edition, 2011.

Suggested Labs:
Hands on work using any relevant software.

Work Study and Methods Engineering **3 (2, 1)**

Prerequisites: Production Systems Design

Objective:
Course gives fundamental concepts and techniques to analyze the work and find ways to improve the methods used.

Contents:
Introduction to work analysis and design, Methods engineering: study of the basic work measurement techniques, applications and limitations of the stop-watch time study, learning curve, Development and use of process flow charts, pre-determined motion time studies (PMTS), micro motion analysis, Human factors underlying the design of specific human-machine systems, Techniques of work optimization, energy expenditure and bodily functions.

Recommended Books:

1. Time and Motion Study What, Why and How-to by Jack Greene, 2011.
2. Time and Motion study by I. L. O.,
3. Work Systems: The Methods, Measurement and Management of Work by M P Groover, 2016.
4. Motion and Time Study: Design and Measurement of Work by Ralph M. Barnes, 7th Edition, 2009.

Suggested Labs:

1. Study through videos
2. Study of simple assembly operations
3. Estimation of process duration through PMTS
4. Development and use of process flow charts
5. Any other lab on discretion of the instructor.

Materials Engineering **4 (3, 1)**

Objective:

To familiarize the students with various industrial materials, their properties and structural changes during manufacturing processes.

Contents:

Types of materials, crystalline & amorphous materials, Solid solutions and phase diagrams, application of materials. Ferrous and Non-Ferrous Metals and alloys, their major properties and their heat treatment. Ceramics, Glasses, Rubbers & Refractory Materials, Polymers, Composites, Environmental Degradation, corrosion. Indigenous materials.

Recommended Books:

1. Basic Principles of Material Engineering by William F. Smith.
2. Fundamentals of material science and engineering: An integrated approach by W. D. Callister and D. G. Rethwisch, 5th Edition, 2015.

Suggested Labs:

Lab work to expose students to micro and macro examination of materials including sample cutting, grinding, polishing, mountings, heat treatment, study of micro structure, determination of grain size and phase analysis.

C). MAJOR BASED CORE (BREADTH)

Industrial Facilities Design **3 (2, 1)**

Prerequisites: *Work Study and Methods Engineering, Production Planning and Control*

Objective:
To enable the students to understand facility design, Material handling equipment analysis, warehousing, layout and location and flow of material, Exposure to relevant computer software.

Contents:
Location and Site selection, Facility design stages, processes, material handling equipment and analysis, Area allocation and space requirements, Flow analysis, fabrication of individual parts, total plant flow, Plant layout, Utilities Layout, Computerized facility layout and location, layout algorithms like CRAFT, ALDEP, CORELAP etc, Strategies for storages.

Recommended Books:
1. Manufacturing Facilities: Location, Planning & Design by D. Sule, B.W.S.-Kent , 3rd Edition, 2008.
2. Location Theory and Decision Analysis: Analytics of Spatial Information Technology, by Yupo Chan, 2nd Edition, 2011.
3. Facilities Planning by Tompkins, White, Bozer & Tanchoco, 4th Edition, 2010.

Suggested Lab:
Hands on experience using relevant computer software

Manufacturing Processes **4 (3, 1)**

Prerequisites: *Workshop Practice*

Objective:
An analysis course that enables the students to recognize the strong interrelationships between material properties and manufacturing processes.

Contents:
Basic concepts of manufacturing processes, Casting processes, Furnaces, Forming and Joining processes, Welding, Brazing and soldering, Adhesive bonding, Traditional and non-traditional machining operations, capabilities and limitations, Rapid prototyping operations, Manufacturing of parts using polymer, composite and powder metallurgy, Process selection.

Recommended Books:
1. Manufacturing Processes for Engineering Materials by S Kalpakjian and S R Schmid, 6th Edition, 2016.
2. DeGarmo's Material & Processes in Manufacturing by Black and Kohser, 2013.

3. Materials and Designs: The art and science of material selection in product design by M. F. Ashby and K. Johnson, Butterworth and Hienmann, 3rd Edition, 2014.
4. Principles of Modern Manufacturing by M. P. Groover, 5th Edition (SI), 2014.
5. Introduction to Manufacturing Processes by John Schey, 3rd Edition, 1999.

Suggested Labs:

1. To Study various Safety Rules for Machining Shop.
2. To Study the Different Materials, their properties and uses in Metal Cutting.
3. To Study various parts and cutting tools used for a Lathe Machine.
4. To Study Various Operations that can be performed on a Lathe Machine.
5. To Make a *Screw Jack* (or some other component) according to given dimensions using different machining operations such as Turning, Facing, Threading, Knurling etc.
6. To Study and perform various welding processes such as Oxyacetylene gas welding and cutting , Electric Arc welding, Spot welding etc.
7. To Study and perform Non Traditional Machining (NTM) operations such as Electrical discharge machining (EDM) and Wire EDM etc.
8. Make a check list of the findings related to manufacturing of parts from given drawing
9. Develop a process plan for the given parts (machined, sheet metals, casting etc.)

Calculate the blank size of the given sheet metal part.

Instrumentation and Control **4 (3, 1)**

Objectives:

Through problem solving and laboratory practice, this course provides a foundation in continuous-time linear control system theory. Further to that it provides a basic understanding of various gauges, transducers and a rationale for their selection.

Contents:

Basic concepts, characteristics, functions of instruments especially for indicating and recording, length, weight, volume, temperature, pressure, flow level, etc. Measuring errors and calibration.

Introduction to the principles of automatic control systems encountered in Mechanical Engineering; Open-loop and closed loops systems. Control Modelling: Block diagrams, transfer functions, Laplace transforms, root locus, Bode diagram Frequency response.

Design parameters: Response Time, relative stability, Overshoot, settling time etc. Classical control systems modelling Temperature, speed, level, flow, proportional, integral and derivative controls, mode of operation of hydraulic, pneumatic, and electrical components, amplifiers servomotors, process controllers, regulating valves, position transducers, Programmable Logic Controllers.

Recommended Books:

1. Feedback Control of Dynamic Systems by Gene F. Franklin, J. David Powell and Abbas Emami-Naeini, Global Edition, 2014.
2. Modern Control Systems by Richard C. Dorf and Robert H. Bishop, 13th Edition, 2017.
3. Instrumentation by Franklyn W. Kirk, Thomas A. Weedon and Phillip Kirk, 5th Edition, 2010.
4. Modern Control System by Ogata, 5th Edition, 2010.

Suggested Lab:

1. To draw the characteristics of temp measuring sensor (RTD, IC, TC, STT)
2. To draw the characteristics of light intensity measuring device (Photovoltaic, Photodiode, Photocell, Phototransistor)
3. To draw the characteristics of position sensing device (potentiometer)
4. To control the Position of a system (open loop, closed loop)
5. To control the Speed of a system (open loop, closed loop)
6. To Study the effects of Proportional, Integrative and Derivative Components on the Automatic Level Control System
7. PID control of Flow rate: Familiarization with the plant
8. Familiarization with Analogue Servo Trainer and Preliminary Procedures for Operation.
9. Parameter Determination of the Modular Servo System: Gain verification and summarization
10. Use of MATLAB/SIMULINK software for Modelling of open and close loop systems.

Production Systems Design **4 (3, 1)**

Prerequisites: *Manufacturing processes*

Objectives:

To familiarize the students with the analysis and design of manufacturing systems.

Contents:

Introduction to Lean Manufacturing, Manufacturing automation fundamentals and strategies, High volume manufacturing systems, Flow

lines, Assembly lines, Automated material handling and storage systems, Process planning, Group technology, Cellular manufacturing systems, Computer networks of manufacturing, Computer integrated manufacturing systems, Flexible manufacturing systems, Modelling of manufacturing systems.

Recommended Books:

1. Automation, Production Systems and Computer Integrated Manufacturing by M. P. Groover, Global Edition, 2016.
2. Systems Engineering and Analysis, by Benjamin S. Blanchard and Wolter J. Fabrycky, 5th Editions, 2010.

Suggested Lab:

1. Working applications of switches, sensors, encoders, servo and stepper motors, speed controller and PID controller
2. Use of Manufacturing System Simulation Software.

Operations of Manufacturing Systems **4 (3, 1)**

Prerequisites: ***Introduction to Engineering Management***

Objective:

The course aims at material requirements, resource planning and inventory management. The course enables the students to apply the acquired knowledge in real situations.

Contents:

Inventory Control, Material requirement planning, Manufacturing resource planning, Enterprise resource planning, Just in time, Total quality manufacturing, Factory dynamics, Push, Pull and hybrid systems, Inventory control in supply chain.

Recommended Books:

1. Factory Physics by Hopp & Spearman, 3rd Edition, 2011.
2. Production and Operations Analysis by Steven Nahmias,7th Edition, 2015

Suggested Labs:

Tutorials & Case Studies on Inventory Control, MRP, Just in Time, Internal bench marking, CONWIP production lines and supply chain.

D). MAJOR BASED CORE (DEPTH)

Environment, Maintenance and Safety **3(3, 0)**

Prerequisites: Human Factors Engineering, Operations of Manufacturing Systems

Objectives:
To up keep the plant and machines by removing every type of trouble and providing safe atmosphere in the organization to improve productivity and to enhance the efficiency and economy of the organization

Contents:
Environment pollution, Air emission management, Waste management, Waste water treatment and control, Soil and ground water protection, Introduction to Pakistan Environment Protection Act 1997 and National Environmental Quality Standards, Key elements of ISO 14000.
Importance of plant maintenance, factors influencing the maintenance, Considerations in designing plant maintenance, Economic aspects of maintenance, care and maintenance of common industrial equipment (like bearings, piping, filters, pumps, compressors, and lubricating systems), maintenance linkage to safety, Different systems/types of maintenance, Laws of Accident Proneness, Accidents preventions. Legal, humanitarian & economic reasons to Prevent Accidents, Safety Measures, Analysis & Procedures, Safety equipment, OHSAS 18000.

Recommended Books:

1. Maintenance Manager's Standard Manual by Thomas A. Wester-Kamp, 2013.
2. A Guide to Effective Industrial Safety by Jack W. Boley, 1977.
3. ISO 14000: the Business Manager's Complete Guide to Environmental Management by Perry Johnson, 1997.
4. Maintenance for Industrial Systems by Ricardo Manzini, Alberto Regattieri, 2010.
5. Introduction to Health and Safety at Work by Phil Hughes, 5th Edition, 2011.

Human Factors Engineering **3 (2, 1)**

Prerequisites: Work Study and Methods Engineering

Objective:
The course enables the students to understand and analyze man-machine interaction, including an introduction to the relevant underlying human sciences.

Contents:
Introduction to Human Factors Engineering, Human Characteristics relevant to ergonomics. Information on Human Role in Artificial Intelligence, information by text, graphics and symbols. Anthropometry,

Anthropology, Principles of workplace design, Equipment and work space, Failure of design, Climatic Factors, Noise and Vibration, Effects of noise on various organs and their prevention, visibility (Illumination, contrast, quality, colour etc.) and its effects, Basic concepts of Human Error detection and reduction. The role of controls in advanced technology, Control devices.

Recommended Books:

1. An Introduction to Human Factors Engineering by John D. Lee. And Christopher D. Wickens, 2017.
2. Hand-Book of Industrial Engineering: Technology and Operations, by Salvendy G.,2001.
3. Human Factors Engineering & Design by Sanders & Mc Cormick, 1993
4. Evaluation of Human Work by John R. Wilson and Sarah Sharples, 4th Edition, 2015.

Suggested Labs:

1. Study of various types of workplaces
2. Noise measurement at different places
3. Illumination measurement at different places
4. Any other lab on discretion of the instructor.

E). INTER-DISCIPLINARY ENGINEERING BREADTH (ELECTIVES)

Introduction to Thermo-Fluids **4 (3, 1)**

Objectives:

To introduce basics of thermodynamic properties, laws of thermodynamics and their application to power and refrigeration cycles. Introduction of basic modes of heat transfer. Formulation of basic equations for Fluid Engineering problems. To determine the friction energy loss for various pipes/ducts geometries and Fluid engineering applications. Introduction to hydraulic machinery.

Contents:

Introductory concepts & definitions, using energy and the laws of thermodynamics, evaluating properties, Control Volume analysis using energy, Second law of thermodynamics, Vapour power and refrigeration systems, Brayton and Rankine cycles, Regeneration cycles. Psychometric Applications. Modes of heat transfer and their rate equations, Fluids and their properties, Fluid Statics, Pressure measurement: Bourdon pressure gauge, Manometers, Forces on a plane area and curved surfaces. Kinematics of fluid flow: Laminar and Turbulent flow, Flow through pipes: loss of head due to friction in pipes, Moody Charts. Introduction to hydraulic machinery.

Recommended Books:

1. Fundamentals of Engineering Thermodynamics by Michael J. Moran and Howard N. Shapiro, 8th Edition, 2015.
2. Introduction to thermal systems engineering: Thermodynamics, fluid Mechanics and heat transfer by Michael J. Moran, Howard N. Shapiro, Bruce R. Munson, 2003.
3. Fundamentals of Fluid Mechanics by Bruce R. Munson, Donald F. Young and Theodore H. Okiishi, 2012.

Suggested Lab:

1) Determination of time constants of various temperature measuring devices
2) Study of Ideal Vapour-Compression Cycle
3) Study of Rankine Cycle
4) Study of Bryton Cycle
5) Hydrostatic pressure on submerged plane
6) Differential pressure measurements using various manometers
7) Reynolds experiment (laminar and turbulent flow)
8) Flow from orifice in the side of a tank (Bernoulli's Equation)
9) Flow measurement with Venturi meter
10) Conservation of momentum (Impact of a Jet)
11) Pressure loss calculations in pipe networks
12) Conductive heat transfer rate calculations.
13) Determination of heat transfer rate in free convection

Determination of heat transfer rate in forced convection

Design of Experiments **3 (3,0)**

Prerequisites: ***Probability and Statistics***

Objective:

The course enables the students to understand modern techniques based on statistical analysis and apply those to improve productivity & quality.

Contents:

Introduction to design of experiments and its applications in industry, Hypothesis testing on means and variances, Analysis of variance, fixed and random effects models, error analysis, Block designs, randomized complete and incomplete block design, Latin square design, factorial design, fixed, random and mixed factors designs, Introduction to response surface methodology. Packages like Minitab & Design Expert can be used.

Recommended Books:

1. Design and Analysis of experiments, by Douglas C. Montgomery, 8th Edition, 2012.

2. Experiments: Planning, Analysis and Parameter design Optimization, Wu and Hamada, 2nd Edition, 2009.

Suggested Labs:

1. Comparison of results of paired t-test with those from pooled and un-pooled variance for a given data set.
2. Coding/ scaling of variables while designing an experiment.
3. Validation of modeling assumptions (normality, constant variance, randomness).
4. Transformation and its effect on the validity of modelling assumptions.
5. Blocking of a nuisance variable.
6. Performing full factorial and fractional factorial analyses and comparison of coefficients by undoing the confounding effect.
7. Contrast formulation and comparisons.
8. Applications of nested design.

F). INTER-DISCIPLINARY ENGINEERING (DEPTH ELECTIVES)

Computer Integrated Manufacturing (CIM) 4 (3, 1)

Prerequisites: CAM, Industrial Facilities Design

Objective:

To expose the students to CIM in general and SME in Specific. The course would make students apply CIM to the local environment and establish strategic alliance in top management support.

Contents:

Introduction to Computer Integrated Manufacturing, components of CIM system, CIM modelling, data flow diagrams and IDEF models, Integration of interconnected networks, computer network protocols, integrated approach to CIM justification and optimization, assessing the impact of investment in CIM, a decision support system for CIM investment, guidelines for implementing CIM, Application of CIM System in small & medium enterprises (SMEs),

Recommended Books:

1. Automation, Production Systems, and Computer Integrated Manufacturing by Groover Mikell, Global Edition, 2016.
2. Computer Integrated Manufacturing by James A. Rehg and Henry Kraebber, 3rd Edition, 2004.
3. CIM justification and optimization by Lin and Nagalingan, 1st Edition, 1999.

Suggested Lab:

1) Part programming on CNC machines
2) Part storage/retrieval programs and applications
3) Automated part identification
4) Part handling by robots and AGV
5) Use of CMM
6) Simulation of CIM
7) IDEF models development
8) Study of a decision support system

Virtual Reality **4 (3, 1)**

Prerequisites: Computer Simulation, Manufacturing Systems

Objectives:

To familiarize the students with the world of virtual manufacturing and enable them to apply the knowledge where real manufacturing facilities are not available (academic level).

Contents:

Virtual reality applications in manufacturing systems design, manufacturing applications of networked virtual reality, virtual reality modelling of occupational safety engineering. Manufacturing systems design optimization using virtual environments, optimization of manufacturing decision support using virtual reality interfaces, analysis and evaluation of virtual environments.

Recommended Books:

1. Virtual and Augmented Reality Applications in manufacturing by Ong, S. K. and Nee, A. Y. C, 2013.
2. Introductory Techniques for 3D computer vision by Trucco, E. and Verri, A., 1st Edition 1998.

Suggested Lab:

1. The working of manufacturing and automation modeling using CAD/CAM and computer-integrated manufacturing methods
2. Working of Virtual CIM Laboratory
3. Working of industrial robots in virtual environment
4. Working of highly automated manufacturing system/factory in virtual environment
5. Study the operation of automated manufacturing systems in virtual environment
6. Virtual reality modeling of occupational safety engineering

Metal Forming and Cutting Analysis **4 (3, 1)**

Prerequisites: Manufacturing Processes

Objective:

The course aims to give the students the basic understanding of forming and machining processes. Students will learn how to classify the processes, effect of tool material and tool geometry. Exposure to design of jigs and fixtures.

Contents:

Objectives of Metal Forming Processes, Classification of processes, Sheet metal formability, Analysis of bending, Drawing; Rolling, Extrusion and Forging Processes, Evaluation of machining performance and its optimization, Objectives of metal cutting processes, Cutting mechanisms, Material removal operations, Cutting tool materials and geometry, Effects of different cutting parameters on tool life and cutting forces, Tool design, Jigs and fixtures design.

Recommended Books:

1. Manufacturing Engineering & Technology by Kalpakjian & Schmid, 7th Edition, 2013.
2. Metal forming: Mechanics and Metallurgy, W. F. Hosford, R. M. Caddell, 4th Edition, 2014.
3. Fundamentals of Metal Machining and Machine Tools by W. A. Knight and G. Boothroyd, 3rd Edition, 2005.
4. Principles of Metal Manufacturing Processes by J. Beddoes, M. Bibby, 1st Edition, 1999.
5. Manufacturing Processes 4: Forming by F Klocke, 2013.
6. Mechanical Metallurgy by G. E. Deiter, 3rd Edition, 1986.

Suggested Labs:

1. To Study various Safety Rules for a Machining Shop.
2. Transformation of given Specimen into the Shape through Machine as per given Specification using different material removal processes.
3. To analyse wear patterns on different types of tools (lathe, Milling, drilling etc.) using tool makers (or any type of available) microscope.
4. To perform different type of sheet metal shearing/bending operations (Punching, Piercing), Blanking, Notching, Perforating, Slitting, v-bending, edge bending etc.) using power (any type of available) press

Tool and Die Design **4 (3, 1)**

Prerequisites: Mechanics of Materials

Objective: This course would familiarize the students with: Jigs and Fixtures, Dies for various sheet metal operations, Fixtures for welding and riveting

Contents:
Tool and die design, Tool materials, Work holding principles, Jigs and Fixtures design, Tools for inspection and gauging, Forming and drawing tools, Tool design for joining processes, Computers in tool design. Terminology for press working operations, Mechanical, hydraulic and pneumatic presses, Design of piercing, Blanking and shearing dies, Design of bending, forming and drawing dies, Design of Plastic injection dies, dies for pressure die casting.

Recommended Books:
1. Fundamentals of Tool Design, Society of Manufacturing Engineers, J. Nee (Editor), 6th Edition, 2010.
2. Die Design Fundamentals by B. Boljanovic, 2005.
3. Jig and Fixture Design by E. Hoffman, 5th Edition, 2004.
4. Jigs and Fixtures Design Manual by Prakash Hiralal, 2nd Edition, 2004.

Suggested Labs:
1. To Study/survey different metals for making/manufacturing of tools
2. To study different clamping, locating and locking components for jigs fixtures
3. To Study the working of power/hydraulic press.
4. To design a blanking die for a typical part.
5. To study the function of compound dies
6. To Study of Progressive Dies
7. To study the function of different components of an injection mould and their working principles.
8. Designing of Plastic Injection Moulds using CAD software.

Automation and Robotics **4 (3, 1)**

Prerequisites: Instrumentation & Control, Production Systems Design

Objective:
The course will enable students to understand control fundamentals, design of control system focusing process control, manufacturing systems, interfacing etc.

Contents:
Process control fundamentals, Relay logic and various control devices, Architecture of programmable logic control units, Introduction to

distributed control system (DCS) and SCADA Sensors for industrial processes, D/A and A/D converters, Industrial processes interfacing with micro-processors, practical applications, Introduction to Robotics, Robot anatomy, Robot configuration, accuracy & Repeatability, Robot specifications, end effectors, Kinematics and Dynamics, Characteristics of Robot applications, Robot Cell Design, types of Robot Applications.

Recommended Books:

1. Industrial Automated System: Instrumentation and Motion Control by T. L. M. Bartelt, 2010.
2. Computer Automation in Manufacturing by Thomas O. Boucher, 2013.
3. Automation, Production Systems & Computer Integrated Manufacturing by Mikell P. Groover,4th Edition 2014.

Suggested Lab:

1. Practicals on various control devices.
2. PLC introduction and Programming (Ladder Diagram)
3. Simulation and Interfacing with Programmable Logic Controller (PLC)
4. SCADA System (Automation Applications)
5. Study and use of Robot for various applications
6. Any other lab on discretion of the instructor.

Reliability Analysis **3 (3, 0)**

Prerequisites: Probability and Statistics

Objective:

The course will enable students to analyze failure mode & effects, to optimize reliability and to develop system reliability models.

Contents:

Introduction to Reliability Engineering, Catastrophic failure models and reliability functions, Failure distributions, Failure data analysis, System reliability evaluation techniques, Reliability optimization, Fault tree analysis, Reliability testing; Load-strength interference models.

Recommended Books:

1. An Introduction to Reliability & Maintainability Engineering by C. E. Ebeling, 2nd Edition 2009.
2. Practical Reliability Engineering by P.O Connor and A. Kleyner, 5th Edition, 2012.
3. Reliability in Engineering Design by K. C. Kapur & L. R. Lamberson, 1977.

G). INTER-DISCIPLINARY MANAGEMENT (DEPTH ELECTIVES)

Human Resource Management **3 (3, 0)**

Objectives:
To understand the historical evolution of Human Resource Management and the different motivational theories, applications and influences in an organization and to equip students with the process of man power planning, recruitment, industrial relations and administration.

Contents:
Theory and practice of HRM, Work groups and their implications for motivation and job satisfaction, Theories of motivation, Manpower planning, Recruitment and selection process, Training and Development, Appraisal Methods. Principles of wage and salary administration, Job analysis & Description, Job Design, Industrial Relations, Causes of Industrial disputes and their resolutions.

Recommended Books:
1. Managing Human Resources by Wayne Cascio, 10th Edition, 2016.
2. Fundamental of Human Resource Management by De Cenzo and Robbins, 2012
3. Elements of Personnel Management by Pratt, K. J. and Bennett, S. G., 1990.
4. A Guide to the Human Resource Body of Knowledge (HRBoK) by Reed and Ulrich, 2017.

Total Quality Management **4 (3, 1)**

Objective:
To make the students understand the philosophy of total quality management and ways of its implementation in the organisation.

Contents:
Understanding quality, commitment and leadership, design for quality, planning for quality, quality system requirements, quality measuring tools and the improvement cycle, Quality assurance, ISO 9001, Six sigma, Kaizen, Balanced score card.

Recommended Books:
1. Total Quality Management with text cases by John S. Oakland, 3rd Edition, 2003
2. Total Quality Management by D.H. Besterfields and C.Besterfield-Michna , 3rd Edition , 2002.
3. Total Quality Management: Key Concepts and Case Studies by D. R. Kiran, 1st Edition, 2016.

Suggested Labs:
Use of Minitab/SPSS/Excel

Logistic & Supply Chain Management **3 (3, 0)**

Prerequisites: Production Planning and Control

Objective:
The aim of the course is to help students learn how to develop facility requirement profile and to eliminate the non value added activities.

Contents:
The logistical system of material management, Developing a value based Supply Chain, optimization of Supply Chain, Strategic relationships in logistics, process methodology, Issues concerning marketing channels functions, Determining the facilities requirement profile, Managing logistics facilities. Developing the logistics organization for effective supply chain management, Customer service and Customer retention.

Recommended Books:
1. Managing the Supply Chain: A strategic Prospective by J. L. Gattorna and D. W Walters, 1996
2. Logistic and Supply Chain Management by Martin Christopher, 5th Edition, 2016.
3. Supply Chain Management (Theories & Practices) by R. P. Mohanty, 2005.

Marketing Management **3(3, 0)**

Objective:
To understand the intricate relationships of various factors which influence the Marketing Environment and also the determining factors which help in understanding the consumers' behaviour.

Contents:
Role and scope of marketing, classification of marketing activities, needs, wants and demands, exchange process, Customer value & satisfaction, Retaining Customers, Social influence on consumers, Informational influences on consumers, Consumer Behaviour and Market Segmentation, Principal Marketing Strategies, Strategic Alternatives, Selecting the pricing objectives, Factors affecting price sensitivity, Selecting a Pricing Method, Setting Advertising objectives and methodologies.

Recommended Books:
1. Marketing Management by Parag Diwan, 2001.

2. Marketing Management by P. T. Kotler and K. L. keller, 15th Edition, 2016.

Financial Management **3 (3, 0)**

Prerequisites: Managerial Accounting

Objective:
The objective of this course is to introduce to the students the basic tools and techniques required in modern financial management. The course will improve the analytical skills of the future managers.

Contents:
Scope and importance of Financial Management, Functions of Financial Manager, Valuation, Ordinary, Due and Perpetuity, Amortization of Loan, Bond Valuation, Financial Statements, Trend Analysis, Common size and Index Analysis, Funds Analysis, flow and Funds statement. Sources and Uses of Funds, Working Capital Management, Factors influencing working capital requirements, Cash Management, Motives for holding cash, Speeding up cash receipts, slowing down cash payments, Receivable Management, Credit & Collection policies, Analyzing the credit applicant, Inventory Management and control, Short term Financing. Spontaneous financing, Factoring A/R Capital Budgeting process.

Recommended Books:
1. Fundamentals of Financial Management by J. V. Horn and J. M. Wachowicz, 13th Edition, 2008.
2. Fundamentals of Finance with Microsoft Excel by S. Benninga, H. A. Rehman, Z. A. Wahid, N. Ahmad, 2012.
3. Fundamental of Financial Management by Brighan and Houston, 12th Edition, 2012.
4. Financial Management: Principles and Applications by J. Keown, 12th Edition, 2014.

Managerial Accounting **3 (3, 0)**

Objectives:
To train the students to prepare balance sheet, profit and loss statements. To assess and analyse any business organization financially with the help of financial reports and utilize the resources and assets effectively to make them profitable.

Contents:
Managerial accounting, Money measurement concept, Financial accounting and managerial accounting, Balance sheet, Financial statement, Income Statement, Book keeping, Debit & Credit, Applications

to investment decisions, Return on investment, Cash in-flow, Economic life, Rate of return, Investment turnover and profit margin, Tests of investment utilization, Assets and their types, liabilities and owners equity, cost accounting and control, basic frame work of budgeting.

Recommended Books:

1. Managerial Accounting by Ray H. Garrison, Eric W. Noreen and Peter Brewer, 15th Edition, 2014.
2. Managerial Accounting by Jack L Smith, Robert M. Keith & William L Stephens, 1988.
3. Managerial Accounting by Stacy Whitecoton and Robert Libby, 2016.

Entrepreneurship **3 (3, 0)**

Objective:

After studying this course the students should be able to evaluate & improve their entrepreneurial potential and be able to generate and test innovative ideas suitable for commercialization.

Contents:

Role of Entrepreneurship in Economic Development, Characteristics of Successful Entrepreneurs, Types of Start-ups. Creativity, Methods of generating innovative ideas. Legal Issues including Patents, Trademarks, Copyrights, Trade Secrets, Licensing, Liability, Insurance, Contracts etc. The Concept of Planning Model, Pre-start-up Stage, Start-up Stage, Early Growth Stage, Later Growth Stage, Fundamentals of a Feasibility Plan. Role of Manufacturing, Products and Technology, Identifying Opportunities.

Recommended Books:

1) Entrepreneurship. by Hisrich, Peters & Shepherd, 8th Edition, 2009.
2) Effectual Entrepreneurship by S. Read, S. Saraswathy, N. Dew and R. Wittbank, 2nd Edition, 2016
3) Fundamentals of Entrepreneurship by S. Ariffin, I. A. Wahab, Z. Hambali, 2012.
4) Entrepreneurship by Bruce Barringer, 5th Edition, 2015.
5) The Financial Times Guide to Business Startups 2017/18: the most Comprehensive Guide for Entrepreneurs by Sara Williams, 30th Edition, 2016.

Management Information Systems **4 (3, 1)**

Prerequisites: Introduction to Computing

Objective:

To enable the students to understand the industrial information and retrieval systems, collecting and recording, analyzing and presenting data, data processing technologies, databases and security issues.

Contents:

Analysis, design and implementation of Industrial information and retrieval systems with special emphasis given to manufacturing systems, gathering, recording, analyzing and presenting the data requirements of an organization, Data processing technologies, Databases and their applications, Data protection, Networking, Backup and security.

Recommended Books:

1. Management Information Systems by K. C. Laudon & J. P. Laudon, 4th Edition, 2015
2. Management Information System by Terrence Lucy, 9th Edition, 2005.

Suggested Lab:

Use of Microsoft Access to create databases

Organizational Behaviour **3 (3, 0)**

Prerequisites: Human Resource Management

Objective:

To make the students aware of organizational structures and work environment.

Contents:

Organizational behaviour with reference to global and cultural diversity. Behaviour and perception of individuals, Attitudes and job satisfaction, Basic motivation concept, Group behaviour, Team work, Communication, Leadership, power and Politics, Conflict and negotiations, Organization structure, Technology, Work design and stress management, Approaches to managing organizational change.

Recommended Books:

1. Organizational Behaviour by Robbins; Stephen R, 2005.

H). NON-ENGINEERING DOMAIN

HUMANITIES

English-I (Functional English) **3 (3, 0)**

Objectives:

To enhance language skills and develop critical thinking

Course Details:
Basics of Grammar
Parts of speech and use of articles
Sentence structure, Active and passive voice
Practice in unified sentence
Analysis of phrase, clause and sentence structure
Transitive and intransitive verbs
Punctuation and spelling

Comprehension
Answers to questions on a given text

Discussion
General topics and every day conversation (topics for discussion to be at the discretion of the teacher keeping in view the level of students)

Listening
To be improved by showing documentaries/films carefully selected by subject teachers)

Translation skills
Urdu to English

Paragraph writing
Topics to be chosen at the discretion of the teacher

Presentation skills
Introduction

Note: Extensive reading is required for vocabulary building

Recommended Books:

a) Grammar

1. Practical English Grammar by A. J. Thomson and A. V. Martinet. Exercises. Third edition. Oxford University Press. 1997. ISBN 0194313492
2. Practical English Grammar by A. J. Thomson and A.V. Martinet. Exercises. Third edition. Oxford University Press. 1997. ISBN 0194313506

b) Writing

1. Writing. Intermediate by Marie-Christine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 0 19 435405 7 Pages 20-27 and 35-41.

c) Reading/Comprehension

1. Reading. Upper Intermediate. Brain Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 453402 2.

d) Speaking

English II (Communication Skills) 3 (3, 0)

Objectives:
To enable the students to meet their real life communication needs

Course Details:

Paragraph writing
Practice in writing a good, unified and coherent paragraph

Essay writing
Introduction

CV and job application

Translation skills
Urdu to English

Study skills
Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension

Academic skills
Letter / memo writing and minutes of the meeting, use of library and internet recourses

Presentation skills
Personality development (emphasis on content, style and pronunciation)

Note: documentaries to be shown for discussion and review

Recommended Books:

a) Grammar

1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2. Third edition. Oxford University Press 1986. ISBN 0 19 431350 6.

b) Writing

1. Writing. Intermediate by Marie-Chrisitine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills.

Fourth Impression 1993. ISBN 019 435405 7 Pages 45-53 (note taking).

2. Writing. Upper-Intermediate by Rob Nolasco. Oxford Supplementary Skills. Fourth Impression 1992. ISBN 0 19 435406 5 (particularly good for writing memos, introduction to presentations, descriptive and argumentative writing).

c) Reading

1. Reading. Advanced. Brian Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1991. ISBN 0 19 453403 0.
2. Reading and Study Skills by John Langan
3. Study Skills by Richard Yorky.

English III
(Technical Report Writing and Presentation Skills) (3, 0)

Objectives:
To enhance language skills and develop critical thinking

Course Details:

Essay writing
Descriptive, narrative, discursive, argumentative

Academic writing
How to write a proposal for research paper/term paper

How to write a research paper/term paper (emphasis on style, content, language, form, clarity, consistency)

Technical Report writing

Progress report writing and presentation

Note: Extensive reading is required for vocabulary building

Recommended Books:

a) Essay Writing and Academic Writing

1. Writing. Advanced by Ron White. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 435407 3 (particularly suitable for discursive, descriptive, argumentative and report writing).

2. College Writing Skills by John Langan. McGraw-Hill Higher Education. 2004.

3. Patterns of College Writing (4th edition) by Laurie G. Kirszner and Stephen R. Mandell. St. Martin's Press.

b) Presentation Skills

c) Reading

The Mercury Reader. A Custom Publication. Compiled by northern Illinois University. General Editors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students).

Engineering Economics **3 (3, 0)**

Objective:

The course would expose students to Engineering Economy techniques, primarily related to performing analysis, synthesizing and coming to a conclusion on projects of all sizes covering a wide range of engineering oriented examples.

Contents:

Introduction to engineering economics, Micro and macroeconomics, Break even analysis, Balance sheet, Cost and investment analysis, Basis for comparison of alternatives, Time value of money, Decision making in present economy, Evaluating replacement alternatives, Cash flow, Interest formulas and equivalence, Depreciation, Economic analysis of operations, Economic analysis of projects.

Recommended Books:

1. Engineering Economy by Leland T. Blank, Anthony J. Tarquin McGraw-Hill
2. Fundamentals of Engineering Economics (2nd Edition), Chan S. Park, Pearson Education.
3. Engineering Economy (15th Edition) by William G. Sullivan, Elin M. Wicks and C. Patrick Koelling, Pearson Education.

Logic and Critical Thinking **3 (3, 0)**

Objective:

The primary objective of this course is to impart a functional ability to reason well; to improve analytical skills and instincts, familiarizing with elementary methods of argument composition, analysis and reasoned decision making.

Contents:

- The Power of Critical Thinking

- Claims and Reasons, Reasons and Arguments, Arguments in the Rough

- The Environment of Critical Thinking
  - Perils of Haunted Mind, Self and the Power of the Group, Subjective and Social Relativism, Scepticism
- Making Sense of Arguments
  - Arguments Basics, Patterns, Diagramming Arguments, Assessing Long Arguments,
- Reasons for Belief and Doubt
  - Conflict Experts and Evidence, Personal Experience, Fooling Ourselves, Claims in the News

- Faulty Reasoning
  - Irrelevant Premises, Genetic Fallacy, Composition, Division, Appeal to the Person, Equivocation, Appeal to Popularity, Appeal to Tradition, Appeal to Ignorance, Appeal to Emotion, Red Herring, Straw Man
- Unacceptable Premises
  - Begging the Question, False Dilemma, Slippery Slope, Hasty Generalization, Faulty Analogy
- Deductive Reasoning: Propositional Logic
  - Connectives and Truth Values, Conjunction, Disjunction, Negation, Conditional, Checking for Validity, Simple Arguments, Tricky Arguments, Streamlined Evaluation
- Deductive Reasoning: Categorical Logic
  - Statements and Classes, Translations and Standard Form, Terms, Quantifiers, Diagramming Categorical Statements, Sizing up Categorical Syllogisms
- Inductive Reasons
  - Enumerative Induction, Sample Size, Representativeness, Opinion Polls, Analogical Induction, Casual Arguments, Testing for Causes, Casual Confusions
- Inference to the Best Explanation
  - Explanations and Inference, Theories and Consistency, Theories and Criteria, Testability, Fruitfulness, Scope, Simplicity, Conservatism
- Judging Scientific Theories
  - Science and Not Science, The Scientific method, Testing Scientific Theories, Judging Scientific Theories, Copernicus versus Ptolemy, Evolution Versus Creationism, Science and Weird Theories, Making Weird Mistakes, Leaping to the Weirdest Theory, Mixing What Seems with What is, Misunderstanding the Possibilities, Judging Weird Theories, Crop Circles, Talking with the Dead

Recommended Books:

1. Vaughn Lewis, 2005, The Power of Critical Thinking, Oxford University Press.
2. Paulsen David W., Cederblom Jerry: 2000, Critical Reasoning, Wadsworth
3. Restall Greg. 2005, Logic: An Introduction, Routledge

Numerical Analysis and Computer Applications 3 (2, 1)

Prerequisites: ***Probability & Statistics, Introduction to Computing***

Objective:

To enable the students to apply their knowledge of calculus for solving such mathematical problems that cannot be solved using analytical techniques.

Contents:

Finite differences and operators form, Interpolation and extrapolation; Lagrange's interpolation, Numerical differentiation based on differences, Numerical integration: Trapezoidal and Simpson's approximations, Romberg integration process, Numerical Solution of non-linear equations; Bracketing and iteration methods, Direct solution of system of linear equations; Gauss-elimination, Direct and indirect factorization, symmetric factorization, tri-diagonal factorization, Iterative methods like Jacobi's iteration and Gauss-Seidel iteration, Single and Multi-step methods, Higher order differential equations, System of differential equations, Numerical solution of linear and nonlinear boundary value problems.

Some of the computer experiments are listed below. The concerned faculty members may add or remove experiments.

Environment pollution, Air emission management, Waste management, Waste water treatment and control, Soil and ground water protection, Introduction to Pakistan Environment Protection Act 1997 and National Environmental Quality Standards, Key elements of ISO 14000.

NAME OF THE EXPERIMENT

1. To find the roots of non-linear equation using bisection method and fixed point iteration procedures.
2. To find the roots of non-linear equation using Newton's method and secant method.
3. To solve the system of linear equations using Gauss elimination method and Gauss-Jordan method
4. To integrate numerically using trapezoidal rule and Simpson rule.
5. To integrate numerically using Romberg integration and Gaussian quadrature

6. Implementation of Lagrange interpolation with different degree polynomials
7. Implementation of Newton's divided difference formulas
8. Curve fitting by least – square approximations.
9. To find the largest eigenvalue of a matrix by Power - method.
10. Implementation of Euler method and modified Euler method
11. Implementation of Runge Kutta methods of order 2 and 3
12. Implementation of Adam Bashforth two steps and three steps methods
13. Implementation of Adam Bashforth four steps methods
14. Implementation of Adam Multon two steps and three steps methods
15. Performance comparison of implicit and explicit multi-steps and single step methods
16. Preparation of lab report

Recommended Books:

1. Numerical Methods for Engineering, Science and Mathematics by Mumtaz Khan
2. Ordinary & Partial Differential Equations with Numerical Techniques for Engineering, Science and Mathematics by Mumtaz Khan.
3. Numerical Methods for Engineers and Scientists by N C Chappra, McGraw Hill.

Pakistan Studies **2 (2, 0)**

Objectives:

- To develop vision of Historical Perspective, Government, Politics, Contemporary Pakistan, ideological background of Pakistan.
- To study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Contents:

1. **Historical Perspective**
   a. Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-e-Azam Muhammad Ali Jinnah.
   b. Factors leading to Muslim separatism
   c. People and Land
      i. Indus Civilization
      ii. Muslim advent
      iii. Location and Geo-Physical features.
2. **Government and Politics in Pakistan**
   Political and constitutional phases: 1947-58, 1958-71, 1971-77, 1977-88, 1988-99, 1999 onward
3. **Contemporary Pakistan**

Economic institutions and issues, Society and social structure, Ethnicity, Foreign policy of Pakistan and challenges, Futuristic outlook of Pakistan

Recommended Books:

1. Burki, Shahid Javed. *State & Society in Pakistan,* The Macmillan Press Ltd 1980.
2. Akbar, S. Zaidi. *Issue in Pakistan's Economy.* Karachi: Oxford University Press, 2000.
3. S.M. Burke and Lawrence Ziring. Pakistan's Foreign policy: An Historical analysis. Karachi: Oxford University Press, 1993.
4. Mehmood, Safdar. *Pakistan Political Roots & Development.* Lahore, 1994.
5. Wilcox, Wayne. *The Emergence of Banglades.,* Washington: American Enterprise, Institute of Public Policy Research, 1972.
6. Mehmood, Safdar. *Pakistan Kayyun Toota,* Lahore: Idara-e-Saqafat-e-Islamia, Club Road, nd.
7. Amin, Tahir. *Ethno - National Movement in Pakistan,* Islamabad: Institute of Policy Studies, Islamabad.
8. Ziring, Lawrence. *Enigma of Political Development.* Kent England: WmDawson & Sons Ltd, 1980.
9. Zahid, Ansar. *History & Culture of Sindh.* Karachi: Royal Book Company, 1980.
10. Afzal, M. Rafique. *Political Parties in Pakistan,* Vol. I, II & III. Islamabad: National Institute of Historical and cultural Research, 1998.
11. Sayeed, Khalid Bin. *The Political System of Pakistan.* Boston: Houghton Mifflin, 1967.
12. Aziz, K. K. *Party, Politics in Pakistan,* Islamabad: National Commission on Historical and Cultural Research, 1976.
13. Muhammad Waseem, Pakistan Under Martial Law, Lahore: Vanguard, 1987.
14. Haq, Noor ul. *Making of Pakistan: The Military Perspective.* Islamabad: National Commission on Historical and Cultural Research, 1993.

Islamic Studies/Ethics **2 (2, 0)**

Objectives:

The course is to enhance vision and facilitate application of Islamic ideology in the real world. The student should be able to find solutions to problems within Islamic practices comfortably instead of alien. Know how a Muslim could essentially use Islamic tools in the world and earn eternal peace as grater value assumption.

Contents:
(A) ISLAMIC STUDIES (For Muslims)

QURAN SHARIF.
Fazail Quran (Importance of Quran) as the ultimate source of knowledge for the betterment of mankind.

Importance of Sunnah, as practical demonstration of Al-Quran and Huqooq-ul-Ibaad.

DEEN-E-ISLAM.
Tauheed, Risalat and Aakherat for eternal peace of mankind.
Concept of Rizk-e-Halal (verses from Al-Quran) and Professional Ethics in the light of Al-Hadith.
Importance of Prayers, Fasting Zakat, Hajj and Jihad in professional performance.
Uswatul Hassanah as vision for workplace and social environmental improvement
Learning from Makki and Madani life of Prophet Muhammad (SAWW) and Sahaaba as leadership and team for commitment and continuous improvement.
Core policies behind Spreading of Islam تبلیغ اسلام and the application of Philosophical thoughts behind Mithaqe-Madina, میثاق مدینه Fateh-e-Mecca, lutajjaH dna ههکمہ حتفہ-vida حجة الوداع for regional and global relations.
Islamic lawfulness, Heritage, Solutions to humanitarian problems, future, oneness, political solidarity as road map to civic civilization.
Importance of honest character, practicing ways for avoiding of sins according to Islam.

Application of Sidq, صدق Tawakkal, توکل Taqua, تقوی the fulfilment of promise, ایذإعهل Simplicity, سادگی respect, obedience, equality and the forgiveness.

(B) Ethics (For Non-Muslims)

Ethical techniques of world religions with special reference to Hinduism, Budhism, Judaism, Christianity and Islam. One hundred ethical presentations from Quran and sayings of the Prophet.
Islam's attitude towards minorities
Promotion of moral values in the society.
A brief review of ethical systems in philosophy

I). MANAGEMENT SCIENCES

Introduction to Engineering Management **3 (3, 0)**

Objective:
The course would enable students to widen their knowledge and understanding of a range of current and developing engineering management issues, management principles and practices.

Contents:
The vision and mission of management, The management process and strategy, Strategic management, The planning process, Organization structures, Human factors, Motivation & leadership, Basics elements of control, Managing, designing and new product development, Managing the supply systems, Marketing, introduction to entrepreneurship.

Recommended Books:
1. Managing Engineering and Technology by Babcock and Morse, Prentice Hall
2. Management by Herald Koontz
3. Management by Robbins Coulter
4. ISO-10007 Quality management systems-Guidelines for configuration management.
5. MIL-HDBK-61A (SE) Military handbook-configuration management guidance.
6. MIL-STD 31000 Technical data packages.
7. Engineering Management by Fraidoon Mazda, Pearson.

Project Management **4 (3, 1)**

Prerequisites: *Engineering Economics, Introduction to Engineering Management*

Objective:
The course enables the students to understand and implement modern project management techniques (using software) related government regulations.

Contents:
Project management concepts, project proposals and feasibility, initiating, Planning, execution, monitoring and control, closing and Exit strategy, knowledge areas as per PMBOK/PRINCE-2, introduction to any Project Management's Software.

Recommended Books:
1. Project Management: A Systems Approach to Planning, Scheduling, and Controlling by Harold Kerzner, John Wiley
2. Case studies in project management, 2nd edition, by Harold Kerzner, John Wiley

3. Project Management Body of Knowledge (PMBOK) 4th edition, by P.M.I.

Suggested Labs:

Hands on practice using M.S. Project/Primavera etc.

J). NATURAL SCIENCES

Calculus **3 (3,0)**

Objective:
To learn fundamentals of mathematics, calculus and analytical geometry.

Contents:
Complex Numbers, De'Moivre's Theorem, Functions: Hyperbolic, Trigonometric and Exponential Functions, Differentiation and its Application to Rate, Speed and Acceleration, Leibritze's Theorem, Equations of Tangents and Normals, Curvature, Radius and Centre of Curvature, Maxima and Minima of Function, Convexity and Concavity, Taylor's and Mclaurin's Series and Expansion of Functions, Errors and Approximations and Limiting Values of Functions, Partial Differential, Euler's Theorem, Integral Calculus: Standard Integrals, Integration by Substitution, by Partial Fractions and by Parts, Integration of Trigonometric Functions, Definite Integrals, Two and three dimensional integration, Volumes of Solids of Revolution

Recommended Books:
1. Schaum's series, Calculus, Schaum's Series (Latest Edition)
2. Schaum's series, Complex, Schaum's series, (Latest Edition)
3. Antom, H. Calculus and Analytic Geometry, John Wiley and Sons. (Latest Edition)
4. Talpur, Calculus and Analytic Geometry, Feroz Sons (Latest Edition)
5. Yousuf, S. M. Mathematical Methods, Ilmi Kutab Khana (Latest Edition)
6. Mathematics for Engineers by Robert D. Wesley, McGraw-Hill
7. Multivariate Calculus by Robert T. Smith, Roland B. Minton, McGraw-Hill

Applied Linear Algebra **3 (3, 0)**

Objective:
To familiarize the students with vectors, matrices, determinants, linear combinations and spaces and enable them to understand the related Geometry.

Contents:
Vector Algebra, Matrix Algebra, Determinants, Linear System of Equations, Linear Transformations, Eigen-values and Eigenvectors

Recommended Book:
1. Linear Algebra and its Applications by David C Lay, Addison-Wesley

Differential Equations **3 (3, 0)**

Objective:
To introduce basic techniques pertaining to matrices and formulation/solution of differential equations.

Contents:

Ordinary Differential Equations:
Basic concepts of ordinary differential equation, General and particular solutions, Initial and boundary conditions, Linear and nonlinear differential equations, Solution of first order differential equation by separable variables and its applications in our daily life situations, The techniques like change of variable, homogeneous, non-homogeneous, exact, non-exact, linear and nonlinear Bernoulli could be used in case of complications. Solution of second order differential equation by theory of operators and its applications as forced and free oscillations, The extension of second order solution criteria to higher order differential equations, Solution of the system of differential equations by theory of operators and its applications in our daily life situations, Laplace solution of ordinary differential equations.

Partial Differential Equations:
Basic concepts, Linear and nonlinear p.d. equations, Quasi linear and Quasi nonlinear p.d. eqution, Homogeneous and non-homogeneous p.d. equations, Solutions of p.d. equations, Boundary and initial conditions as Dirichlet condition, Neumann condition, Robbins/Mixed condition, Classification of p.d. equations as Elliptic, Parabolic and Hyperbolic.

Analytic solution by separation of variables of the Steady-state Two-Dimensional Heat equation/Laplace equation and Unsteady-State One-Dimensional Heat equation/Diffusion equation with homogeneous and non-homogeneous boundary conditions. D' Alembert's solution of two-dimensional wave equation with homogeneous and non-homogeneous boundary conditions.
Fourier series:

Periodic waveforms and their Fourier representations, Calculating a Fourier series, Fourier series of odd and even functions, half range Fourier series, Fourier series solution p.d. equations.

Recommended Books:

1. Modern Differential Equations by Abell and Braselton, McGraw-Hill
2. Advanced Engineering Mathematics by Louis C. Barrett, McGraw-Hill
3. Ervin and Kreyszig, E. Advanced Engineering Mathematics, John Wiley and Sons, (Latest Edition).
4. Speigal M. R., Theory and Problems of Laplace Transforms, Schaum's Outline Series.

Engineering Mechanics **3(2, 1)**

CONTENTS:

Foundations of Mechanics: Fundamental concepts and definitions.
Force Systems: Force, rectangular components, moment, resultant couple (two and three dimensional systems).
Equilibrium: Mechanical systems, isolation and equilibrium conditions for two and three dimensional systems.
Structures: Plane trusses, method of joints, method of sections, frames.
Friction: Types of friction, application of friction in wedges, screws, journal bearings, thrust bearings, flexible belts.
Virtual Work: Introduction, work, virtual displacement and virtual work, principle of virtual work, potential energy and stability.

Recommended Books:

1. Vector Mechanics for Engineers: Statics and Dynamics, by Ferdinand Beer and Johnston, Jr., E. Russell, 2015.
2. Engineering Mechanics (Statics) by R. C. Hibbler, 13th Edition, 2012.
3. Engineering Mechanics Dynamics & Mastering Engineering Package, by Russell C. Hibbeler, 12th Edition, 2009.
4. Engineering Mechanics: Statics by James L. Meriam and L. G. Kraige, 2014.
5. Engineering Mechanics: Dynamics by James L. Meriam and L. G. Kraige, 2015.

Probability and Statistics **3 (3, 0)**

Prerequisites: Calculus

Objective:

To develop an understanding of the basic concepts of probability and statistics.

Contents:

Measures of central tendency and dispersion, Moments, Introduction to classical Probability theory, Bayes theorem, Random variables (discrete and continuous), Probability distributions (Normal, Binomial, Poisson etc.), Expectation, Conditional distribution and conditional expectations, Correlation and regression.

Recommended Books:

1. Probability & Statistics for Engineers & Scientists by Walpole, Myers, Myers & Ye, Prentice Hall
2. Engineering Statistics by D. C. Montgomery, John Wiley
3. Business Statistics by Mark L. Berenson and David Iivine.

Master of Industrial Engineering

Eligibility Criteria:
As per university admission policy

Program Structure:

The ME/MS Industrial Engineering programme was reviewed thoroughly. It was agreed by the committee that for ME/MS minimum credit hours earned by a student shall be 30 as per following distribution:

Component	**Credit Hours**
Core Courses	12
Electives	12
Thesis	06
Total	**30**

*****

Programme Objectives:

The objectives of MS/ME Industrial Engineering program shall be to produce graduates, who:

- Are highly valued and technically sound professionals, well prepared for their subsequent assignments, duties and responsibilities as professional engineers,
- Have been provided core education in this programme,
- Can apply foundational scientific concepts and sound engineering principles efficiently and effectively starting from conceptual design till final deliverables, utilizing advanced technological capabilities,
- Have experience in conducting independent research work and document it with fact finding approach,
- Can professionally support and communicate technical solutions and results.

While there can be many tracks, the committee identified and developed coursework in four areas namely:

1 Manufacturing
2 Operations Research
3 Quality Management
4 Engineering Management

1. Manufacturing Track	
Core Courses (select at least 4)	
Course Title	**CR**
Manufacturing Planning & Control	3
Optimization	3
Quality Engineering	3
Manufacturing Systems	3
Advanced Manufacturing Processes	3
CAD/CAM	3
Computer Simulations	3
Concurrent Engineering	3
Advanced Mathematics	3
Computer Applications	3
Electives:	
Course Title	**CR**
Computer Integrated Manufacturing	3
Engineering Economics	3
Finite Element Analysis	3
Human Resource Management	3
Benchmarking	3
Scheduling	3
Tool Design	3
Artificial Intelligence	3
Ergonomics	3
Supply Chain Management	3
Research Methodology	3
Business Process Simulation	3
Retail Management	3
Warehouse Management and Distribution Network	3
Supplier Relationship Management	3
Business Process Re-engineering	3
Project Management	3
Six Sigma Methodologies	3
Special Topic	3

2. Operations Research Track	
Core Courses (select at least 4)	
Course Title	**CR**
Deterministic Optimization	3
Stochastic Optimization	3
Computer Simulations	3
Mathematical Statistics	3
Computer Applications	3
Real Analysis	3
Electives:	
Course Title	**CR**
Queuing Theory	3
Dynamic Programming	3
Game Theory	3
Network Analysis	3
Stochastic Processes	3
Artificial Intelligence	3
Replacement Models	3
Supply Chain Management	3
Business Process Simulation	3
Retail Management	3
Warehouse Management and Distribution Network	3
Supplier Relationship Management	3
Combinatorial Optimization	3
Research Methodology	3
Business Process Re-engineering	3
Special Topic	3

3. Quality Management Track	
Core Courses (select at least 4)	
Course Title	**CR**
Inferential Statistics	3
Organizational Systems	3

Project Management Framework & Tools	3
Six Sigma Methodologies	3
Operations Research	3
Reliability Analysis	3
Computer Simulations	3
Statistical Quality Control	3
Total Quality Management	3
Advanced Mathematics	3
Computer Applications	3
Electives:	
Course Title	**CR**
Quality Assurance	3
Supply Chain Management	3
Design and Analysis of Experiments	3
Manufacturing Planning & Control	3
Lean and Agile Manufacturing	3
Maintenance & Safety	3
Benchmarking	3
Quality Engineering	3
Business Process Simulation	3
Retail Management	3
Warehouse Management and Distribution Network	3
Supplier Relationship Management	3
Cost and Management Accounting	3
Research Methodology	3
Business Process Re-engineering	3
Special Topic	3

4. Engineering Management Track			
Core Courses (select at least 4):			
Course Title	**Lec**	**Lab**	**CR**
Operations Management	3	0	3
Project Management	3	0	3
Management Information System	3	0	3
Engineering Economics	3	0	3
Human Resource Management	3	0	3
Total Quality Management	3	0	3
Supply Chain Management	3	0	3
Computer Simulations	3	0	3
Advanced Mathematics	3	0	3
Computer Applications	3	0	3
Research Methodology	3	0	3
Organizational Behaviour	3	0	3
Electives:			
Course Title	**Lec**	**Lab**	**CR**
Project Evaluation & Feasibility Analysis	3	0	3
Computer Integrated Manufacturing	3	0	3
Business Forecasting	3	0	3
Energy Management	3	0	3
Environmental Management & Safety	3	0	3
Operations Research	3	0	3
Marketing Management	3	0	3
Cost & Management Accounting	3	0	3
Benchmarking	3	0	3
Business Process Re-engineering	3	0	3
Business Process Simulation	3	0	3
Retail Management	3	0	3
Warehouse Management and Distribution Network	3	0	3
Supplier Relationship Management	3	0	3
Special Topic	3	0	3

Details of Postgraduate Courses in Industrial Engineering

Advanced Manufacturing Processes **3 (3, 0)**
Non-traditional machining and thermal cutting processes - Super finishing processes - Selection of manufacturing materials and processes - Joining and assembly processes - Design for manufacturing (processing and assembly) - Product and production relationships.

Advanced Mathematics **3 (3,0)**
Approximations and error analysis, methods to find roots of non-linear algebraic equations, solution of systems of linear algebraic equations, deriving empirical equations to suit experimental data, numerical differentiation and integration, numerical solution of differential equations, the determination of Eigen values, Fourier analysis and its engineering applications.

Artificial Intelligence **3 (3, 0)**
Introduction to AI, expert systems, knowledge-based systems, inductive logic programming, fuzzy sets and systems, evolutionary computation techniques, hyper heuristics, machine learning, hybrid intelligent systems, data mining and knowledge discovery, Genetic algorithm and artificial neural networks.

Benchmarking **3 (3, 0)**
Strategic planning and the evolution of benchmarking, types of benchmarking, common criticisms of benchmarking; Steps in benchmarking, planning benchmark study- seven 'to-do' items, determination of activities to benchmark, identifying the benchmark team, scheduling the study and determination of key factors to measure, Identification of target organization (benchmark partner). Execution of the study: Data collection, data analysis. Implementing improvement, strategy assessment.

Business Forecasting **3 (3, 0)**
Forecasting alphabet, applications, classification of forecasting methods, Importance of sales forecast, Forecasting approaches (deterministic and probabilistic), Time series causal forecasting, Time series projective forecasting, Service level models, Information for dependent demand, Use of computer software in business forecasting.

Business Process Reengineering **3 (3, 0)**
Fundamentals of process management; importance of process decisions and process choices; strategic process decisions for manufacturing and

service environments. Costs, quality, and timeliness as the primary attributes of value; creation of value through strategies and processes.
Process improvement tools and frameworks; process maps, value stream mapping, service blueprinting, reengineering, Poka-Yoke, lean systems and six-sigma. Simulation and modelling of discrete event systems and processes. Implementing BPR methodology, building the reengineering organization; identifying BPR opportunities, understanding existing processes, reengineering processes, blueprinting new business systems, performing transformation.

Business Process Simulation (3, 0)
Relationships between business processes, Process flow measurement, including key process measures, their interrelationships, and managerial levers for controlling, Effects of variability on process performance,
Modelling for business process improvement; Basics of business process model; Modelling rules & Notations; hierarchy and concurrency Concept of domains; Evaluating Simulations; Private versus Public- Modelling process participants; Modelling verification; Structure business process models using collaboration,; Advanced Event Definitions; Techniques for modeling, analyzing, and redesigning a process.

CAD/CAM 3 (3, 0)
Computer methods in industrial design, Advanced computer geometric modeling, transformations and projection, CAD/CAM databases, Introduction to automated machine tools and cutting tools, tool path planning, Management of cutting tools, Numerical control, Motion control, Robotics, CNC machine tools programming, use of modelling software.

Combinatorial Optimization 3 (3, 0)
Algorithmic and structural approaches in combinatorial optimization with a focus upon theory and applications. Topics include: polyhedral methods, network optimization, the ellipsoid method, graph algorithms, matroid theory and sub modular functions.

Computer Applications 3 (3, 0)
Computer hardware and software, Databases, Communication and networks, Constants and variables, Arithmetic operations, Intrinsic functions, Algorithm design, Flowcharts, and Pseudo codes, IF statements, Do loop, While loop, Data files, Formatted Input and Output, Logical and character data type, Arrays: one-dimensional, two-dimensional, Subprograms: Functions and subroutines, Numerical Applications, Introduction to programming language.

Computer Integrated Manufacturing 3 (3, 0)
CIM strategy, CIM components, Concurrent engineering, GT and cellular systems, FMS, Robotic systems, Systems integration, Selection of CIM

systems, Modeling and implementation of CIM systems, Enterprise resource planning, Future trends in CIM.

Computer Simulations **3 (3, 0)**

Concept of simulation modelling, selecting the appropriate input distribution, random number generation, simulation languages, output analysis, alternatives comparison, variance reduction technique, models of complex systems, case studies for simulation using any simulation software.

Cost and Management Accounting **3 (3, 0)**

Financial Accounting, Income statement and principles of accrual accounting, Balance sheet and recording of transactions, Accounting process, Revenue recognition, Inventory/cost of goods sold, Statement of cash flow, Long term assets/depreciation, long term debt, Current liabilities and contingencies, Marketable securities, intangibles, Cost concepts, Indirect allocation of cost.

Concurrent Engineering **3 (3, 0)**

Theory and philosophy of Concurrent Engineering, Planning the transition and Reducing organizational and cultural barriers, Product cycle time, Customer satisfaction, Reduction in engineering change orders or reworks, Strategies for selecting, staffing and managing multi-disciplinary functional project-teams. Principles of DFA/DFM for parts reduction and assembly, Learn design for X concepts (e.g., DFM, DFA, DFS, etc.) Pinpoint organization change and the effects of new engineering order, QFD, Taguchi method, Axiomatic design.

Design and Analysis of Experiments **3 (3, 0)**

Sampling and descriptive statistics, Parameter estimation, Tests of hypothesis on the means, variance, and ratios, Testing for goodness of fit, Non-parametric tests, Experiments with single factor, Randomized blocks, Latin squares and incomplete block designs, Factorial and fractional factorial designs, Regression analysis, Taguchi's concepts and approach to parameter design, Response surface methodology, use of Minitab software.

Deterministic Optimization **3 (3, 0)**

Selection of an OR tool for a particular production/operations management application, Formulating deterministic optimization models, Defining objectives, decisions and constraints, Writing symbolic models and implementing those using optimization software, Using Excel data table functions to conduct sensitivity analysis, Interpretation of sensitivity tables, simplex tableaus, duality analysis, application of OR methods.

Dynamic Programming **3 (3, 0)**

Introduction: Sequential decision processes, DP functional equations, problem formulation and solution, State transition graph models, state-

space generation, complexity, greedy algorithms, probabilistic dynamic programming.
Applications of DP: Optimal allotment, all-pairs shortest path problems, assembly-line balancing, optimal binary search tree problem, optimal covering problem, discounted profits problem, flowshop problem, Integer linear programming. Integer knapsack problem, mini max problem, optimal distribution and optimal permutation problems, optimal selection problem, Process scheduling problem, Transportation problem, Traveling salesman problem.
Modelling of DP problems. Introduction to DPS.

Energy Management **3 (3, 0)**
Attitudes to energy efficiency, objective of energy management, priorities, and strategies. Plant control, control and use of an energy management system.
Monitoring: Remote monitoring and out-station operation, degree days performance lines and targeting, Audits, Environmental, energy and social.
Energy Modelling and Forecasting, reserves and relation of resources to future options. Energy demand models, Energy Transmission & Utilization, Waste Heat Recovery System, Energy Resources, Solar Energy Conversion Systems.

Engineering Economics **3 (3, 0)**
Cost concepts and design economics, cost estimation techniques, developing project cash flows, lease versus buy decisions, replacement analysis, dealing with uncertainty, impact of Income tax and inflation on economic analysis, capital financing and allocation.

Environmental Management & Safety **3 (3, 0)**
Professional and self-development, Quality and resource planning, Integrated business risk management, Environmental and waste management, Workplace evaluation and control, Health and safety management and legislation, Environmental impact assessment, ISO 14000, Reduction of carbon footprint.

Ergonomics **3 (3, 0)**
Principles of ergonomics, Human characteristics relevant to Ergonomics, the system approach and aspects of Ergonomics, role of human factors engineering in Artificial Intelligence, anthropometry, types of anthropometry, body dimensions of various organs, failure of design, anthropology and its types, climatic factors, sound and its measurements, effects of noise on various organs, principles of good lighting.

Basic cognitive capabilities and limitations of the workers, environmental situation and limitations conducting an ergonomic assessment,

Developing an ergonomic program, Ergonomic issues related to posture, materials Handling/Lifting using the NIOSH, Frequent types of injuries related to workplace design, Repetitive motion, and cumulative trauma disorders, Preventing ergonomically related injuries by redesigning the workplace, Designing displays for Workers, Transfer and design of information, Controls and control arrangements.

Finite Element Analysis **3 (3, 0)**

Matrix forces method, Matrix stiffness method, variational formulation and approximation (Boundary and initial-Value problems, gradient and divergence theorems), Ritz methods, method of weighted residuals, time-dependent problems. Finite Element Error Analysis (Approximation Errors, Various measures of errors, Convergence of solutions and accuracy of solutions), Numerical integration & computer implementation, Coordinate transformation (Integration on a Master Element, Modeling, Mesh Generation), Load Representation, use of finite element software.

Game Theory **3 (3, 0)**

Theory of rational choice, integration with intelligence and decision making, axioms, the expected utility maximization theorem, Bayesian conditional probability systems.

Basic Models: Games in extensive form, strategic forms and normal representation, Equivalence and reduced normal representation, elimination of dominated strategies.

Equilibria of strategic form games: Nash equilibrium theory, computation and significance of Nash equilibria, the Focal point effect, Purification of randomized strategies in equilibria, infinite strategies sets, The two person zero-sum game with equilibrium points, two-person non-zero sum game, Mixed strategies and behavioural strategies, Auctions, bargaining and cooperation in two-person games.

Human Resource Management **3 (3,0)**

Role and Organization of Personnel Function, Behaviour Aspects, Human Resources Planning, Recruitment, Job Analysis and Design, Managing Performance. Training and Development, Pays and Benefits, Industrial Relations.

Inferential Statistics **3 (3,0)**

Fundamentals of hypothesis testing: one-sample t-test, Two-sample t-tests, ANOVA and other tests with numerical data, Two-sample and c-sample tests with categorical data, multiple regression and response surfaces.

Lean and Agile Manufacturing **3 (3,0)**

Products and product development processes, Processes and process development, Requirements of materials, Planning and control of material, Capacity planning and control, Supply chains, The KISS principle, Operations support and administration, Implementing and Running Leanness and Agility, Staying Lean and Agile, Selling the concept internally, Applying the knowledge to develop your program.

Maintenance & Safety **3 (3,0)**

Planned and preventive maintenance, Predictive maintenance, Corrective maintenance, Advanced concepts (Reliability centred maintenance, Total productive Maintenance), Concepts of maintainability engineering, Design for maintainability, Availability, Decision models in maintenance management. National and international standards for preventing accidents in the workplace, recent developments in industrial systems' safety and risk analysis techniques.

Management Information System **3 (3, 0)**

Introduction of MIS, Meaning & Role, organization structures, Business Process, Systems Approach. Programmed & Non- Programmed, Strategic & Project Planning for MIS, Models of Decision Making different types of IS: MIS, DSS, ESS. MIS and the information Concepts, System Concepts, Handling system complexity MIS and system concepts, need for system analysis, SSAD, MIS and System Analysis. Development of MIS, Ascertaining the Class of information, Management of quality in MIS, MIS: the factors of success and failure. EMS and MIS, MIS Service industry, choice of IT in MIS.

Manufacturing Planning & Control **3 (3, 0)**

Deterministic inventory problems, Material requirement planning, manufacturing resource planning, Enterprise resource planning, Just-in-time manufacturing, Variability basics and their influence, Push-Pull and hybrid production systems and Supply chain management.

Manufacturing Systems **3 (3, 0)**

Introduction to modern manufacturing strategy and the importance of Quick Response Manufacturing. Manufacturing systems and models, assembly lines, single model assembly line, mixed models assembly lines, line balancing, transfer lines, group technology, coding schemes, cellular manufacturing, production flow analysis, flexible manufacturing systems, planning and control hierarchy of FMSs, machine setup and operations sequencing, material handling systems, storage and retrieval systems

Marketing Management **3 (3, 0)**

Introduction to the fundamental concepts of marketing, customer orientation, competition and core strengths, introductory finance,

Marketing research and analysis, Marketing strategy, Implementation planning, Project, Process and supplier management, market segmentation, product life cycle, distribution networks, social marketing, product promotions, Marketing Mix.

Mathematical Statistics **3 (3, 0)**

Probability spaces and random elements, Integration and differentiation, probability distributions and their characteristics, conditional expectations, asymptotic theory; Populations, samples, and models; statistics, sufficiency and completeness; statistical decision theory; statistical inference; asymptotic criteria and inference; Unbiased statistics, their variances, the Least squares estimates (LSE) in Linear models, the UMVUE and the BLUE, robustness of LSEs, Bayes decisions and estimators, invariance, maximum likelihood, the likelihood function and the MLEs, Uniform, Gamma, and Beta processes, Normal and the exponential family of processes, Sampling statistics, probability generating function, moment generating function.

Network Analysis **3 (3, 0)**

Formulation of network problems as linear programming problem, The trans-shipment problem, trees and feasible tree solutions, economic motivation for network Simplex method, degeneracy and cycling, termination and initialization issues, decomposition into sub problems, computer implementation, Inequality constraints, scheduling production and inventory, the Caterer problem, the Integrality theorem, doubly stochastic matrices, covers and matchings in bipartite graphs, chains and antichains in partially ordered sets, The assignment and transportation problems as network problems, Upper-bounded trans-shipment problems, Maximum flow through networks: The primal-dual method for network flows.

Operations Management **3 (3, 0)**

Operations and productivity, operations strategy for competitive advantages, forecasting, design of goods and services, managing quality including SPC, capacity planning, location and layout strategies, supply chain management, inventory management including JIT, aggregate planning, MRP, maintenance and reliability, decision making tools, linear programming, transportation models, waiting lines model, learning curves, introduction to simulation, statistical tools for management.

Operations Research **3 (3, 0)**

How the simplex method works, Tableau and Dictionary methods, pitfalls (initialization, iteration and termination) in Simplex method and ways to avoid those, Speed of computation, How fast is Simplex method, The Duality theorem, Gaussian Elimination and matrices- number of steps, speed and accuracy issues, the LP decomposition of matrices, the revised

Simplex method, General LP problems and their solution by Simplex Method, Theorems on Duality, Feasibility and infeasibility of problems, Primal-dual relationship, sensitivity analysis, Efficient allocation of scarce resources, scheduling production and inventory, the cutting stock problem, matrix games.

Optimization **3 (3, 0)**

Introduction to design and optimization, Mathematical formulation of design optimization Problems, Multi-criteria optimization, Fundamental concepts of optimality. Gradient vector, Hessian matrix, Taylor series expansion, Quadratic forms, and Eigenvalues of matrices, Necessary and sufficient conditions for optimality of unconstrained and equality constrained problems, Necessary and sufficient conditions for optimality of constrained problems, Kuhn-Tucker conditions, and post optimality analysis, Global, optimality, convex functions, convex programming problems, Linear Programming and Sequential Linear Programming, One dimensional minimization, polynomial interpolation and Golden section search, Unconstrained Minimization, Exterior, Interior, and Extended Interior Penalty function approaches, Augmented Lagrange Multiplier Method for equality and inequality constrained problems.

Organizational Behaviour **3 (3, 0)**

Management functions and roles. Need for systematic study of human behaviour. Challenges and opportunities for O.B., Responses to Global and Cultural Diversity. Foundations of Individual Behaviour, Perception and Industrial Decision Making. Values, Attitudes and Job Satisfaction, Motivation Concepts, Group Behaviour & Work Teams, Organization System.

Organizational Systems **3 (3, 0)**

Integrating management systems, management, safety, managing indirect costs, controlling risks and cost, Management commitment and policy, responsibility and authority, objectives and targets, plan consideration, plan implementation, standard operating procedures, employees involvement, management and control of contactors and vendors, emergency preparedness and contingency planning, document control and record keeping processes, process risk analysis and assessment, measurement and evaluation, non-conformances and incident investigations.

Project Evaluation & Feasibility Analysis **3 (3, 0)**

Project Planning & Appraisal, Managing Project with Project Management Tools, Project Management Control, Indicators and Measurement of Monitoring and Evaluation, General Management Skills, Financial aspects of new project, Feasibility analysis of a model project, Sensitivity analysis.

Project Management **3 (3, 0)**

Project Management and Project Control, Qualitative and Quantitative Risk Management, Project Management Structures Strategy, Portfolio and Program Management, Project cost estimation, Project procurement management, Managing Data and Configurations for effective project management, Managing Technology: Innovation, Learning and Maturity. Time, Cost and Critical Chain Management, Project Performance Measurement & Value Management, Improving quality in project and program, use of MS Project or Primavera.

Project Management Framework and Tools **3 (3, 0)**

Define project, program and portfolio management, project structure, project life span, modelling project management, project management model in three decades, model with portfolio potential, logical progression, Marasco pyramid model, Project dynamics, project environment, project control, program and portfolio management, optimization portfolio management

Quality Assurance **3 (3, 0)**

Basic elements of a quality assurance system, Quality standards such as ISO 9001 and ISO 17025, Structuring quality management system documentation: quality manual, quality plans, procedures, work instructions, records, QMS implementation and maintenance, Strategic and competitiveness issues in QMS, Computer-based information systems for QMS, Role of TQM and statistical methodologies in QMS, Quality auditing and management reviews, Continuous improvement through corrective and preventive action, Familiarization with other standards such as ISO 14001, SA 8000, OHSAS 18000,

Quality Engineering **3 (3, 0)**

Principles of modern quality control techniques, KAIZEN by TQC/TQM, Management and Planning Tools, Affinity Diagrams, Interrelationship Digraph, Tree Diagram, Project teams, Project Management Techniques, Adventure based team building and leadership, Basic Tools, Prioritization matrices and Matrix diagrams, Organizational and cultural issues, Implementing change and new technologies, Deming, Baldrige and other total quality awards, Introduction to Six Sigma, Quality assurance Audit Programs, and ISO certification.

Queuing Theory **3 (3, 0)**

Description and characteristics of queuing systems, Poisson process and exponential distribution, Markovian property, stochastic processes and Markov Chain.

Birth-death queuing models: Kendall notation, steady-state solution for M/M/1 models, steady-state difference equation, M/M/c, and M/M/c/k models, Erlang formula, queuing with unlimited services, Network, Series

and Cyclic queues, Models with general arrival and service patterns: Single server and multiple server queues with Poisson arrivals and general service, multi-channel queues with Poisson arrivals and constant service.

Real Analysis **3 (3, 0)**

Topological properties of the real numbers, Completeness and least upper bound property. Cardinality of sets. Theory of metric spaces, Cauchy and convergent sequences, compactness, completeness, and connectedness, Continuous functions between metric spaces, Differentiability of functions of one variable, Differentiability of functions of several variables.

Reliability Analysis **3 (3, 0)**

Models and Uncertainties, Standards and Guidelines, Failure Models, Qualitative System Analysis, Systems of Independent Components, Component Importance, Dependent Failures, Counting Processes, Markov Processes, Reliability of Maintained Systems, Reliability of Safety Systems, Life Data Analysis, Accelerated Life Testing, Bayesian Reliability Analysis, Reliability Data Sources, use of Minitab or some other software.

Research Methodology **3 (3, 0)**

Introduction to research, definition and objectives of research, types of researches, Building blocks of research, Formulation and statement of problem; Theoretical framework, hypothesis development, elements of research design, sampling design, data collection instruments, measurement of variables, data analysis techniques, hypothesis testing, inference, preparation of research report and presentation; use of Minitab, MS Excel or some other software for analysis.

Retail Management **(3, 0)**

Introduction to Retailing; Building and Sustaining Relationships in Retailing; Strategic Planning in Retailing; Retail Institutions by Ownerships, by Store-Based Strategy; by Web, Non-Store Based and other Forms of Traditional Retailing; Identifying and Understanding Consumers; Information Gathering and Processing in Retailing; Trading Area Analysis; Site Selection; Financial Dimensions; Developing Merchandise Plans; Financial Merchandise Management; Pricing in Retailing.

Replacement Models **3 (3, 0)**

Introduction to replacement models, decision whether to repair or replace, modelling the decision, assumptions related to replacement decision, uncertainty in replacement acquisition costs, modelling and estimation of model parameters, modelling maintenance requirements and estimation of maintenance as well as life cycle costs.

Scheduling **3 (3, 0)**

Introduction to scheduling problem, performance measures of scheduling, single and multi-machines scheduling, parallel machines scheduling, flow shop scheduling, job shop scheduling, open shop scheduling and project scheduling.

Six Sigma Methodologies **3 (3, 0)**

Introduction to Six Sigma, Internal & External Customers, Define Measure Analyse Improve Control (DMAIC) Cycle, Six Sigma goals and Matrices, Six Sigma Training, Six Sigma Teams, Green, Black and Master Black Belt, Design for Six Sigma, Define Measure Analyse Design Verify (DMADV) , Case Studies.

Statistical Quality Control **3 (3, 0)**

Review of Probability Theory, Effect of sample size on Control charts for variable (X-Bar and R or S) and attributes (p, np, c, u, CUSUM etc), determining the control limits and plotting the data; interpretation of charts, Gauge R & R analysis, identification of out-of-statistical control situations, trends and control mechanisms, Process capability and related indices, Type I and Type II errors, Single, double, multiple and sequential sampling, developing operating characteristic curves, acceptance Sampling: Sampling Plans, the ABC and Mil Standards.

Stochastic Optimization **3 (3, 0)**

Approaches to optimization with uncertainty, stochastic optimization, and dynamic (multi-stage) stochastic optimization, two-stage and multistage stochastic programs, dynamic programming (Markov decision process) approach, finite and infinite horizon problems, deterministic DP approximation method for large-scale problems. Usage of computational techniques and applications.

Stochastic Processes **3 (3, 0)**

Review of probability theory, expected value, Moment and probability generating functions, characteristic functions, Laplace transform, Conditional expectations, Exponential distribution, hazard rate function, Probability related inequalities; limit theorems, random variables and random processes, Poisson process: Inter-arrival and waiting time distributions, conditional distribution of arrival times, non-homogeneous and compound Poisson processes, Renewal Theory, branching processes, Stationary and non-stationary processes, random walk, discrete and continuous time Markov chains, Chapman-Kolmogorov equations, Brownian motion, Martingales.

Supply Chain Management **3 (3, 0)**

The era of Physical Distribution Management, the Concept of Supply Chain, Channels Strategy and Alliances, the Changing Business Environment,

Customer Focus in the Supply Chain, Achieving Customer Satisfaction Objectives, Transportation Choices in the Supply Chain, Inventory Management in the Supply Chain, Supply Chain Communications, International Supply Chain Management. Issues and Implications, Information for Supply Chain Management.

Supplier Relationship Management **3(3, 0)**

Levels of supplier relationship; Lifecycle; Stakeholder identification; Sourcing and selecting suppliers; Detailed response assessment; Non-disclosure agreements; Service Level; Defining key performance indicators and deliverables; Contract types and duration; Contract placement and termination; Negotiation, litigation; Limitations of liability; Influencing suppliers; Handling conflict; Potential closure situations - end of contract, premature termination; Risk assessment for exit stage.

Special Topic **3 (3, 0)**

Any relevant subject can be offered depending upon the available expertise and local needs.

Tool Design **3 (3, 0)**

Tool design objectives and nomenclature, Tool Materials, Work holding principles, Jig Design, Fixture Design, Tool Design for Inspection and Gauging, Forming and Drawing Tools, Tool Design for Joining Processes, Computers in Tool Design.

Total Quality Management **3 (3, 0)**

The concepts and principles of quality management, the quality management leading companies in the implementation of total quality management, techniques philosophies of modern quality leaders, the strategies used by some of the for process management, introduction and application of tools.

Warehouse Management and Distribution Network **3 (3, 0)**

Warehousing and Physical Distribution; Location of Function on the Organization Chart; Need for Warehousing and Physical Distribution; Inventory as Working Capital; Stockholding costs and its Influences; Functions of Warehousing; Storage of Materials, FIFO / LIFO-Layout-Identification-Bar-coding; Maintaining Inventory Accuracy, Stocktaking-Cycle Counting-Technology; Warehouse Safety; Measuring Effectiveness and Efficiency

RECOMMENDATIONS

1. The Universities are encouraged to adopt the OBE at their earliest.
2. In view of the latest developments and alignments in the region, the universities are encouraged to include teaching of appropriate languages thereby enhancing placement opportunities for their graduates.
3. University-Industry Linkage:
    a. At least four Industrial visits in a year should be organized and properly monitored by the University.
    b. Lectures/seminars from the industry should be organized
    c. Industrial Internships are very important part of the students' education. It should preferably start after second year examinations followed by a proper feedback mechanism from the Industry.
    d. Final year projects should be Industry-Based and of Practical Nature (Real Life Problem) to the extent possible and each group should comprise up to four students.
    e. Industry representation should be ensured in the project viva-voce.

4. To strengthen the communications skills of the engineering graduates, regular presentations including seminars by the students should be arranged.
5. All non-engineering courses should be linked and taught from the engineering perspective. Rote learning should be discouraged.
6. Islamic Studies: How to inculcate Islamic Values in Daily Life / Engineering Profession.
7. Pakistan Studies: Emphasis on where Pakistan Stands in terms of international benchmarks compared to other countries of the region.
8. The focus of the English courses should be on enhancing the presentation skills of students and preparing them for interviews and tests/ exams like ToEFL, IELTS, GRE, ESOL etc.

ANNEXURE - D

Note: One course will be selected from the following six courses of Mathematics.

COMPULSORY MATHEMATICS COURSES FOR BS (4 YEAR) *(FOR STUDENTS NOT MAJORING IN MATHEMATICS)*

1. MATHEMATICS I (ALGEBRA)

Prerequisite(s): Mathematics at secondary level
Credit Hours: 3 + 0

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions. *Matrices:* Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer's rule.

Quadratic Equations: Solution of quadratic equations, qualitative analysis of roots of a quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations.

Sequences and Series: Arithmetic progression, geometric progression, harmonic progression. *Binomial Theorem:* Introduction to mathematical induction, binomial theorem with rational and irrational indices. *Trigonometry:* Fundamentals of trigonometry, trigonometric identities.

Recommended Books

1. Dolciani MP, Wooton W, Beckenback EF, Sharron S, *Algebra 2 and Trigonometry*, 1978, Houghton & Mifflin, Boston (suggested text)
2. Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston
3. Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, PWS-Kent Company, Boston

2. MATHEMATICS II (CALCULUS)

Prerequisite(s): Mathematics I (Algebra)
Credit Hours: 3 + 0

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline

Preliminaries: Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities. *Limits and Continuity:* Limit of a function, left-hand and right-hand limits, continuity, continuous functions.

Derivatives and their Applications: Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives.

Integration and Definite Integrals: Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

Recommended Books

1. Anton H, Bevens I, Davis S, *Calculus: A New Horizon* (8th edition), 2005, John Wiley, New York
2. Stewart J, *Calculus* (3rd edition), 1995, Brooks/Cole (suggested text)
3. Swokowski EW, *Calculus and Analytic Geometry*, 1983, PWS-Kent Company, Boston
4. Thomas GB, Finney AR, *Calculus* (11th edition), 2005, Addison-Wesley, Reading, Ma, USA

3. MATHEMATICS III (GEOMETRY)

Prerequisite(s): Mathematics II (Calculus)
Credit Hours: 3 + 0

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of geometry to apply the concepts and the techniques in their respective disciplines.

Course Outline

Geometry in Two Dimensions: Cartesian-coördinate mesh, slope of a line, equation of a line, parallel and perpendicular lines, various forms of equation of a line, intersection of two lines, angle between two lines, distance between two points, distance between a point and a line.

Circle: Equation of a circle, circles determined by various conditions, intersection of lines and circles, locus of a point in various conditions.

Conic Sections: Parabola, ellipse, hyperbola, the general-second-degree equation

Recommended Books

1. Abraham S, Analytic Geometry, Scott, Freshman and Company, 1969

2. Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston
3. Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, PWS-Kent Company, Boston

4. COURSE FOR NON-MATHEMATICS MAJORS IN SOCIAL SCIENCES

Title of subject:		MATHEMATICS
Discipline	:	BS (Social Sciences).
Pre-requisites	:	SSC (Metric) level Mathematics
Credit Hours	:	03 + 00
Minimum Contact Hours:		40
Assessment	:	written examination;
Effective	:	2008 and onward

Aims : To give the basic knowledge of Mathematics and prepare the students not majoring in mathematics.

Objectives : After completion of this course the student should be able to:

- Understand the use of the essential tools of basic mathematics;
- Apply the concepts and the techniques in their respective disciplines;
- Model the effects non-isothermal problems through different domains;

Contents :

1. *Algebra*

Preliminaries: Real and complex numbers, Introduction to sets, set operations, functions, types of functions. *Matrices:* Introduction to matrices, types of matrices, inverse of matrices, determinants, system of linear equations, Cramer's rule. *Quadratic equations:* Solution of quadratic equations, nature of roots of quadratic equations, equations reducible to quadratic equations. *Sequence and Series:* Arithmetic, geometric and harmonic progressions. *Permutation and combinations*: Introduction to permutation and combinations, *Binomial Theorem:* Introduction to binomial theorem. *Trigonometry:* Fundamentals of trigonometry, trigonometric identities. *Graphs:* Graph of straight line, circle and trigonometric functions.

2. *Statistics*

Introduction: Meaning and definition of statistics, relationship of statistics with social science, characteristics of statistics, limitations of statistics and main division of statistics. *Frequency distribution*: Organisation of data, array, ungrouped and grouped data, types of frequency series, individual, discrete and continuous series, tally sheet method, graphic presentation of the frequency distribution, bar frequency diagram histogram, frequency polygon, cumulative frequency curve. *Measures of central tendency*: Mean medium and modes, quartiles, deciles and percentiles. *Measures of dispersion*: Range, inter quartile deviation mean deviation, standard deviation, variance, moments, skewness and kurtosis.

Recommended Books

1. Swokowski. E. W., '*Fundamentals of Algebra and Trigonometry*', Latest Edition.
2. Kaufmann. J. E., '*College Algebra and Trigonometry*', PWS-Kent Company, Boston, Latest Edition.
3. Walpole, R. E., '*Introduction of Statistics*', Prentice Hall, Latest Edition.
4. Wilcox, R. R., '*Statistics for The Social Sciences'*,

5. MATHEMATICS FOR CHEMISTRY

Credit Hours: 3

Prerequisites: Mathematics at Secondary level

Specific Objectives of Course:

To prepare the students not majoring in mathematics with the essential tools of Calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline

Preliminaries: Real Numbers and the Real Line, *Functions and their graphs*: Polynomial Functions, Rational Functions, Trigonometric Functions, and Transcendental Functions. Slope of a Line, Equation of a Line, Solution of equations involving absolute values, Inequalities. *Limits and Continuity:* Limit of a Function, Left Hand and Right Hand Limits, Continuity, Continuous Functions. *Derivatives and its Applications:* Differentiation of Polynomial, Rational and Transcendental Functions, Extreme Values of Functions. *Integration and Indefinite Integrals:* Integration by Substitution, Integration by Parts, Change of Variables in Indefinite Integrals. Least-Squares Line.

Recommended Books

1. Thomas, Calculus, 11th Edition. Addison Wesley publishing company, 2005.
2. H. Anton, I. Bevens, S. Davis, Calculus, 8th edition, John Willey & Sons, Inc. 2005.
3. Hughes-Hallett, Gleason, McCallum, et al, Calculus Single and Multivariable, 3rd Edition. John Wiley & Sons, Inc. 2002.
4. Frank A. Jr, Elliott Mendelsohn, Calculus, Schaum's Outline Series, 4th edition, 1999.
5. E. W. Swokowski, Calculus and Analytic Geometry PWS Publishers, Boston, 1983.
6. John H. Mathews, Numerical Methods for Mathematics Science and Engineering, Prentice-Hall, Second Edition 1992.

6. MATHEMATICS FOR PHYSICS

Contents

1. **Preliminary calculus.**

- Differentiation
  Differentiation from first principles; products; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz' theorem; special points of a function; theorems of differentiation.
- Integration
  Integration from first principles; the inverse of differentiation; integration by inspection; sinusoidal function; logarithmic integration; integration using partial fractions; substitution method; integration by parts; reduction formulae; infinite and improper integrals; plane polar coordinates; integral inequalities; applications of integration.

2. Complex numbers and hyperbolic functions

- The need for complex numbers
- Manipulation of complex numbers
  Additions and subtraction; modulus and argument; multiplication; complex conjugate; division
- Polar representation of complex numbers Multiplication and division in polar form
- de Moivre's theorem
  Trigonometrical identities; finding the nth roots of unity; solving polynomial equations
- Complex logarithms and complex powers

- Applications to differentiation and integration
- Hyperbolic functions
  Definitions; hyperbolic-trigonometric analogies; identities of hyperbolic functions; solving hyperbolic equations; inverses of hyperbolic functions; calculus of hyperbolic functions

3. Series and limits

- Series
- Summation of series
  Arithmetic series; geometric series; arithmetico-geometric series; the difference method; series involving natural numbers; transformation of series
- Convergence of infinite series
  Absolute and conditional convergence; convergence of a series containing only real positive terms; alternating series test
- Operations with series
- Power series
  Convergence of power series; operations with power series
- Taylor series
  Taylor's theorem; approximation errors in Taylor series; standard McLaurin series
- Evaluation of limits

4. Partial differentiation

- Definition of the partial derivative
- The total differential and total derivative
- Exact and inexact differentials
- Useful theorems of partial differentiation
- The chain rule
- Change of variables
- Taylor's theorem for many-variable functions
- Stationary values of many-variable functions
- Stationary values under constraints

5. Multiple integrals

- Double integrals
- Triple integrals
- Applications of multiple integrals
  Areas and volumes; masses, centers of mass and centroids; Pappus' theorems; moments of inertia; mean values of functions

- Change of variables in multiple integrals
  Change of variables in double integrals;

6. Vector algebra

- Scalars and vectors
- Addition and subtraction of vectors
- Multiplication by a scalar
- Basis vectors and components
- Magnitude of a vectors
- Multiplication of vectors
  Scalar product; vector product; scalar triple product; vector triple product
- Equations of lines and planes
  Equation of a line; equation of a plane
- Using vectors to find distances
  Point to line; point to plane; line to line; line to plane
- Reciprocal vectors

7. Matrices and vector spaces

- Vectors spaces Basic vectors; the inner product; some useful inequalities
- Matrices
- The complex and Hermitian conjugates of a matrix
- The determinant of a matrix
  Properties of determinants
- The inverse of a matrix
- The rank of a matrix
- Simultaneous linear equations
  N simultaneous linear equations in N unknowns
- Special square matrices
  Diagonal; symmetric and antisymmetric; orthogonal; Hermitian; unitary normal
- Eigen vectors and eigen values
  Of a normal matrix; of Hermitian and anti-Hermitian matrices; of a unitary matrix; of a general square matrix
- Determination of eigen values and eigen vectors Degenerate eigen values

8. Vector calculus

- Differentiation of vectors Composite vector expressions; differential of a vector

- Integration of vectors
- Space curves
- Vector functions of several arguments
- Surfaces
- Scalar and vector fields
- Vector operators
- Gradient of a scalar field; divergence of a vector field; curl of a vector field
- Vector operator formulae
- Vector operators acting on sums and products; combinations of grad, div and curl
- Cylindrical and spherical polar coordinates
- Cylindrical polar coordinates; spherical polar coordinates.

ANNEXURE - E

Statistics-I **Credit 3 (2-1)**

Definition and importance of Statistics in Agriculture, Data Different types of data and variables

Classification and Tabulation of data, Frequency distribution, stem-and-Leaf diagram, Graphical representation of data Histogram, frequency polygon, frequency curve.

Measure of Central tendency, Definition and calculation of Arithmetic mean, Geometric mean, Harmonic mean, Median quantiles and Mode in grouped and un-grouped data.

Measure of Dispersion, Definition and Calculation of Range, quartile deviation, Mean deviation, Standard deviation and variance, coefficient of variation.

Practical

a. Frequency Distribution
b. Stem-and-Leaf diagram
c. Various types of Graphs
d. Mean, Geometric mean Harmonic Mean,
e. Median, Quartiles Deviation, mean Deviation.
f. Standard Deviation, Variance, Coefficient of variation,
g. Skewness and kenosis

Recommended Books

1. Introduction to Statistical Theory Part- I by Sher Muhammad and Dr. Shahid Kamal (Latest Edition)
2. Statistical Methods and Data Analysis by Dr. Faquir Muhammad
3. A. Concise Course in A. Level Statistic with world examples by J. Crashaw and J. Chambers (1994)
4. Basic Statistics an Inferential Approach 2nd Ed. (1986) Fran II. Dietrich-II and Thomas J. Keans

Statistics-II **Credit 3 (2-1)**

Sampling Probability and non-Probability Sampling, Simple random sampling stratified random sampling Systematic sampling error, Sampling distribution of mean and difference between two means. Interference

Theory: Estimation and testing of hypothesis, Type—I and type-II error, Testing of hypothesis about mean and difference between two means using Z-test and t-test, Paired t-test, Test of association of attributes using X2 (chi-square) Testing hypothesis about variance.

Practical

a. Sampling random sampling
b. Stratified random sampling.
c. Sampling distribution of mean
d. Testing of hypotheses regarding population mean
e. Testing of hypotheses about the difference between population means
f. Chi-square test
g. Testing of Correlation Coefficient
h. Fitting of simple linear regression
i. One-way ANOVA
j. Two-way ANOVA

Recommended Books

1. Introduction to Statistical Theory Part-II by Sher Muhammad and Dr. Shahid Kamal (Latest Edition)
2. Statistical Methods and Data Analysis by Dr. Faquir Muhammad
3. Principles and Procedures of Statistics A Bio-material approach, 2nd Edition, 1980 by R. G. D Steal and James H. Tarric
4. Statistical Procedures for Agricultural Research 2nd Edition (1980) by K. A. Gomez and A. A. Gomez

ANNEXURE - F

Introduction to Information and Communication Technologies

Course Structure:	Lectures: 2 Labs: 1	**Credit Hours:** 3
Pre-requisite:	**None**	**Semester: 1**

Course Description

This is an introductory course on Information and Communication Technologies. Topics include ICT terminologies, hardware and software components, the internet and World Wide Web, and ICT based applications.

After completing this course, a student will be able to:

- Understand different terms associated with ICT
- Identify various components of a computer system
- Identify the various categories of software and their usage
- Define the basic terms associated with communications and networking
- Understand different terms associated with the Internet and World Wide Web.
- Use various web tools including Web Browsers, E-mail clients and search utilities.
- Use text processing, spreadsheets and presentation tools
- Understand the enabling/pervasive features of ICT

Course Contents

Basic Definitions & Concepts
Hardware: Computer Systems & Components
Storage Devices, Number Systems
Software: Operating Systems, Programming and Application Software
Introduction to Programming, Databases and Information Systems
Networks
Data Communication
The Internet, Browsers and Search Engines
The Internet: Email, Collaborative Computing and Social Networking
The Internet: E-Commerce
IT Security and other issues
Project Week
Review Week

Text Books/Reference Books

1. Introduction to Computers by Peter Norton, 6th International Edition, McGraw-Hill
2. Using Information Technology: A Practical Introduction to Computer & Communications by Williams Sawyer, 6th Edition, McGraw-Hill
3. Computers, Communications & information: A user's introduction by Sarah E. Hutchinson, Stacey C. Swayer
4. Fundamentals of Information Technology by Alexis Leon, Mathews Leon, Leon Press.