CURRICULUM

OF

MECHATRONICS ENGINEERING
MS/MSc/ME

(Revised 2016)

HIGHER EDUCATION COMMISSION
ISLAMABAD

CURRICULUM DIVISION, HEC

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Mr. Abid Wahab	Assistant Director (Curr)
Mr. Riaz-ul-Haque	Assistant Director (Curr)

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PREFACE

The curriculum, with varying definitions, is a plan of the teaching-learning process that students of an academic programme are required to undergo. It includes objectives and learning outcomes, course contents, scheme of studies, teaching methodologies and methods of assessment of learning. Knowledge in all academic disciplines is expanding and even new disciplines are also emerging, it is imperative that curriculum are developed and revised regularly.

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).

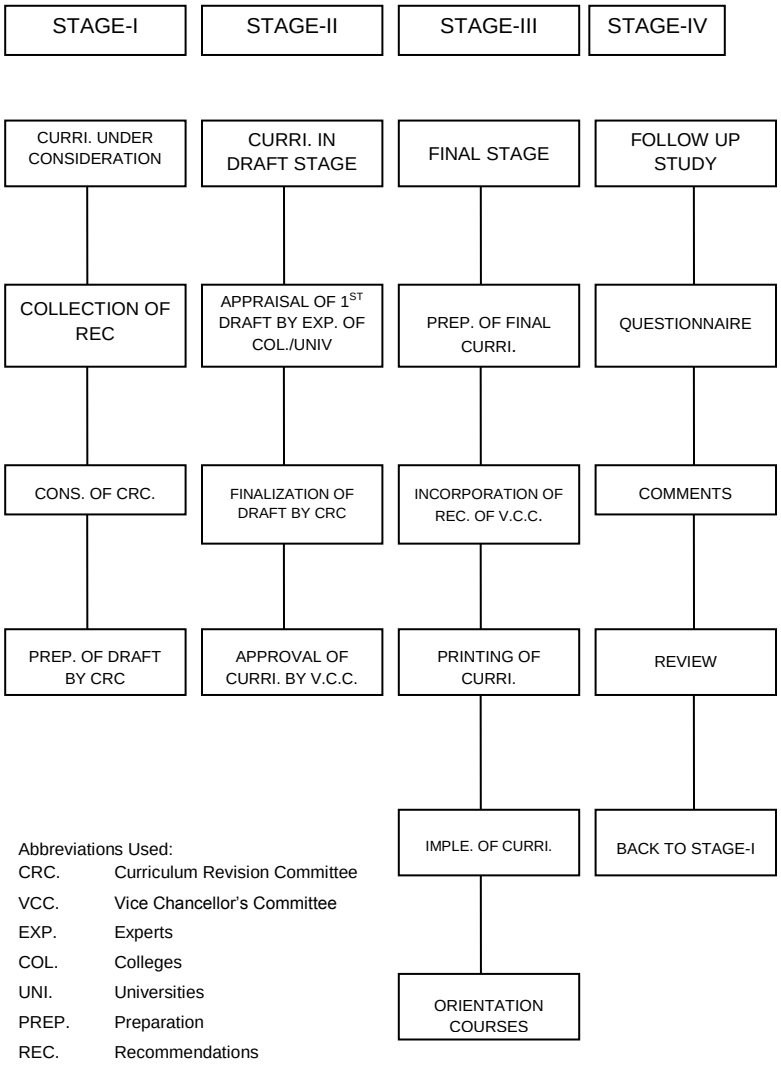
In compliance with the provisions, the Curriculum Division of HEC undertakes the revision of curricula after every three years through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities,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

In order to impart education at par with quality international standards, HEC NCRCs have developed unified templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering in 2007 and 2009.

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 (www.hec.gov.pk).

(Fida Hussain)
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

Abbreviations Used

NCRC.	National Curriculum Revision Committee
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INTRODUCTION

The Preliminary meeting of National Curriculum Revision Committee (NCRC) in the discipline of Mechatronics Engineering was held from October 19-21, 2015 at LEJ Centre, University of Karachi, under aegis of Higher Education Commission. The objective of meeting was to revise and prepare preliminary draft curriculum for BS/BE/BSc & MS/ME/MSc levels of Mechatronics Engineering. The following members attended the meeting:-

Sr.	Name & Address	Status
1.	Dr. Akhtar Nawaz Malik, Director, Foundation University, Rawalpindi Campus.	**Member/Convener**
2.	Dr. Kunwar Faraz Ahmad Khan, HoD, Department of Mechatronics Engineering, NUST College of E & ME, Peshawar Road, Rawalpindi.	**Member/Secretary**
3.	Dr. Zareena Kausar, HoD, Department of Mechatronic Engineering, Air University B-Block Ground Floor Sector E-9, Islamabad.	**Member**
4.	Mr. Syed Riaz Akbar Shah, Professor, Department of Mechatronic Engineering, University of Engineering & Technology, B-5 Phase V, Hayatabad, University Campus, Peshawar.	**Member**
5.	Dr. Jawaid Daudpoto, Professor, Department of Mechanical Engineering, Mehran University of Engineering & Technology, Jamshoro.	**Member**
6.	DR. Faraz Junejo, HoD, Department of Mechatronics, Shaheed Zulfiqar Ali Bhutto Institute of Science & Technology, 90 & 100 Clifton, Karachi.	**Member**

7.	Dr. Ahmad Hussain, Chairman / Professor, Department of Mechanical Engineering, Nazeer Hussain University, ST-2, Block # 4, Federal B Area, Karachi.	**Member**
8.	Dr. Nasimullah, Associate Professor, Electrical Engineering. City University of Science & Information Technology, Dalazak Road, Peshawar.	**Member**
9.	Dr. Sarvat Mushtaq Ahmad, Associate Professor /Dean, Faculty of Mechanical Engineering, GIK Institute of Engineering Science & Technology, Room # G03, FME, GIKI, Topi, Distt, Swabi. KPK.	**Member**
10.	Mr. Hashim Raza Senior Director, Nuclear Equipment Workshop-2, Pakistan Atomic Energy Commission, Plot # 3 & 4, Sector 22, Korangi Industrial Area, Karachi.	**Member**
11.	Dr. Abdur Rehman Abbassi, Head (MS Program), KINPOE (Affiliated with PIEAS) Karachi.	**Member**
12.	Dr. Aamir Hassan, Group Captain / Director, Design Management Office, Pakistan Aeronautical Complex, PAC Board, Kamran Kalan, District Attock.	**Member**
13.	Dr. Muzaffar Mehmood, Associate Professor, PAF-Karachi Institute of Economics & Technology, Main Campus, Korangi Creek, Karachi 75190.	**Member**
14.	Dr. Amir Sultan, Chairman, Department of Mechatronics Engineering, Chakwal campus, University of Engineering and Technology, Taxila.	**Member**

15.	Dr. Ali Raza, Assistant Professor, Department of Mechatronics & Control Engineering, University of Engineering & Technology, Lahore.	**Member**
16.	Dr. Bilal Ahmed Siddiqui, Assistant Professor, Department of Mechanical Engineering, DHA Suffa University, DG-78, Off Khayaban-e-Tufail, Phase VII (EXT), DHA, Karachi.	**Member**
17.	Dr. Syed Naqvi, Dean , Faculty of Computer Science, Institute of Business and Technology, Main Ibrahim Hydri Road, Korangi creek, Karachi.	**Member**

The meeting started with recitation of Verses from the Holy Quran by Mr. Riaz-ul-Haque, Assistant Director (Curriculum), HEC. Mr. Riaz-ul-Haque welcomed the participants on the behalf of HEC and thanked them for their participation in this important exercise.

The house unanimously selected Dr. Akhtar Nawaz Malik, Director, Foundation University, Rawalpindi as **Convener** and Dr. Kunwar Faraz Ahmad Khan, HoD, Department of Mechatronics Engineering, NUST College of Electrical & Mechanical Engineering, Rawalpindi as **Secretary** of the meeting. Mr. Haque then requested the respectable Convener & Secretary to convene proceedings of all technical sessions of the meeting for three days. The Convener thanked the participants for his selection and started proceedings of the meeting in accordance with the agenda.

Day 1

The convener emphasized the need for periodic revision of curriculum in view of the fact that new techniques and methodologies are evolving the world over at a fast pace. Since the initial Curriculum for BSc/BS/BE/MS Mechatronics was developed in 2011, the goal of this meeting was to finalize that draft curriculum with consensus. The meeting started with identifying the weakness observed by industrial reps in mechatronics graduates when they step into practical life and the means addressing this weakness through an improved design of curriculum. Another point of emphasis was the integration and interlinking of courses in the mechanical, electrical, computing domain to form a cohesive curriculum and plan of study, instead of simply grouping together a few courses from each domain. In order to realize this concept, four groups were formed to look into the four major domains of subjects, i.e., Mechanical, Electronics,

Mechatronics and Basic Sciences/Humanities. The groups were asked to analyze and revise the contents of courses in their domain with special emphasis to identify duplication in content with different subjects, propose integration measures and present their conclusions on the next day. Subsequently, all courses in the curriculum were discussed individually and an initial draft of the revised curriculum was formulated.

Day 2

On the day 2, the changes in the curriculum proposed in Day 1 were analyzed in detail and an exhaustive debate was carried out with input from the 4 groups regarding the courses within their domains. This resulted in the collective finalization of the course contents, allocation of credit hours, selection of text books, and elective courses. The elective courses were also discussed and it was proposed that in order to enable the formulations of streams at the undergraduate level the number of elective courses should be increased, which should be offered in the 3rd and 4th year. New courses were also proposed to be included as part of the core curriculum. The committee also focused on improving the social sciences domain of the curriculum and proposed an additional social science elective in the curriculum. At the end of the day, the BSc/BS/BE Mechatronics Curriculum was prepared and finalized for review of all members.

Day 3

On the final day of the meeting the Final Draft of the curriculum for the Mechatronics Engineering was compiled and finalized gathering all the recommendations. The course content was also thoroughly discussed with a view to eliminate duplication with the course. After three days of rigorous deliberations, the committee unanimously proposed the outlines of draft curriculum of Mechatronics Engineering for undergraduate & graduate engineers, which will be considered in the final meeting of NCRC scheduled within three months' time.

The Committee, during the proceedings of the meeting, agreed that the draft curriculum will be sent to all members of the Committee, and if possible to expatriate Pakistani Mechatronics Engineers living abroad for further critical analysis and to submit their critical evaluation, suggestions, and recommendations, within **one month** to the Convener/ Secretary for onward submission to HEC.

Ms. Ghayur Fatima, Director Curriculum, HEC who joined the session latterly thanked the Convener and all the members of the committee for their high quality contribution towards preparation of the preliminary draft curriculum in the discipline of Mechatronics Engineering. The committee appreciated the efforts made by Mr. Riaz-ul-Haque & Ms. Ghayur Fatima for their coordination and guidance during the whole sessions and lauded the local hospitality provided by LEJ center.

The committee also proposed a couple of initiative to strengthen Mechatronics Engineering activity in Pakistan. This includes formation of Society of Mechatronics Engineers of Pakistan (SMEP) and a call for 1st Mechatronics Systems Engineering Conference (MSEC) Pakistan in summer 2017. In addition in was recommended that a few subjects for example Environment, Health and Safety should be covered through seminars/workshop instead of including them as part of the curriculum. All universities are requested to take steps for holding such seminars.
The meeting ended with vote of thanks to and from the chair.

The final meeting of National Curriculum Revision Committee (NCRC) in the discipline of Mechatronics Engineering was held from March 7-9, 2016 at LEJ Centre, University of Karachi, to finalize the Curriculum for BSc/BS/BE Mechatronics Engineering. The following members attended the meeting:-

Sr.	Name & Address	Status
1.	Dr. Akhtar Nawaz Malik, Director, Foundation University, Rawalpindi Campus.	**Member/Convener**
2.	Brig. Dr. Javaid Iqbal, Dean, Department of Mechatronics Engineering, NUST College of E & ME, Peshawar Road, Rawalpindi.	**Member/Secretary**
3.	Dr. Zareena Kausar, HoD, Department of Mechatronic Engineering, Air University B-Block Ground Floor Sector E-9, Islamabad.	**Member**
4.	Dr. Jawaid Daudpoto, Professor, Department of Mechanical Engineering, Mehran University of Engineering & Technology, Jamshoro.	**Member**
5.	DR. Faraz Junejo, HoD, Department of Mechatronics, Shaheed Zulfiqar Ali Bhutto Institute of Science & Technology, 90 & 100 Clifton, Karachi.	**Member**
6.	Dr. Ahmad Hussain, Chairman / Professor, Department of Mechanical Engineering,	**Member**

	Nazeer Hussain University, ST-2, Block # 4, Federal B Area, Karachi.	
7.	Engg. Dr. Nasimullah, Associate Professor, Electrical Engineering. City University of Science & Information Technology, Dalazak Road, Peshawar.	**Member**
8.	Dr. Sarvat Mushtaq Ahmad, Associate Professor /Dean, Faculty of Mechanical Engineering, GIK Institute of Engineering Science & Technology, Room # G03, FME, GIKI, Topi, Distt, Swabi. KPK.	**Member**
9.	Mr. Abid Chohan Director Production, Nuclear Equipment Workshop-2, Pakistan Atomic Energy Commission, Plot # 3 & 4, Sector 22, Korangi Industrial Area, Karachi.	**Member**
10.	Dr. Abdul Rehman Abbasi Head (MS Program), KINPOE (Affiliated with PIEAS) Karachi	**Member**
11.	Dr. Muzaffar Mehmood, Dean, PAF-Karachi Institute of Economics & Technology, Main Campus, Korangi Creek, Karachi 75190.	**Member**
12.	Dr. Adeel Mehmood, Assistant Professor, Department of Electrical Engineering, COMSATS Institute of Information Technology Islamabad.	**Member**
13.	Mr. Bilal Ahmed Siddiqui, Assistant Professor, Department of Mechanical Engineering, DHA Suffa University, DG-78, Off Khayaban-e-Tufail, Phase VII (EXT), DHA, Karachi.	**Member**

14.	Dr. Amir Sultan, Chairman, Department of Mechatronics Engineering, Chakwal campus, University of Engineering and Technology, Taxila.	**Member**
15.	Dr. Syed Naqvi, Dean , Faculty of Computer Science, Institute of Business and Technology, Main Ibrahim Hydri Road, Korangi creek, Karachi .	**Member**
16.	Ms. Ghayyur Fatima, Director Academics Division, Higher Education Commission, Is lamabad	

Day 1

The meeting started with recitation of Verses from the Holy Quran by Dr. Sarvat Mushtaq Ahmad. Ms. Ghayyur Fatima, Director Academics Division, HEC welcomed the participants on the behalf of HEC and thanked them for their participation in this important exercise.

In the absence of Dr. Akhtar Nawaz Malik (Convener) due to flight delay, the house unanimously selected Brig. Dr. Javaid Iqbal, Dean, Department of Mechatronics Engineering, NUST College of E & ME, Peshawar Road, Rawalpindi as **Acting Convener** and Dr. Sarvat Mushtaq Ahmad,Dean, Faculty of Mechanical Engineering, GIK Institute of Engineering Science & Technology, Topi, Distt, Swabi as **Acting Secretary** of the meeting. Ms. Ghayyur Fatima then requested the respectable Convener & Secretary to convene proceedings of technical sessions. The Acting Convener thanked the participants for his selection and started proceedings of the meeting in accordance with the agenda.

Since the initial draft of the Curriculum for BSc/BS/BE Mechatronics was developed in an earlier meeting held between 19 -21 October 2015, the goal of this meeting was to finalize that draft curriculum with consensus. In this meeting, two groups were formed to look into the two major streams of Mechatronics, i.e., Mechanical and Electronics. The course contents developed by these groups were jointly discussed and unanimously approved. Furthermore, following additions were made to existing curricula for improvements.

- For clarity and uniformity FYP- HEC Course outline is written while taking into account Capston and NUST-FYP guidelines.

- Health and Safety education to be made mandatory through 1-2 days seminar/workshop for faculty, staff and students, preferably prior to commencement of BE studies.
- For complete coverage of PLOs, a Community Service Course (1-1) to be made mandatory. This course will consist of Seminars and field work. Field work can be carried out, such as working in Orphan House, old homes, Govt. School etc. This course will not contribute towards CGPA; however result (Satisfactory) will appear on transcript.

Day 2

Dr. Akhtar Nawaz Malik (Convener) chaired the meeting on second day; an exhaustive debate was carried out collectively resulting in the finalization of the course contents, allocation of credit hours, selection of text books, and elective courses. At the end of the day, the final draft of the BSc/BS/BE Mechatronics Curriculum was prepared approved.

Day 3

On third day; objective of the meeting was to finalize MS/MEng Mechatronics curricula. In this regard, a lengthy discussion was carried out, which resulted in the finalization of: different specializations, group of core and elective courses and selection of text books for MS/Meng Mechatronics Program. Furthermore, in continuation from last meeting, it was proposed to establish “Mechatronics Engineering Society Pakistan (MESP)” for promoting Mechatronics discipline in Pakistan. This society will aim to organize annual international conferences through collaboration of different Engineering Universities in Pakistan.

Ms. Ghayyur Fatima, Director Academics Division, HEC appreciated the Convener, Secretary and the members of the Committee for sparing their time for this noble cause.

The Meeting ended with the vote of thanks to the HEC, Convener, Secretary and members of National Curriculum Revision Committee.

2-4 Years MS PROGRAMME
6-8 Years PhD PROGRAMME

INTRODUCTION PG PROGRAM

Mechatronics refers to a flexible, multi-technological approach for integration of mechanical engineering, computer engineering, electronics and information sciences. Mechatronics is essential in the design of intelligent products. It allows engineers to transform their virtual concepts into real life applications. It is a relatively new concept relating to the design of systems, devices and products aimed at achieving an optimal balance between basic mechanical structure and its overall control. The programme involves research and coursework that will push the frontiers of technology in intelligent product design and development. The research activities involve design and control of intelligent robotic systems and automated machines. Modern state-of-the-art industries have changed rapidly from pure mechanical-, manufacturing-, and process-controlled type to electro-mechanical, fully automated and computerized. It has become the requirement for people working on those processes and production lines to have knowledge of all the related systems.

Considering the need of the time most of the state of the art industries in the world have changed from pure mechanical, manufacturing or process controlled to the ones where the processes are more of electromechanical, fully automated and mostly controlled by computers. To achieve the quality products even the most simple production lines and production processes in the industries have a blend of computers in them. It has become the requirement for people working on such processes and production lines to have knowledge of all the related systems. Graduates should have a strong command on engineering principles as well as a sound capability of converting concepts to reality. They could find themselves in industry engaged with maintenance and operation of plant equipment such as boilers, compressors, turbines, instrumentation, automation and control of advanced industrial processes using such tools as PLC and microcontroller-based control systems, process simulation for plant modifications, defense and R&D applications, engineering management, or a variety of similar areas.

PROGRAM OBJECTIVES

The main objectives of Masters in Mechatronics Engineering programme are as below:-

- Enables the students to pursue a rigorous post doctorate / research programme in Mechatronics Engineering.
- Improve the marketability of our students in the local industry, public sector and R & D organizations.

- Provide technical confidence and financial guidance needed to start a small-scale industry to graduates interested in self-employment.

MECHATRONICS PROGRAMME – EDUCATIONAL OBJECTIVES

The broad objectives of the Postgraduate program in Mechatronics Engineering are to instill in its students a solid foundation of mathematical, scientific and engineering knowledge in addition to developing the intellectual skills essential for prosperity and success in their careers. The program is structured in such a manner that the students are provided a firm theoretical foundation with opportunity to strengthen their knowledge through research assignments, practical training and projects. graduates from the programme should:

- Be effective, innovative and research oriented mechatronics engineers having strong quantitative and analytical skills.
- Be practically sound and able to use engineering tools to enhance their productivity.
- Be able to design, analyze, and solve complex problems and develop effective processes that encapsulate multi domain technologies.
- Be effective leaders with high morals and professional ethics.

PROGRAM LEARNING OUTCOMES

Program Learning Outcomes should demonstrate that our graduates have the following abilities:

- **Engineering Knowledge**: Apply multidisciplinary engineering knowledge to formulate and solve real world problems.
- **Problem Analysis:** Identify and formulate solutions to complex problems by performing extensive research and application of concepts gained throughout the program.
- **Design/Development of Solutions:** Design processes, components and solutions by keeping in view the requirements of the society and environment.
- **Investigation:** Investigate specific engineering problems, analyze and interpret the resultant data by tools learnt during the coursework and synthesize the data to come to a meaningful conclusion.
- **Modern Tool Usage:** Handle and use state of the art equipment to experimentally validate the theoretical concepts.
- **Engineer and the Society:** Asses societal problems and devise solutions.

- **Environment and Sustainability:** Become aware of the need for sustainable development and realize their role for making the environment livable.
- **Ethics:** Apply professional ethics to all engineering practices and recognize civic duties and engage in activities to accomplish them.
- **Individual and Teamwork:** Work on technically diverse team-based projects.
- **Communication:** Develop basic technical presentation skills, written and oral, to effectively express ideas and knowledge.
- **Project Management:** To make effective use of time, resources and skills during team-based projects, which involves integrating knowledge and technical skills from diverse subjects?
- **Research and Life Long Learning:** Obtain lifelong skills of analytical thinking, problem analysis and optimized solution formulation to contribute to uplifting and growth of the society at large and recognize the importance of continued learning

MS MECHATRONICS ENGINEERING PROGRAMME

Duration:	**2-4 years**
Number of semesters:	**4-8**
Number of weeks per semester:	**18 (16 for teaching and 2 for examinations)**
Total number of credit hours:	**30**
Number of credit hours per semester:	**6-12**
Core Courses (Maximum):	**9-12 Credit Hours**
Elective Courses (Maximum):	**12-15 Credit Hours**
Research Work	**6 Credits Hours**

MS in Mechatronics Engineering

Suggested Core Courses

The individual universities/institutions may include three to four core courses from the below given core courses and include the remaining courses as electives, keeping in view the demand vis-à-vis the available faculty and facilities.

S. No.	Course Code	Course Title	CHs
1	MTS- XXX	Advanced Robotics	03
2	MTS- XXX	Data Acquisition and Control	03
3	MTS- XXX	Image Processing for Intelligent Systems	03
4	MTS- XXX	Advanced Embedded Systems	03
5	MTS-XXX	Mobile Robotics: Methods and Algorithms	03
6	MTS-XXX	Mechatronic System Design	03
7	MTS-XXX	Embedded Control Systems	03
8	MTS-XXX	Linear Dynamic Systems	03
9	MTS-XXX	Linear Control Systems	03
10	MTS-XXX	Machine Learning	03
11	MTS-XXX	Artificial Intelligence	03
12	MTS-XXX	Smart Electrical Networks and Systems	03
13	MTS-XXX	Sensor and Sensing Technology	03
14	MTS-XXX	Stochastic Systems	03
15	MTS-XXX	Advanced Engineering Mathematics	03

Elective Courses

S. No.	Course Code	Course Title	CHs
1	MTS- XXX	Motion Planning for Mobile Robots	03
2	MTS- XXX	Advanced Manufacturing Design Techniques	03
3	MTS- XXX	Machine Vision	03
5	MTS- XXX	Precision Manufacturing Systems	03
6	MTS- XXX	Optimization of Engineering Systems	03
7	MTS- XXX	Micro-Manufacturing Systems and Technology	03
8	MTS- XXX	Industrial Control Technology	03
9	MTS- XXX	Fuzzy Control Systems	03
10	MTS- XXX	Optimal Control	03
11	MTS- XXX	Kinematics of Mobile Robotic Systems	03
12	MTS- XXX	Cognitive Robotics	03
13	MTS- XXX	Computational Geometry	03
14	MTS- XXX	Linear Control Systems	03
15	MTS- XXX	Advanced Measurement Techniques	03
16	MTS- XXX	Manufacturing System Design	03
17	MTS- XXX	Computer Integrated Manufacturing	03
18	MTS- XXX	Robust Control	03
19	MTS- XXX	Adaptive Control	03
20	MTS- XXX	Discrete Time Control Systems	03
21	MTS- XXX	Special Topics in Manufacturing Engineering	03
22	MTS- XXX	Advanced Manufacturing Technologies	03
23	MTS- XXX	Micro-Electro Mechanical Systems	03
24	MTS- XXX	Laser Material Processing	03
25	MTS- XXX	Rapid Prototyping, Tooling and Automation	03
26	MTS- XXX	Digital Control Systems	03
28	MTS- XXX	Filtering & Tracking	03
29	MTS- XXX	Paradigms of Artificial Intelligence	03
30	MTS- XXX	Advanced Modelling and Simulation	03
31	MTS- XXX	Real Time Systems	03
32	MTS- XXX	Programming of Embedded Systems	03
34	MTS- XXX	Artificial Neural Networks	03
35	MTS- XXX	Bio Medical Instrumentation	03

36	MTS- XXX	Optomechatronic Systems	03
37	MTS- XXX	Fuzzy Logic Hybrid Systems	03
38	MTS- XXX	Natural Language Processing	03
39	MTS- XXX	Smart Materials and Structures	03
40	MTS- XXX	Digital Integrated Circuit Design	03
41	MTS- XXX	Bio Medical Instrumentation	03
42	MTS- XXX	Biomedical Clinical Information Systems	03
43	MTS- XXX	Bio-Informatics Systems	03
44	MTS- XXX	Signals and Images in Medicine	03
45	MTS- XXX	Biomechanics	03
46	MTS- XXX	Prosthetics and Rehabilitation	03
47	MTS- XXX	Biosensors and instrumentation	03
48	MTS- XXX	Selected Topics in Biomedical Engineering	03
49	MTS- XXX	Medical Devices Design and Standards	03
50	MTS- XXX	Human Machine Interaction	03
51	MTS- XXX	Advance Bio Materials	03
52	MTS- XXX	Finite Element Methods	03
53	MTS- XXX	Introduction to Modelling and Analysis	03
54	MTS- XXX	Advanced Digital Signal Processing	03
55	MTS- XXX	Computational Modelling of Physiological Systems	03
56	MTS-XXX	Or any other relevant course (s)	03

Research Credits (MS)

MTS-XXX	Thesis Research	06

The recommended courses for M.Eng./M.Sc./M.E. programmes in Mechatronics Engineering with specialization in Robotics and Industrial Automation, Smart Electromechanical Systems and Biomechatronics are given below as an example. However, the individual universities/institutions may design their own specialization programmes keeping in view the demand vis-à-vis the available faculty and facilities.

1. MS in Mechatronics Engineering (Robotics and Industrial Automation)

a) Core Courses

Course Code	Course Title	CHs
MTS-XXX	Advanced Robotics	03
MTS-XXX	Data Acquisition and Control	03
MTS-XXX	Image Processing for Intelligent Systems	03
MTS-XXX	Advanced Embedded Systems	03

b) Elective Courses

Course Code	Course Title	CHs
MTS-XXX	Motion Planning for Mobile Robots	03
MTS-XXX	Advanced Manufacturing Design Techniques	03
MTS-XXX	Machine Vision	03
MTS-XXX	Machine Learning	03
MTS-XXX	Precision Manufacturing Systems	03
MTS-XXX	Optimization of Engineering Systems	03
MTS-XXX	Micro-Manufacturing Systems and Technology	03
MTS-XXX	Industrial Control Technology	03
MTS-XXX	Fuzzy Control Systems	03
MTS-XXX	Optimal Control	03
MTS-XXX	Kinematics of Mobile Robotic Systems	03
MTS-XXX	Cognitive Robotics	03
MTS-XXX	Computational Geometry	03
MTS-XXX	Linear Control Systems	03
MTS-XXX	Advanced Measurement Techniques	03
MTS-XXX	Manufacturing System Design	03
MTS-XXX	Computer Integrated Manufacturing	03
MTS-XXX	Robust Control	03
MTS-XXX	Adaptive Control	03
MTS-XXX	Discrete Time Control Systems	03
MTS-XXX	Special Topics in Manufacturing Engineering	03
MTS-XXX	Advanced Manufacturing Technologies	03
MTS-XXX	Micro-Electro Mechanical Systems	03
MTS-XXX	Laser Material Processing	03
MTS-XXX	Rapid Prototyping, Tooling and Automation	03
MTS-XXX	Digital Control Systems	03

MTS-XXX	Mobile Robotics	03
MTS-XXX	Filtering & Tracking	03

c) Research Credits (MS)

MTS-XXX	Thesis Research	06

2. MS in Mechatronics Engineering (Smart Electromechanical Systems)

a) Core Courses

Course Code	Course Title	CHs
MTS-XXX	Advanced Robotics	03
MTS-XXX	Data Acquisition and Control	03
MTS-XXX	Image Processing for Intelligent Systems	03
MTS-XXX	Advanced Embedded Systems	03

b) Elective Courses

Course Code	Course Title	CHs
MTS-XXX	Artificial Intelligence	03
MTS-XXX	Paradigms of Artificial Intelligence	03
MTS-XXX	Linear Control Systems	03
MTS-XXX	Micro-Electro Mechanical Systems	03
MTS-XXX	Advanced Modelling and Simulation	03
MTS-XXX	Sensor and Sensing Technology	03
MTS-XXX	Real Time Systems	03
MTS-XXX	Programming of Embedded Systems	03
MTS-XXX	Artificial Neural Networks	03
MTS-XXX	Bio Medical Instrumentation	03
MTS-XXX	Pattern Recognition and Analysis	03
MTS-XXX	Optomechatronic Systems	03
MTS-XXX	Fuzzy Logic Hybrid Systems	03
MTS-XXX	Natural Language Processing	03
MTS-XXX	Smart Materials and Structures	03
MTS-XXX	Stochastic Systems	03
MTS-XXX	Digital Integrated Circuit Design	03

c) Research Credits (MS)

MTS-XXX	Thesis Research	06

3. MS in Mechatronics Engineering (Bio mechatronics)

a) Core Courses

Course Code	Course Title	CHs
MTS-XXX	Advanced Robotics	03
MTS-XXX	Data Acquisition and Control	03
MTS-XXX	Image Processing for Intelligent Systems	03
MTS-XXX	Advanced Embedded Systems	03

b) **Elective Courses**

Course Code	Course Title	CHs
MTS-XXX	Bio Medical Instrumentation	03
MTS-XXX	Biomedical Clinical Information Systems	03
MTS-XXX	Bio-Informatics Systems	03
MTS-XXX	Signals and Images in Medicine	03
MTS-XXX	Biomechanics	03
MTS-XXX	Prosthetics and Rehabilitation	03
MTS-XXX	Biosensors and instrumentation	03
MTS-XXX	Selected Topics in Biomedical Engineering	03
MTS-XXX	Medical Devices Design and Standards	03
MTS-XXX	Linear Control Systems	03
MTS-XXX	Machine Learning	03
MTS-XXX	Human Machine Interaction	03
MTS-XXX	Advance Bio Materials	03
MTS-XXX	Finite Element Methods	03
MTS-XXX	Introduction to Modelling and Analysis	03
MTS-XXX	Advanced Digital Signal Processing	03
MTS-XXX	Computational Modelling of Physiological Systems	03

c) Research Credits (MS)

MTS-XXX	Thesis Research	06

SCHEME OF STUDIES FOR
MS IN MECHATRONICS

Semester 1

S. No.	Subject Code	Subject Name	Credit Hours (Cr Hrs)	Cr Hrs
1	MTS-XXX	Core 1	3-0	9
2	MTS-XXX	Core 2	3-0	
3	MTS-XXX	Elective 1	3-0	

Semester 2

S. No.	Subject Code	Subject Name	Credit Hours (Cr Hrs)	Cr Hrs
1	MTS-XXX	Core 3	3-0	9
2	MTS-XXX	Core 4	3-0	
3	MTS-XXX	Elective 2	3-0	

Semester 3

S. No.	Subject Code	Subject Name	Credit Hours (Cr Hrs)	Cr Hrs
1	MTS-XXX	Elective 3	3-0	6
2	MTS-XXX	Elective 4	3-0	

Semester 4(If students opt for research work based degree)

S. No.	Subject Code	Subject Name	Credit Hours (Cr Hrs)	Cr Hrs
1	MTS-XXX	Thesis Research	3-0	6

Semester 4(If students opt for coursework bases degree)

S. No.	Subject Code	Subject Name	Credit Hours (Cr Hrs)	Cr Hrs
1	MTS-XXX	Elective 5	3-0	6
2	MTS-XXX	Elective 6	3-0	

DETAIL OF COURSES
CONTENTS AND TEXT BOOKS
MS MECHATRONICS ENGINEERING

MTS-XXX Data Acquisition and Control

Course Objectives

1. This course is designed to develop an understanding of modern data acquisition techniques.
2. The course is intended to give detailed explanation of passive and active electrical transducers, signal conditioning circuits along with digital interfacing techniques.
3. An overview of digital control systems and digital controller design will be given.

Topic Covered

1. Introduction to Data acquisition.
2. Passive and Active Electrical Transducers.
3. Signal Conditioning Circuits.
4. Digital Interfacing.
5. Data Communication and Networks.
6. ADC and DAC, Timers and Counters.
7. Digital measurements and control programming for real time systems.
8. Introduction to Digital Control Systems.
9. Digital Controller Design.

Text/Reference Books

1. **TRANSDUCERS AND INSTRUMENTATION**, D.V.S. MURTY, Prentice-Hall International, Inc.
2. **"DIGITAL CONTROL SYSTEM ANALYSIS AND DESIGN"** by C. L. Phillips and H. T. Nagle, Jr., 3rd edition, Prentice-Hall International, Inc.
3. **"Process Control Instrumentation Technology"** by Curtis D Johnson.

MTS-XXX **Image Processing for Intelligent Systems**

Course Objectives

1. This course presents the theory and practice of digital image processing with Matlab. Numerous examples and practical hands-on exercises are included in the course.

2. One major topic of image processing is covered in every lecture, typically consists of a discussion of the basic theoretical concepts and some examples illustrating practical imaging problems.
3. The course will also deal with the application of the techniques in a simulated robot soccer environment.

Topic Covered

1. Introduction to Image Processing
2. Image Processing Fundamentals
3. Image Enhancement in Spatial Domain
4. Image Enhancement in Frequency Domain
5. Image Restoration
6. Geometric transformations
7. Colour Image Processing
8. Image compression
9. Case studies pertaining to intelligent systems
10. Implementation of techniques in Robot Soccer and manufacturing environment

Text/Reference Books

1. **Digital Image Processing**, R. C. Gonzalez and R. E. woods, 2nd edition, Pearson Education, Inc., 2002.
2. **Additional readings: Digital Image Processing using MATLAB**, R. C. Gonzalez,R. E. Woods and S.L. Eddins, Pearson Education, Inc., 2004.

MTS-XXX Advanced Embedded System

Course Objectives

1. This course is designed to develop an understanding of modern embedded systems.
2. The course is intended to give detailed explanation of processor architecture and design, memory access, programming of embedded systems and integration of embedded systems in real time environment.
3. An overview of programmable logic devices and system on chip will also be given along with IC fabrication and design challenges.

Topic Covered

1. Introduction to embedded systems
2. Hardware architecture for embedded systems
3. Single purpose processors
4. General purpose processors
5. Application specific processors

6. Programmable logic devices like, Programmable array logic (PAL) Programmable logic array (PLA), complex Programming logic device (CPLD)
7. Application Specific Integrated Circuits (ASIC)
8. Field Programmable Gate Arrays (FPGA)
9. Software for embedded systems
10. Introduction to development environment: FPGA development kit (Spartan-III)
11. Introduction to Verilog
12. Development of various applications like Mux, Demux, counters, registers, ALU etc.

Text/Ref Books

1. **Computer Architecture**, A Quantitative approach by Dr. David A. Patterson and Dr. Paul Hennessey, - Digital Computer Electronics by Malvino& Brown.
2. **Embedded System Design**: A unified Hardware/Software Introduction. By Frank Vahid& Tony D. Givarigis,
3. **Embedded System Design**. Hardware/ Software System, by P. Marwedel
4. **FPGA prototyping by VHDL examples**: Xilinx Spartan-3 version, By Pong P. Chu - Wiley-Interscience.

MTS-XXX **Artificial Intelligence**

Course Objectives

1. To understand the concept of rational behavior and intelligent agents.
2. To understand how to formulate a problem using informed and uninformed search strategies.
3. To learn how to represent knowledge for intelligent agents.
4. To be able to create software for intelligent agents using procedural languages such as C and Java as well as using declarative languages such as PROLOG.

Topic Covered

1. Introduction to Artificial Intelligence and its sub-areas.
2. Intelligent agents Problem solving through uninformed search
3. Problem solving through informed search. Heuristics
4. Introduction to knowledge representation
5. First-order logic and Prolog
6. Understand the notions of rational behavior and intelligent agents.
7. Develop general appreciation of goals, subareas, achievements and difficulties of AI.
8. Knowledge of methods of blind as well as informed search and ability to practically apply the corresponding techniques.

9. General understanding of major concepts and approaches in knowledge representation, planning, learning, robotics and other AI areas.
10. Developing programming skills for AI applications.
11. Exposure to logic programming with Prolog.
12. Introduction to some advanced topics
13. Present and future of AI

Text/ Reference Books

1. **Artificial Intelligence:** A Modern Approach, 2nd ed. S. Russell and P. Norvig, Prentice Hall, 2003
2. **Artificial Intelligence:** Structures and Strategies for Complex Problem Solving, 6th ed. G. Luger, Addison Wesley, 2009

MTS-XXX Sensors and Sensing Technology

Course Objectives

Introduces the fundamental issues in sensing and various sensor technologies including motion sensors, velocity sensors, GPS sensors, acoustic sensors, light and image sensors, and range sensors. Also demonstrates sensor technologies using a system approach to show how they can be integrated into a complete digital system.

Topic Covered

1. Measurements: Combining multiple signal and noise sources
2. Data acquisition: Getting Signals to computers
3. Light and image sensors
4. Imaging and range-finding instruments
5. Sound Sensing
6. Touch Sensing
7. Navigation Sensing
8. Chemical Sensing
9. Sensing and Security
10. Multi-component security systems
11. People Sensing

Text / Reference Books

1. Smart Sensors and Sensing Technology By Sen Gupta, Gourab (Ed.)
2. Optical, Acoustic, Magnetic, and Mechanical Sensor Technologies Edited By Krzysztof Iniewski
3. Handbook of modern sensors: physics, design and applications By Jacob Fraden
4. Sensor Technology Handbook By Jon S. Wilson

5. Chemical Sensors Comprehensive Sensor Technologies By Ghenadii Korotcenkov

MTS-XXX Motion Planning for Mobile Robots

Course Objectives

1. This course is designed to serve as an introduction the broad area of robotics, intelligent machines that can act of their work, and specifically mobile robotics.
2. It will deal primarily with algorithmic issues.
3. It will discuss how we can approach the three key issues in mobile robotics: building a map of our surroundings, knowing where we are, and formulating a plan to get us where we want to go (mapping, localization and path planning)?

Topics Covered

1. An overview of concepts in robot motion planning.
2. Sensor-Based Motion Planning Algorithms
3. the “Bug” algorithms
4. the TangentBug algorithm
5. Implementation
6. The configuration space of a rigid body.
7. The classical motion planning paradigms:
8. the potential functions
9. the roadmaps
10. the cellular decompositions
11. The sampling based algorithms:
12. the probabilistic roadmaps
13. single query sampling based planners
14. Map making and SLAM
    the Kalman filter
    the SLAM problem
    the Bayesian approaches to map making
15. Non-holonomic drive systems
    the types of drive systems
    the legged robots
    the crawling robots
    trajectory planning for non-holonomic systems
    Motion planning for multiple robots
    Notion of configuration x time space
    Mapping of moving obstacles in configuration x time space
    Centralized vs. decoupled planning
    Decoupled planning techniques: Velocity tuning, coordination diagram, prioritized planning

Text/Reference Books

1. **Principles of Robot Motion**, Theory Algorithms and Implementations by Howie Choset, Kevin Lynch, Seth Hutchinson, George Kantor Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun
2. Probabilistic Robotics Sebastian Thrun
3. Any Other book on Mobile Robots

MTS-XXX **Kinematics of Mobile Robotic Systems**

Course Objectives

1. There are three key questions in Mobile Robotics. Where am I? Where am I going? How do I get there?
2. To answer these questions the robot has to have a model of the environment (given or autonomously built) perceive and analyze the environment find its position within the environment plan and execute the movement.
3. This course will deal with Locomotion and Navigation (Perception, Localization, Planning and Motion Generation) algorithms.

Topic Covered

1. Introduction: problem statements, typical applications, video
2. Locomotion with legs and wheels
3. Mobile Robots Kinematics I: Kinematics model
4. Mobile Robots Kinematics II: Kinematics model
5. Mobile Robots Kinematics III: Motion control
6. Perception I: Sensing and Perception
7. Perception II: Sensing and Perception, Uncertainty Representation
8. Feature extraction
9. Localization I: Introduction, odometry
10. Localization II: Map representation, introduction to probabilistic map- based/Markov localization
11. Localization III: , Markov localization, Kalman filter localization
12. Localization IV: Kalman filter localization, Other examples of localization systems, map building.

Text/Reference Books

1. Roland Siegwart and Illah Nourbakhsh "**Introduction to Autonomous Mobile Robots**" ISBN 0-262-19502 (hardbound) Cambridge: MIT Press
2. George Bekey "**Autonomous Robots**" ISBN 0-262-025787 (hardbound) Cambridge: MIT Press.

MTS-XXX **Cognitive Robotics**

Course Objectives

1. Cognitive robotics addresses the emerging field of autonomous systems possessing artificial reasoning skills.
2. Successfully-applied algorithms and autonomy models form the basis for study, and provide students an opportunity to design such a system as part of their class project.
3. Theory and application are linked through discussion of real systems such as the Mars Exploration Rover.

Topic Covered

1. Introduction to Cognitive Robotics
2. Kinodynamic and Randomized Path Planning
3. Model-based Diagnosis and Mode Estimation
4. Solving Optimal CSPs through Conflict-Learning
5. Mission-level Task Planning
6. Dynamic Plan Execution Under Uncertainty
7. Mixed Human Robotic Exploration
8. Hidden State and Model-based Reactive Planning
9. Continuous, Incremental Path Planning and Exploration
10. Cognitive Game Theory
11. Visual Interpretation using Probabilistic Grammars
12. Working with and Learning from Humans as Partners

Text/Reference Books

1. Patnaik, Srikanta "**Robot Cognition and Navigation - An Experiment with Mobile Robots**" Series: Cognitive Technologies 2007
2. Ronald Brachman and Hector J. Levesque, "**Knowledge Representation and Reasoning**", Morgan Kaufmann, 2004. [MIT Press]
3. Raymond Reiter, "**Knowledge in Action: Logical Foundations for Specifying and Implementing Dynamical Systems**". MIT Press, 2001. [MIT press]

MTS-XXX **Machine Vision**

Course Objectives

1. To understand algorithms for automated computer vision.
2. To create mathematical models of images and objects and using these to perform inference.
3. To learn how to use these models to automatically find, segment and track objects in scenes, perform face recognition and build three-dimensional models from images.

Topic Covered

1. Introduction to computer vision.
2. Image Formation and Filtering
3. Grouping and Fitting
4. Image segmentation
5. Texture analysis
6. Shape from shading,
7. Object Modeling
8. Visual Servoing
9. Recognition
10. Optical Flow
11. Stereo Vision
12. Structure from Motion
13. Activity Recognition
14. Case studies pertaining to intelligent systems
15. Simulation of techniques on manipulators and mobile robots and Manufacturing

Text/Reference Books

1. **Computer Vision: Algorithms and Applications** by Richard Szeliski, 2nd edition, Pearson Education, Inc., 2002.
2. **Computer Vision** a Modern Approach By Jean Ponce

MTS-XXX Paradigms of AI

Course Objectives

1. To understand the concepts of artificial intelligence, intelligent machines and differences between natural and artificial intelligence.
2. To understand the fundamental concepts of neural networks, neuro-modelling, several neural network paradigms and its applications.
3. To understand the concepts of fuzzy sets, fuzzy logic control and its applications.
4. To be able to create software for intelligent agents using these techniques.

Topic Covered

1. Introduction to Artificial Intelligence
2. Course Overview
3. Natural and Artificial Intelligence
4. Intelligent Machines
5. Overview of the four AI techniques.
6. Artificial Neural Networks
7. Neuro-Models
8. Introduction to ANN
9. Biological Neural Networks
10. Primitive ANNs

11. MLPs and the BP Algorithm
12. ANN Applications
13. Kohonen Self organizing Map
14. ART1 and Fuzzy ART
15. Simulation Exercises
16. Fuzzy Logic
17. Introduction to Fuzzy Logic
18. Fuzzy Sets
19. Fuzzy Logic Control
20. Case Studies and Applications
21. Simulation Exercises

Text/ Reference Books

1. "Machine Learning" Tom M. Mitchell, McGraw Hill, USA, 1997.
2. "Fundamentals of Neural Networks: Architectures, Algorithms and Applications", Laurene Fausett, Prentice Hall, U.S.A., 1994.
3. "Using Fuzzy Logic", Jun Yan, Michael Ryan and James Power, Prentice Hall, 1995.
4. "Neural Networks and Fuzzy Logic", Bart Kosko, Prentice Hall, USA, 1991.

MTS-XXX Computational Geometry

Course Objectives

Computational geometry abounds with beautiful problems and solutions that arise in many application domains, including computer graphics, geographic information systems, manufacturing technology, path planning for robots, and graph drawing. The course will contain review of basic algorithms and discussion of active research topics in the design and analysis of efficient algorithms and data structures for geometric problems with applications in computer graphics, pattern matching, manufacturing, robotics, facility location, and geographic information systems. Practical issues pertaining to efficient and accurate implementations, and related to libraries of geometric data structures and algorithms will also be discussed.

Topic Covered

1. Polygons, triangulation, visibility, art gallery problems
2. Convex hulls in two and higher dimensions
3. Proximity problems: closest pair, closest point queries
4. Voronoi diagrams, Delaunay diagrams
5. Geometric minimum spanning trees, traveling salesman problem
6. Arrangements of lines, hyperplanes; geometric duality
7. Intersection problems; Bentley-Ottmann sweep
8. Point location search.
9. Parametric search, randomization.

10. Selected research topics in computational geometry
11. Selected application areas: one or two selected from computer graphics, manufacturing, robotics, GIS, geometric optimization.

Text/Reference Books

1. **Computational Geometry in C** by Joseph O'Rourke (Cambridge University Press; 2008 edition, ISBN # 978-3-540-77973-5).
2. **Computational Geometry: Algorithms and Applications** by Mark de Berg, Marc van Kreveld, Mark Overmars, and Otfried Cheong, third revised edition, Springer-Verlag, 2008. ISBN # 978-3-540-77973-5.

MTS-XXX Natural Language Processing

Course Objectives

1. This course is an in-depth overview of techniques for processing human language.
2. How should linguistic structure and meaning be represented?
3. What algorithms can recover them from text? And crucially, how can we build statistical models to choose among the many legal answers?
4. The course covers methods for trees (parsing and semantic interpretation), sequences (finite-state transduction such as tagging and morphology), and words (sense and phrase induction), with applications to practical engineering tasks such as information retrieval and extraction, text classification, part-of-speech tagging, speech recognition, and machine translation.
5. There are a number of structured but challenging programming assignments.

Topic Covered

1. Introduction
2. Language models
3. Probability concepts
4. Bayes' Theorem, Smoothing n-grams
5. Improving CFG with features
6. Context-free parsing
7. Earley's algorithm
8. Probabilistic parsing
9. Human sentence processing
10. Semantics
11. Forward-backward algorithm
12. Expectation Maximization
13. Finite-State
14. Morphology and phonology

15. Log-linear models

Text/Reference Books

1. Chris Manning and Hinrich Schütze, "**Foundations of Statistical Natural Language Processing**", MIT Press. Cambridge, MA: May 1999.
2. Brian Roark, Richard Sproat "**Computational Approaches to Morphology and Syntax**" Oxford Surveys in Syntax & Morphology
3. Daniel Jurafsky and James H. Martin "**An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition**" Second Edition, 2009

MTS-XXX Advanced Manufacturing Design Techniques

Course Objectives

1. The essence of industrial wealth generation is the profitable manufacture and marketing of products and processes.
2. The manufacturing environment has to continuously adapt to the ever more discerning expectations of customers and to meet increasing competition.
3. There is a need to exploit developing technologies, advanced manufacturing processes and computer based techniques with efficient operation and effective management.
4. Furthermore, modern manufacturing systems must integrate a wide range of methods, technologies, equipment and people in a flexible manner to accommodate the rates of change to be anticipated.
5. This course will take a detailed look at most of the Advanced Manufacturing Techniques that have emerged to achieve higher quality and productivity.

Topic Covered

1. Introduction
2. Automation and Control Technologies
3. Introduction to automation
4. Industrial Control Systems
5. Sensors, Actuators and other control components
6. Numerical Control
7. Industrial Robotics
8. CIM
9. Discrete Control using PLCs and PCs
10. Material Handling and Identification Technologies
11. Overview of Material handling Equipment
12. Material Transport Systems (Industrial Trucks, AGVs, Monorails)
13. Automated Storage Systems
14. Automatic Data Capture

15. Manufacturing Systems
16. Single Station manufacturing cells
17. Group Technology
18. Flexible Manufacturing Systems
19. Automated Assembly Systems
20. Advanced Inspection Technologies
    a. Optical Inspection techniques
    b. Machine Vision
21. Manufacturing Support Systems
    a. Uses of CAD/CAM in the production system
    b. Process Planning and Concurrent Engineering
    c. Lean Production and Agile Manufacturing
    d. Advanced Manufacturing Techniques
    e. Micro/ Nano Fabrication
    f. Rapid Prototyping/Tooling
    g. Virtual Manufacturing
    h. Intelligent Manufacturing Systems

Text/Reference Books

1. Automation, Production Systems and Computer Integrated Manufacturing by Mikell P. Groover
2. Fundamentals of Modern Manufacturing: Materials, Processes and Systems by Mikell P. Groover
3. Any Other book on Manufacturing and CIM

MTS-XXX Industrial Control Technology

Course Objectives

1. To learn state-of-art modern control systems.
2. To understand modern control technology and the theoretical fundamentals of process control, logic, binary operations, digital data conversion and discrete control.
3. To develop PLC programs and applications to solve practical control problems.

Topic Covered

1. Discrete control systems – introduction, fundamental concepts, relay control, PLC,
2. Fundamental logic concepts connected to discrete control systems
3. Introduction to the linear control systems
4. Discrete control systems with PLC
5. PLC programming
6. Lead and lag compensation
7. SCADA systems
8. CNC Programming
9. Advanced CNC programming Functions

10. Concept of CIM
11. Automated Storage and Retrieval System
12. Programming of Industrial Robots

Text/Reference Books

1. L. A. Bryan, E. A. Bryan "**Programmable Controllers Theory and Implementation**"

MTS-XXX Real Time Systems

Course Objectives

The aim of the course is to bring students up to a point that they understand the motivation, theoretical background, and some of the work that has been done in the field of real-time systems. A student leaving the course should be able to apply some of the simpler techniques, such as rate monotonic analysis, to practical problems without any further study, and prepared to understand the literature if they choose to follow the course with further readings and individual study.

Topic Covered

1. Introduction to real-time systems
2. Typical real time applications
3. Hard versus Soft Real Time Applications
4. Uniprocessor scheduling (Static/dynamic/state priority scheduling)
5. Clock Driven scheduling
6. Priority Driven Scheduling of periodic tasks
7. Pre emptive/Non-pre emptive systems
8. Resource sharing
9. Mixing real time and non-real time systems
10. Multiprocessor and distributed systems

Text / Reference Books

1. **Real Time Systems** by Jane Liu
2. **Real-time systems design and analysis** by Phillip A. Laplante
3. Real-Time Systems and Programming Languages (Third Edition) by Alan Burns and Andy Wellings
4. **Real-Time Systems and Software** by Alan C. Shaw
5. Latest Journal and Conference papers on Real Time Systems

MTS-XXX Fuzzy Logic Hybrid Systems

Course Objectives

The course covers the main aspects of fuzzy systems together with their applications. It involves teaching of hybrid systems (neuro-fuzzy, and

fuzzy-genetic), hybrid intelligent systems and examples to problem solving using hybrid intelligent systems.

Topic Covered

1. Introduction to fuzzy logic
2. Fuzzy logic applications
3. Introduction to fuzzy sets and fuzzy operations
4. Fuzzy logic control design
5. Application of fuzzy logic to robots and intelligent machines
6. Neuro-fuzzy systems
7. Fuzzy-Genetic systems
8. Application of hybrid fuzzy systems to robotics and intelligent machines
9. Type-2 fuzzy systems

Text / Reference Books

1. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence," by J.S.R. Jang, C.T. Sun, and E. Mizutani, Prentice Hall, 1996
2. Foundations on Neuro-Fuzzy Systems, D. Nauck, F. Klawonn, R. Kruse, Wiley, Chichester, 1997
3. Fuzzy Logic with Engineering Applications by T.J. Ross, McGraw-Hill Book Company, 1995.
4. Fuzzy Control, K.M. Passino, S.Yurkovich, Addison-Wesley-Longman, 1998.
5. Neural Fuzzy Systems: A Neuro-Fuzzy Synergism., by Lin, (1996) , Prentice Hall.
6. Fuzzy Sets, Uncertainty, and Information by G.J. Klir and T.A. Folger, Prentice Hall, Inc.

MTS-XXX Precision Manufacturing Systems

Course Objectives

Micro manufacturing deals with the precision manufacturing techniques used to build devices on micro and nano scale. At this scale conventional manufacturing techniques become obsolete and material properties and scaling laws cannot be neglected as they play a major role in defining the end product. Moreover, the ambient environment in which the manufacturing process is being carried out helps in determining the properties of the manufactured device. In this course, recent practices in manufacturing micro and nano scale products would be presented. In addition, latest characterisation and measurement techniques would also be discussed. By the end of the course, students would be conversant with state-of-the-art laboratory equipment and processes used in fabrication.

Topic Covered

1. Manufacturing engineering in microelectronics
2. Micro electro mechanical, nano, opto and micro scale manufacturing
3. Examination of systems design, equipment, process and operational issues and linkages to business strategies
4. Crystal growth
5. Thin film deposition processes and patterning
6. Removal processes
7. Vacuum engineering
8. Characterization techniques
9. Imaging, metrology and profiling techniques
10. Packaging, assembly, and self-assembly
11. Contamination control
12. Clean room practices

Text / Reference Books

1. Marc J. Madou "Fundamentals of Microfabrication and Nanotechnology" CRC Press.
2. M. Koc and T. Ozel "Micro-Manufacturing: Design and Manufacturing of Micro-Products" Wiley, 2011

MTS-XXX Advanced Measurement Techniques

Course Objectives

To help students to gain an in-depth understanding of basic measurement theory, operating principle of modern measurement techniques, capabilities of practical measuring machines and their applications in advanced manufacturing.

Topic Covered

1. Basics of measurement; Measurement uncertainty, data analysis and modeling; Displacement measurement (capacitive, inductive and magnetic sensors; Linear scales); Interferometry (heterodyne and homodyne, calibration);
2. Surface metrology (Instrumentation – stylus and optical; Characterisation – profile and areal; Calibration);
3. Scanning probe microscopy (SPM dimensional metrology, Calibration);
4. Materials metrology (General materials metrology, SPM for materials, Energy beam techniques, Analytical techniques);
5. Low force and mass measurement;
6. Coordinate measuring machines.

Text / Reference Books

1. John F.W. Galyer and C. Shotbolt “Metrology for Engineers” Cassell, 1990.
2. Anand K. Bewoor and V. A. Kulkarni “Metrology and Measurements” Mcgraw-Hill, 2009

MTS-XXX Smart Materials and Structures

Course objectives

Smart materials are characterized by new and unique properties that can be altered in response to environmental stimuli. They can exceed the current abilities of traditional materials and can therefore be used in a wide range of applications. This course is designed to provide introduce students to smart materials and structures, and provide a strong foundation for further studies and research on these materials.

Topic Covered

1. Structure, processing, and properties of smart materials
2. Dependence of properties on structure
3. Processing and design
4. Mechanical, thermal, electrical, magnetic and optical smart materials systems
    a. Shape memory materials
    b. Electrostrictive materials
    c. Magnetostrictive materials
5. Active polymers
6. Design, modeling and applications of smart materials systems

Text / Reference Books

1. M.V. Gandhi and B.S. Thompson “Smart materials and structures” Springer, 1992
2. M. Schwartz “Smart Materials” CRC Press, 2008

MTS-XXX Biomedical Clinical Information System

Credit Hours: 3-0

Pre requisites: None

Course Objectives

1. The course focuses on medical informatics which serves as the backbone in organizational management of information in medical research, patient care and medical support.

2. This course will combine medical science and computer sciences to develop and better understand the data available and hence deliver better medical care inside and outside hospitals.
3. Due to our rural-centric demographic distribution, wider adoption of Telemedicine can be expected in short future.
4. This course will fulfil the data storage and processing needs.
5. This will also lead towards development and management of decision support systems (DSS), which is an important tool for doctors and Telemedicine systems.

Topic Covered

1. Aspects of medical data acquisition, processing, storage and normalization.
2. Typical biomedical signals and applications
3. Building blocks of data acquisition systems
4. Common sources of noise in biomedical signals
5. Evidence based medical decision support.
6. Models & databases
7. User interfaces
8. Coding and classification of medical data
9. Available tools
10. Statistical analysis
11. Database topologies and their advantage for handling medical informatics
12. Various structures of data collection, storage & distribution
13. Hands on training on relational databases systems including Microsoft Access.
14. Structured Programming Language (SQL) programming
15. Hypertext Markup Language (HTML) and HTML Forms
16. Development of ODBC compliant databases with SQL & HTML
17. JavaScript programming

Text/Reference Books

1. **Health Informatics:** Practical Guide For Healthcare And Information Technology Professionals (Fifth Edition) (Hoyt, Medical informatics), Fifth edition by Robert E Hoyt, Nora Bailey & Ann Yoshihashi
2. **Biomedical Informatics:** Computer Applications in Health Care and Biomedicine (Health Informatics), Third edition by Edward H
3. **SQL: A Beginner's Guide** by Robert Sheldon, Latest Edition
4. **Fundamentals of SQL Programming** by Ramon A. Matta, McGraw-Hill, Latest Edition

MTS-XXX Optomechatronic Systems

Course Objectives

1. To understand the basics of Optomechatronic systems.
2. To understand the importance of Mechatronics elements in the field of Optomechatronic system.
3. To familiarize the students with various micro-fabrication techniques in the field of Optomechatronics.
4. To familiarize the students with various software used in the design and simulation of MEMS/MOEMS.

Topic Covered

1. Optomechatronic Technology
   i. Historical Background of Optomechatronic Technology
   ii. Optomechatronics: Definition and Fundamental Concepts
2. Fundamental Functions of Optomechatronic Systems
3. Principles of Optics
   i. Reflection and Refraction
   ii. Lenses, Multiple Lens Systems, Aperture Stops and Pupils
   iii. Optical Aberrations
   iv. Polarization, Coherence, Interference and Diffraction
   v. Optical Fiber Transmission
   vi. Gaussian Beam Optics
4. Mechatronics Elements of Optomechatronic System
   i. Optomechatronic Actuation
   ii. Optomechatronic Sensing
   iii. Optical Scanning, Optical Switching
   iv. Zoom Control, Visual Auto focusing
   v. Optical Signal Transmission and Display
   vi. Dynamic Systems and Control
5. Visual (Optical) Information Feedback Control
6. Micro-fabrication Techniques
   i. Bulk micromachining
   ii. Surface micromachining
   iii. CMOS-compatible MEMS and MOEMS
   iv. Compound-semiconductor-based MEMS and MOEMS
   v. Technologies for continuous surface profiles
7. Optomechatronic Systems in Practice
8. Laser Printers
9. Optical Storage Disk
10. Atomic Force Microscope
11. Confocal Scanning Microscope
12. Projection Television
13. Visual Tracking System
14. Adaptive Optics
15. MEMS/MOEMS CAD and Simulation

i. FEM Simulation using COMSOL Multiphysics

16. Micro-fabrication: Design and Simulation

Text/Reference Books

1. **Optomechatronic: Fusion of Optical and Mechatronics Engineering** by Hyungsuck Cho, CRC Press, 1st Edition 2005
2. **MOEMS: Micro-opto-electro-mechanical Systems**by M Edward Motamedi, SPIE Press, Illustrated Edition 2005
3. **Fundamentals of Microfabrication and Nanotechnology**by Marc J Madou, CRC Press, 3rd Edition 3 Vol Set

EE-XXX Micro Electro Mechanical Systems

Course Objectives

1. MEMS corresponds to the study and understanding of systems and devices at micro level.
2. At this level design choices are limited not only by the challenges in fabrication but also by the proper grasp of dominant physical, chemical, and biological principles acting on the devices.
3. This course deals with the fundamentals of Micro and nano electro mechanical systems (MEMS and NEMS).
4. The course offers insight in MEMS design principles, detailed fabrication techniques, and detailed analysis of processes involved in MEMS system implementation.
5. Discussion about micro sensors, micro actuators and their modeling techniques are also part of this course.

Topic Covered

1. Introduction to microfabrication
2. Overview of microfabrication
3. Silicon based MEMS processes
4. New materials
5. Electrical and mechanical concepts
6. Semiconductor materials
7. Carrier density calculations
8. Conductivity and resistivity
9. Stress and strain
10. Intrinsic stresses
11. Resonant frequency and Q factor
12. Electrostatic sensing and actuation
13. Parallel plate capacitors and applications
14. Interdigitated finger capacitors
15. Comb drives
16. Thermal sensing and actuation
17. Thermal expansion
18. Thermal couples

19. Thermal resistors
20. Thermal sensors
21. Piezoresistive sensing
22. Sensor materials
23. Sensor mechanical analysis
24. Bulk micromachining
25. Dry / wet etching
26. DRIE
27. Gas-phase etchants
28. Anisotropic etching
29. Surface micromachining
30. Basic processes
31. Structural and sacrificial material
32. Stiction/anti stiction methods
33. Microfluidic applications
34. Basic concepts
35. Design of channels and valves
36. Optical MEMS
37. Lenses
38. Mirrors

Text/Reference Books

1. **Foundation of MEMS** by Chang Liu, Latest Ed, PEARSON, Prentice-Hall Inc (Text Book)
2. **Fundamentals of microfabrication: The science of miniaturization** by Marc J. Madou, Latest Ed. CRC Press (Reference Book)

MTS XXX: Biomedical Instrumentation

Course Objectives

1. The students will acquire knowledge in medicine and learn to communicate with physicians adequately to understand and consider their thoughts completely.
2. They shall learn about the working principles and application of modern medical products.
3. The students shall know about the application of current medical products in diagnosis and therapy and be able to critically evaluate data and draw conclusions.
4. The students shall be prepared for the international labour market and should have the ability to work and communicate effectively in national and international contexts. The students shall learn to apply research methods.

Topic Covered

1. Introduction to Biomedical Engineering, history, semantics in different countries.
2. Medical Terminology, major organ systems, generation of bioelectrical potentials, a generalized medical instrument, system-transfer function.
3. Measurement of flow, flow sensors, Measurements of the respiratory system, physiology and instruments.
4. Body temperature and temperature sensors.
5. Incubators: Physiology and instruments.
6. Bioelectrodesand Biopotential (EMG and EEG).
7. ECG (Eindhoven, Goldberger, Wilson), 3D Projection
8. Cardiac rhythm interpretation with relationship to defibrillation and pacing.
9. Bioinstrumentation amplifiers, noise, electrical field, shielding,
10. driven right leg concept.
11. Pumps: infusion, perfusion, insulin pumps, safety concepts
12. Basic working concepts of diagnostic ultrasound, plain x-ray, CT, MRI, PET.
13. Blood flow measurement by ultrasound, laser, and electromagnetic methods.

Text/Reference Books

Webster. John G: Medical Instrumentation, 3rd edition, Wiley and Sons.

MTSXXX: Biosensors and Instrumentation

Objectives

1. The Biosensors and Instrumentation module examines the methods used to interface sensors for biological and biomedical applications with electronics. One focus will be on transducers, meaning devices which convert information from one form of energy to another. In this case the final form for the information will be an electrical signal but the transducers themselves could be optical, mechanical, etc., and operate in a number of different ways (eg., capacitive, potentiometric, photonic).
2. This course will also go beyond sensing to look at methods of actuation for closed loop smart systems. Examples from the state of the art in biosensor research will be provided and a number of guest lectureres from active researchers in this field will provide context.
3. Students will undertake a horizon scanning research exercise to investigate the industrial and research potential of a specific type of biosensor. This will be assessed by both formal reports and a presentation given to and marked by the whole class.

Topic Covered

1. Transducer Basics: Sensors and Actuators, definitions, types of sensors, target analytes, various recognition, signals, and device types.
2. Sensor calibration, dynamic Range, signal to noise, sensitivity, selectivity, interference
3. Instrumentation for Electrochemistry: Potentiostats, impedance measurements, bridge circuits
4. Transducer Basics: Sensors and Actuators, definitions, types of sensors, target analytes, various recognition, signals, and device types.
5. Sensor Amplification: Op-amps, basic circuits
6. Glucose biosensors
7. Enzyme sensors
8. Membrane protein sensors: ion channels, receptors
9. Whole cell sensors
10. Temperature measurements
11. Mechanical sensor instrumentation: Strain gauges, piezoelectric sensors and actuators, capacitive sensor interfaces. FET based sensors: MOSFET revision, FET based biosensors, nano-wire sensors.
12. Optical biosensors:
13. Fibre-optic sensors,
14. Neural sensors and actuators: Microelectrode arrays, neural implants
    Implantable medical devices:
15. Biofouling, materials and regulation.

Text/Reference Books

1. Instrumental Methods in Electrochemistry, Southampton Electrochemistry Group, Ellis Horwood or Halsted Press.
2. Medical Instrumentation: Application and Design John G. Webster, Wiley, (4th Edition) Ultra Low Power Capacitive Sensor Interface W. Bracke, R. Puers& C. Van Hoof; Springer.
3. Biomedical Instruments - Theory and Desig W. Welkowitz, S. Deutsch, M. Akay; Academic Press Inc.
4. Ultra-Low Power Bioelectronics R. Sarpeshkar; Cambridge University Press.

MTS XXX: Signals and Images in Medicine

Objectives

1. Medical signal and image processing is an active area of research. This course presents the fundamentals of digital signal processing with particular emphasis on problems in biomedical research and clinical medicine.

2. It covers principles and algorithms for processing both deterministic and random signals. Topics include data acquisition, imaging, filtering, coding, feature extraction, and modeling. The focus of the course is a series of labs that provide practical experience in processing physiological data, with examples from cardiology, speech processing, and medical imaging. The students shall learn to apply research methods.

Topic Covered

1. Biomedical Signals and Images
    a. ECG: Cardiac electrophysiology, relation of electrocardiogram (ECG) components to cardiac events, clinical applications.
    b. EEG and EMG: Basics of EEG, concept of different bands in EEG, EMG.
    c. Imaging Modalities: Survey of major modalities for medical imaging: ultrasound, X-ray, CT, MRI, PET, and SPECT.
    d. MRI: Physics and signal processing for magnetic resonance imaging.
    e. Surgical Applications: A survey of surgical applications of medical image processing.
2. Fundamentals of Deterministic Signal and Image Processing
    a. Data Acquisition: Sampling in time, aliasing, interpolation, and quantization.
    b. Digital Filtering: Difference equations, FIR and IIR filters, basic properties of discrete-time systems, convolution.
    c. DTFT: The discrete-time Fourier transform and its properties. FIR filter design using windows.
    d. DFT: The discrete Fourier transform and its properties, the fast Fourier transform (FFT), the overlap-save algorithm, digital filtering of continuous-time signals.
    e. Sampling: Sampling and aliasing in time and frequency, spectral analysis.
    f. Image processing I: Extension of filtering and Fourier methods to 2-D signals and systems.
    g. Image processing II: Interpolation, noise reduction methods, edge detection, homomorphic filtering.
3. Probability and Random Signals
    a. PDFs: Introduction to random variables and probability density functions (PDFs).
    b. Classification: Bayes' rule, detection, statistical classification.
    c. Estimating PDFs: Practical techniques for estimating PDFs from real data.
    d. Random Signals I: Time averages, ensemble averages, autocorrelation functions, crosscorrelation functions.

e. Random signals II: Random signals and linear systems, power spectra, cross spectra, Wiener filters.
f. Blind source separation: Use of principal component analysis (PCA) and independent component analysis (ICA) for filtering.

4. Image Segmentation and Registration
   a. Image Segmentation: statistical classification, morphological operators, connected components.
   b. Image Registration I: Rigid and non-rigid transformations, objective functions.
   c. Image Registration II: Joint entropy, optimization methods.

Text/Reference Books

1. Gonzales, R. C.: Digital Image Processing, Prentice Hall, New Jersey, 2008.
2. Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, John Wiley & Sons,2000.
3. Geoff Doughetry: Digital Image Processing for Medical Applications.

MTS XXX: Biomechanics

Objectives

1. To describe the various elements comprising a computational model of the human neuromusculoskeletal system
2. To formulate and solve differential equations that govern the motion of rigid-body (link-segmental) dynamical systems
3. To describe the mechanical properties of various soft tissues, especially muscle, ligament, and tendon;
4. To formulate and solve differential equations that incorporate the major physiological properties of muscle, ligament, and tendon
5. To formulate simple, integrative models of the human neuromusculoskeletal system
6. To formulate and solve differential equations that govern the motion of rigid-body (link-segmental) dynamical systems
7. To use computational models of the human body to study movement.

Topic Covered

1. Dynamics of (planar) segmental systems: Degrees of freedom , Free-body diagrams, Force and moment equilibrium, Equations of motion, Muscle moment arms , Numerical integration of equations of motion , Computational examples, Mechanical properties of soft tissue Muscle
2. Tendon and ligament
3. Muscle modeling : Hill-type models and Computational examples, Equations for Musculotendon dynamics

4. Muscle Activation Dynamics: Excitation-contraction dynamics, First-order model for activation dynamics, Analysis of Biomechanical Systems , Inverse Dynamics , Forward Dynamics
5. Determining Muscle Forces: Indeterminate problem in biomechanics, Static optimization method , Dynamic optimization method.
6. Material properties of bone & cross-sectional properties. The mechanics of Joints.
7. Measuring techniques of force, pressure, acceleration, strain.

Text/Reference Books

1. Biomechanics of the Musculoskeletal System. Edited by B. Nigg and W. Herzog, Second Edition, Wiley 1999.
2. Pandy MG, Barr RE. Biomechanics of the Musculoskeletal System,

MTS XXX: Advanced Biomaterials

Objectives

1. This course provides a theoretical and practical understanding of the mechanical properties of biomaterials. The course aims to bring an understanding of the fundamental relationships between the mechanical properties of a range of biomaterials and the biomedical applications of those materials.
2. This course provides a theoretical and practical understanding of the mechanical properties of biomaterials. The course aims to bring an understanding of the fundamental relationships between the mechanical properties of a range of biomaterials and the biomedical applications of those materials. It looks at several applications of materials and the principles that have led to the choice of biomaterials for those applications. The use and properties of each type of material will be discussed in the light of current clinical applications (implants, surgical tools, catheters, biological implants).

Topic Covered

1. Dynamics of (planar) segmental systems: Degrees of freedom, Free-body diagrams, Force and moment equilibrium, Equations of motion, Muscle moment arms, Numerical integration of equations of motion, Computational examples, Mechanical properties of soft tissue Muscle.
2. Principles of materials science and mechanical properties. Refresher on basic concepts: the structure of solids, static mechanical properties eg stress, strain, failure, fracture toughness, multiaxial load analysis, simple bending, dynamic mechanical properties eg fatigue, viscoelasticity, creep, mathematical models of materials, tribology, wear, lubrication, testing methodology.

3. Polymers. Mechanical properties of polymers and their relationship to polymer structure, molecular weight, crystallinity, fillers, plasticisers and crosslinking. Applications of polymers in medicine, eg soft tissue augmentation or repair, medical device coverings, catheters, sutures, tools, devices and problems with current generation polymers for their applications eg degradation.
4. Biological materials. Mechanical properties and structures of tendons, ligaments, bone and cartilage, soft tissues. Applications of devices made from materials of biological origin (eg. coraline hydroxyapatite, collagen implants). Problems of use of treated biological tissues (resorption, inflammation, disease).
5. Ceramics. Mechanical properties and production of bioceramics: inert (Al2O3, zirconias, silicon nitride) and bioactive (hydroxyapatite and other calcium phosphates, bioglass, calcium sulphates). Applications of ceramics in medicine (artificial joints, coatings, heart valves) and problems with use of ceramics (wear particles, poor union to bone).
6. Metals. Properties of the major metals in use in medicine (316L stainless steel, cobalt chrome, titanium and titanium alloys). Manufacturability and Applications in orthopaedics (eg. joints, plates screws, rods, bars), dentistry (dental implants, braces, fillings)

Text/Reference Books

1. Park, Joon, and Roderic S. Lakes. Biomaterials: an introduction. Springer Science & Business Media, 2007.

Recommendations

- This curriculum may be used as a guideline by the universities and institutions in Pakistan to develop their curriculum in order to have uniform standard education in their programmes.
- The NCRC used HEC curriculum template as the standard working document for BE/BS/BSc mechatronics curriculum. The curriculum is divided into engineering and non-engineering domain. Engineering courses are proposed to make up to 65-70% of total curriculum, whereas, the non-engineering courses cover 30-35% the curriculum Engineering domain of the curriculum is further divided into computing, foundation, breadth (Core), and depth (Core).
- The committee recommended addition of new courses to the revised curriculum. These courses are Social Science Elective II. Electrical Network Analysis, Fundamentals of thermal Sciences, Engineering Elective III, Signals and Systems, Modeling and Simulation and Solid Modeling. In addition to this, Power Electronics and Industrial Automation are included in the revised curriculum as elective courses.
- The committee decided that health and safety education is to be made mandatory through 1-2 days seminar/workshop for faculty, staff and students.
- The committee proposed the formation of Mechatronics Engineering Society of Pakistan to strengthen the Mechatronics Engineering activities. It was decided that an International Conference will be held annually or biennially and will be rotated within different universities of the country.
- It is recommended that Mechatronics engineering faculty members should have a MS/PhD with background in Mechatronics, Control Systems, Mechanical, Electrical/ Electronics, Robotics, Systems Engineering, Automation, Industrial Engineering or experience in academia or industry in Mechatronics systems.
- The curriculum of MS/MSc/ME programme is revised and approved.