C U R R I C U L U M

A N D

S Y L L A B U S

FOR

UNDERGRADUATE PROGRAMME

IN

MECHANICAL ENGINEERING

(**Applicable for 2024 - 28 batch onwards**)

(**Also applicable for 2023-27 batch from 3rd semester**)

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF ADVANCED MANUFACTURING TECHNOLOGY

(Deemed to be University)

HATIA, RANCHI - 834 003

DEPARTMENT OF MECHANICAL ENGINEERING

About the department.

The erstwhile Department of Manufacturing Engineering was renamed as Department of Mechanical and Manufacturing Engineering in November 2020 with the introduction of B. Tech. (Mechanical Engineering) from the academic year 2020-21. The name was changed again to Department of Mechanical Engineering in January 2025 as per the nomenclature of AICTE, New Delhi.

Vision.

The department will strive hard to achieve excellence in technical education by offering major and interdisciplinary engineering courses pertaining to mechanical engineering, advanced manufacturing, and automation, and to develop strong competence in these domains.

Mission.

1) Development of up-to-date curriculum for undergraduate and postgraduate programmes, incorporating the latest and futuristic academic, research and industrial needs.
2) Development of various laboratories with state-of-the-art equipment to enable imparting of quality education.
3) Produce high calibre, highly competent, and self-reliant undergraduates, and postgraduates in Mechanical Engineering, who will possess sound scientific knowledge and critical thinking skills and engage in activities relevant to Indian industries with ethical values and flair for research.
4) Become a centre of excellence in manufacturing research by conducting innovative research in the areas relevant to advanced manufacturing and by developing technology solutions for Indian manufacturing industries to ensure sustainability and self-reliance.

Courses offered.

The department is offering a 4-years B. Tech. programme in Mechanical Engineering from academic year 2020-21, a 2-years M. Tech. programme in Manufacturing Engineering over the past three decades and PhD programme in Mechanical and Manufacturing Engineering over the past one-and-half decades. The department plans to start a M. Tech. programme in Mechanical Engineering with specializations in Design, Thermal and Manufacturing streams from academic year 2026-27 in place of the ongoing M. Tech. programme in Manufacturing Engineering.

UNDERGRADUATE PROGRAMME IN MECHANICAL ENGINEERING

A) Programme Educational Objectives (PEOs).

PEO-1	Plan, design, construct, maintain and improve mechanical engineering systems that are technically sound, economically feasible and socially acceptable.
PEO-2	Apply analytical, computational, and experimental techniques to address the challenges faced in mechanical and allied engineering streams.
PEO-3	Communicate effectively using conventional platforms as well as innovative / online tools and demonstrate collaboration, networking & entrepreneurial skills.
PEO-4	Exhibit professionalism, ethical attitude, team spirit and pursue lifelong learning to achieve career, organizational and societal goals.

B) Programme Outcomes (POs).

PO-1	**Engineering knowledge**. Apply the knowledge of mathematics, science, engineering, and technology to the solution of complex mechanical engineering problems.
PO-2	**Problem analysis**. Identify, formulate, review existing literature, and analyse complex engineering problems to reach substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO-3	**Design / development of solutions.** Design solutions for mechanical engineering problems and design system components or processes that meet the specified needs with appropriate societal, economical, and environmental considerations.
PO-4	**Conduct investigations of complex problems.** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO-5	**Modern tool usage.** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling, to complex mechanical engineering activities with an understanding of the limitations.
PO-6	**The engineer and society.** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues, and the consequent responsibilities relevant to professional engineering practice.
PO-7	**Environment and sustainability.** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO-8	**Ethics.** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO-9	**Individual and teamwork.** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-10	**Communication.** Communicate effectively with the engineering community and with society at large, including the ability to comprehend, create effective reports, make effective presentations, and give and receive clear instructions.
PO-11	**Project management and finance.** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO-12	**Life-long learning.** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

C) Programme Specific Objectives (PSOs).

PSO-1	Apply mechanical and interdisciplinary knowledge to analyse, design and manufacture products to address the needs of the society.
PSO-2	Apply state of the art tools and techniques to conceptualize, design and introduce new products, processes, systems, and services.
PSO-3	Inculcate the motivation to pursue higher studies for contribution to research and development as well as to inspire them to become entrepreneurs.

D) Credit framework under the four-years undergraduate programme with multiple entry and multiple exit options.

The undergraduate programme in Mechanical Engineering allows the students to experience a holistic and multidisciplinary education with a minor of their choice and the feasibility of exploring learning in different Institutions. The table shows the credit structure for various levels under the four-years undergraduate programme with multiple entry and exit options.

Level	Qualification Title	Credits	Exit credits*	Semesters
1	One-year UG Certificate in Mechanical Engineering	41	4	2
2	Two-years UG Diploma in Mechanical Engineering	81	4	4
3	Three-years B. Voc. / B. Sc. (Mechanical Engineering)	123	4	6
4	Four-years B. Tech. (Mechanical Engineering)	160	-----	8
5	Four-years B. Tech. (Mechanical Engineering) with Multidisciplinary Minor	180	-----	8
6	Four-years B. Tech. Honors (Mechanical Engineering)	180	-----	8

* *Students exiting the programme after the even semester of an academic year shall obtain these additional minimum credits by completing the prescribed vocational courses (skill-based courses / mini project / internship) to be eligible for the certificate / diploma / degree, as applicable.*

a) Multiple entries and exits: The students may enter the undergraduate programme at **Level 1**, **Level 2**, **Level 3,** and **Level 4**, as applicable, in an odd semester and such entries will be governed by the applicable admission guidelines of NIAMT from time to time. Students may exit the undergraduate programme after an even semester after completing the exit credit requirements as applicable. The students exiting after the second semester will get a UG Certificate in Mechanical Engineering (**Level 1**). Those exiting after the fourth and sixth semesters will get a UG Diploma in Mechanical Engineering (**Level 2**) and a B. Voc. / B. Sc. in Mechanical Engineering (**Level 3**) respectively.

b) **Level 4:** Students will receive the B. Tech. (Mechanical Engineering) degree upon successful completion of all eight semesters either at a stretch or with opted exits and re-entries.

c) **Level 5:** The four-years B. Tech. (Mechanical Engineering) with Multidisciplinary Minor enables students to take five additional courses in a multidisciplinary minor of twenty credits distributed over semesters IV to VIII. Students will select the multidisciplinary minor at the end of second semester.

d) **Level 6:** The four-years B. Tech. Honors (Mechanical Engineering) enables the students to take five additional Honors courses of twenty credits in Mechanical Engineering distributed over semesters IV to VIII. Students will exercise the choice of Honors at the end of second semester. A student must have a minimum CGPA of 7.5 after the second semester to opt for B. Tech. Honors (Mechanical Engineering). Also, they must have a minimum overall CGPA of 7.5 at the end of eighth semester and must have passed all courses on the first attempt.

E) Online courses.

UGC Regulations permit up to 40% of the total courses being offered in a semester through online learning courses offered over SWAYAM platform and / or other State Level Common Platforms which may be developed in future with participation of different Universities / HTEIs. Only the courses that have no practical (as per the structure of Undergraduate Programme) will be allowed to be done in online mode. The allowed list of courses will be compiled and approved by the department from time-to-time.

F) Course categories and coding conventions.

1)	Basic Sciences / Engineering Sciences	BSC$## / ESC$##
2)	Humanities, Social Sciences and Management Sciences	HSM$##
3)	Basic Sciences / Engineering Sciences / Humanities, Social Sciences and Management Sciences offered by the Department of Mechanical Engineering (solely or jointly with another Department)	MES$##
4)	Professional Core	MEC$##
5)	Laboratory Courses	"P" will be appended to respective theory course code
6)	Professional Electives / Open Electives	MEE$## / MEO$##
7)	Project, Seminar, and Internship	MEP$##
8)	Mandatory or Audit Courses	MAA$##
9)	Honours Courses	MEH$^#
10)	Multidisciplinary Minor	MEM1$# (Minor in Mechanical Engineering) MEM2$# (Minor in Manufacturing Engineering)

Note:

The symbol $ stands for year (1-4) and the symbol ^ stands for semester (1 or 2).

The symbol # stands for one number (1-9) and the symbol ## stands for two numbers (01-99) indicating the course serial numbers.

DISTRIBUTION OF COURSES

1) Basic Sciences (8 Courses, 24 Credits) - (Category Code: BSC)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	BSC101	Engineering Chemistry	-----	3	0	0	3
2	BSC101P	Engineering Chemistry Laboratory	-----	0	0	2	1
3	BSC102	Mathematics I (Calculus & Linear Algebra)	-----	3	1	0	4
4	BSC103	Engineering Physics	-----	3	0	0	3
5	BSC103P	Engineering Physics Laboratory	-----	0	0	2	1
6	BSC104	Mathematics II (Differential Equations & Complex Analysis)	-----	3	1	0	4
7	MES201	Mathematics III (Transforms & Numerical Analysis)	-----	3	1	0	4
8	MES202	Mathematics IV (Probability, Statistics & Quality Control)	-----	3	1	0	4

2) Humanities, Social Sciences and Management Sciences (6 Courses, 12 Credits) - (Category Code: HSM)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	HSM101	English Communication for Professionals	-----	2	0	0	2
2	HSM101P	English Communication for Professionals Laboratory	-----	0	0	2	1
3	MES104	Professional Ethics & Universal Human Values	-----	3	0	0	3
4	MES301	Professional Development	-----	2	1	0	3
6	MES401	Innovation & Entrepreneurship	-----	3	0	0	3

3) Engineering Sciences (12 Courses, 27 Credits) - (Category Code: ESC)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	ESC101	Basic Electrical & Electronics Engineering	-----	3	0	0	3
2	ESC101P	Basic Electrical & Electronics Engineering Laboratory	-----	0	0	2	1
3	MES101	Engineering Mechanics	-----	3	1	0	4
4	MES102	Engineering Graphics & Design Practice*	-----	1	0	4	3
5	MES103	Workshop Practice	-----	0	0	2	1
6	MES105	Engineering Materials	-----	3	0	0	3
7	MES105P	Engineering Materials Laboratory	-----	0	0	2	1
8	MES106	Machine Drawing Practice*	MES102	1	0	4	3
9	ESC201	Applied Electrical & Electronics Engineering	ESC101	3	0	0	3
10	ESC201P	Applied Electrical & Electronics Engineering Laboratory	-----	0	0	2	1
11	MES203	Programming for Problem Solving using Python	-----	3	0	0	3
12	MES203P	Programming for Problem Solving using Python Laboratory	-----	0	0	2	1

** These subjects will be evaluated as theory subjects.*

4) Professional Core (26 Courses, 61 Credits) - (Category Code: CORE)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	MEC201	Engineering Thermodynamics	-----	3	1	0	4
2	MEC202	Fluid Mechanics and Hydraulic Machines	-----	3	0	0	3
3	MEC202P	Fluid Mechanics and Hydraulic Machines Laboratory	-----	0	0	2	1
4	MEC203	Strength of Materials	MES101	3	0	0	3
5	MEC203P	Strength of Materials Laboratory	-----	0	0	2	1
6	MEC204	Kinematics of Machines	-----	3	1	0	4
7	MEC205	Manufacturing Technology I	-----	3	0	0	3
8	MEC205P	Manufacturing Technology I Laboratory	-----	0	0	2	1
9	MEC206	Thermal Engineering	MEC201	3	0	0	3
10	MEC206P	Thermal Engineering Laboratory	-----	0	0	2	1
11	MEC301	Dynamics of Machines	-----	3	0	0	3
12	MEC301P	Dynamics of Machines Laboratory	-----	0	0	2	1
13	MEC302	Design of Machine Elements	-----	3	1	0	4
14	MEC303	Metrology & Measurements	-----	3	0	0	3
15	MEC303P	Metrology & Measurements Laboratory	-----	0	0	2	1
16	MEC304	Heat and Mass Transfer	MEC201	3	0	0	3
17	MEC304P	Heat and Mass Transfer Laboratory	-----	0	0	2	1
18	MEC305	Manufacturing Automation	-----	3	0	0	3
19	MEC306	Computer Aided Design	-----	3	0	0	3
20	MEC306P	Computer Aided Design Laboratory	-----	0	0	2	1
21	MEC307	Computer Aided Manufacturing	-----	3	0	0	3
22	MEC307P	Computer Aided Manufacturing Laboratory	-----	0	0	2	1
23	MEC308	Manufacturing Technology II	-----	3	0	0	3

24	MEC308P	Manufacturing Technology II Laboratory	-----	0	0	2	1
25	MEC401	Operations Research	-----	3	0	0	3
26	MEC402	Internal Combustion Engines	MEC206	3	0	0	3

5) Professional Electives (4 Courses, 12 Credits) - (Category Code: PELEC)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	MEE301	Additive Manufacturing	-----	3	0	0	3
2	MEE302	C++ Programming for Mechanical Engineers	-----	2	0	2	3
3	MEE303	Computational Methods in Mechanical Engineering	MES201	3	0	0	3
4	MEE304	Data Analytics and Machine Learning	MES203	3	0	0	3
5	MEE305	Fluid Machinery	MEC202	3	0	0	3
6	MEE306	Fracture Mechanics	BSC102 / MES105 / MEC203	3	0	0	3
7	MEE307	Industrial Robotics	-----	3	0	0	3
8	MEE308	Sensors and Applications	ESC202	3	0	0	3
9	MEE401	Automobile Engineering	-----	3	0	0	3
10	MEE402	Biofluid Mechanics	-----	3	0	0	3
11	MEE403	Biomechanics	-----	3	0	0	3
12	MEE404	Composite Materials and Structures	-----	3	0	0	3
13	MEE405	Computer Aided Inspection	MEC303	3	0	0	3
14	MEE406	Computer Integrated Manufacturing	MEC306 / MEC307	3	0	0	3
15	MEE407	Cryogenics	-----	3	0	0	3
16	MEE408	Design for Manufacturing & Assembly	MEC205 / MEC306 / MEC203 MEE301	3	0	0	3
17	MEE409	Fluid Power Control	-----	3	0	0	3
18	MEE410	Gas Dynamics & Jet Propulsion	MEC206	3	0	0	3
19	MEE411	Heat Treatment Technology	MES105	3	0	0	3
20	MEE412	Machine Tools Design	MEC203 / MEC204 / MEC301 / MEC302 / MEC308	3	0	0	3
21	MEE413	Material Characterization Techniques	-----	3	0	0	3
22	MEE414	Material Handling Systems & Equipment	-----	3	0	0	3
23	MEE415	Mechanical Behaviour & Testing of Materials	-----	3	0	0	3
24	MEE416	Mechatronics and Industrial Automation	ESC202	3	0	0	3
25	MEE417	Metal Forming Technology	MEC205	3	0	0	3
26	MEE418	Micro and Nano Manufacturing	-----	3	0	0	3
27	MEE419	Non-destructive Testing	-----	3	0	0	3
28	MEE420	Non-traditional Machining Processes	-----	3	0	0	3
29	MEE421	Optimization Techniques for Engineering Design	-----	3	0	0	3
30	MEE422	Power Plant Engineering	MEC206	3	0	0	3
31	MEE423	Production Planning and Control	-----	3	0	0	3
32	MEE424	Programmable Logical Controllers	ESC202	3	0	0	3
33	MEE425	Refrigeration & Air-conditioning	MEC206	3	0	0	3
34	MEE426	Reverse Engineering	MEC306	3	0	0	3
35	MEE427	Supply Chain Management	-----	3	0	0	3
36	MEE428	Surface Engineering	BSC101 / MES105 / MEC205 / MEC308	3	0	0	3
37	MEE429	Sustainable Manufacturing	------	3	0	0	3

6) Open Electives (3 Courses, 9 Credits) - (Category Code: OELEC)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	MEO301	Artificial Intelligence in Manufacturing	MES203	3	0	0	3
2	MEO302	Industrial Engineering & Management	-----	3	0	0	3
3	MEO303	Maintenance Engineering & Management	-----	3	0	0	3
4	MEO401	3D Printing and Design	-----	3	0	0	3
5	MEO402	Financial & Accounting Management	-----	3	0	0	3
6	MEO403	Industry 4.0	MEE308	3	0	0	3
7	MEO404	Product Design and Ergonomics	-----	3	0	0	3
8	MEO405	Renewable Energy Engineering	-----	3	0	0	3
9	MEO406	Soft Computing Techniques	MEE302 / MES203	3	0	0	3
10	MEO407	Virtual Reality (VR)	MEE302	3	0	0	3

7) Mandatory and Audit Courses (6 Courses, 0 Credits) - (Category Code: MAA)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	MAA101	Induction Programme	-----	3 Weeks			0
2	MAA102	Sports and Yoga / NCC / NSS	-----	0	0	2	0
3	MAA103	Indian Knowledge System	-----	2	0	0	0
4	MAA104	Sports and Yoga / NCC / NSS	-----	0	0	2	0
5	MAA201	Environmental Science	-----	2	0	0	0
6	MAA202	Constitution of India	-----	2	0	0	0

8) Project, Seminar, and Internship (4 Courses, 15 Credits) - (Category Code: PPS)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	MEP301	Summer Internship	-----	4 Weeks (min.)			2
2	MEP401	Summer Internship	-----	4 Weeks (min.)			2
3	MEP402	Seminar	-----	0	0	4	2
4	MEP403	Mechanical Engineering Project	-----	0	0	18	9

Note

1) Seminar - 2 Credits - Students will study a recent research paper under the supervision of a faculty member of this department and present the same in the form of a seminar. The seminar topic must be from an area of Mechanical Engineering different from their project topic.
2) Summer Internship (industrial or academic) - 2 Credits each - Students will undergo training / internship for a minimum period of 4 weeks during the summer vacation of the second year and third year. Attachment with IISc / IITs / NITs or technical universities in India and abroad (excluding NIAMT, Ranchi) is also allowed in lieu of the industrial training. Evaluation will be conducted during the seventh semester. The evaluation will be based on technical report and presentation.
3) Mechanical Engineering Project - 9 Credits - The project work will be done in an area of Mechanical Engineering. Interdisciplinary work where Mechanical Engineering is primary can also be done. The project is mandatory for Level 6, while the students of Levels 4 to 5 may opt for one of the following in lieu of the project.
    a) Three or more courses related to Mechanical Engineering and have not been studied by the student (as per the course structure in this document) from SWAYAM or similar channels leading to 9 (nine) credits.
    b) One full semester internship in a Mechanical Engineering related industry (academic internships are not allowed) during the VIII semester. The internship should be project-based. Upon completion of internship, student will submit a report duly endorsed by a competent authority from the industry where the internship was done.

9) Honors Courses (5 Courses, 20 Credits) - (Category Code: HONS)

S#	Code	Name of subject	Pre-requisites	L	T	P	Credits
1	MEH221	Advanced Engineering Materials	MES105	3	1	0	4
2	MEH222	Advanced Fluid Mechanics	MEC202	3	1	0	4
3	MEH223	Advanced Welding Technology	MEC205	3	1	0	4
4	MEH311	Fuels, Combustion and Emission Control	MEC206	3	1	0	4
5	MEH312	Analysis of Thermal Power Cycles	MEC206	3	1	0	4
6	MEH313	Computational Fluid Dynamics	MEC202	3	0	0	3
7	MEH313P	Computational Fluid Dynamics Laboratory	-----	0	0	2	1
8	MEH321	Advanced Heat Transfer	MEC304	3	1	0	4
9	MEH322	Advanced Metal Forming Technology	MEC205	3	1	0	4
10	MEH323	Mechanical Vibrations & Analysis	-----	3	1	0	4
11	MEH411	Finite Element Methods in Mechanical Engineering	MES201 / MEC304	3	0	0	3
12	MEH411P	Finite Element Methods in Mechanical Engineering Lab.	-----	0	0	2	1
13	MEH412	Advanced Metal Cutting Technology	MES105 / MEC308	3	1	0	4
14	MEH413	Design of Heat Transfer Equipment	MEC304	3	1	0	4
15	MEH421	Advanced CAD and Computational Geometry	MEC306	3	0	0	3
16	MEH421P	Advanced CAD and Computational Geometry Laboratory	-----	0	0	2	1
17	MEH422	Dies, Moulds & Tools Engineering	MES105 / MEC205 / MEC308	3	0	0	3
18	MEH422P	Dies, Moulds & Tools Engineering Laboratory	-----	0	0	2	1
19	MEH423	Advanced Internal Combustion Engines	MEC402	3	1	0	4

10) Multidisciplinary Minor in Mechanical Engineering (5 Courses, 20 Credits) - (Category Code: MDM)

S#	Code	Name of subject (Matching code in B. Tech. (Mech.))	Pre-requisites	L	T	P	Credits
1	MEM121	Engineering Mechanics (MEC101)	-----	3	1	0	4
2	MEM122	Engineering Thermodynamics (MEC201)	-----	3	1	0	4
3	MEM123	Fluid Mechanics and Hydraulic Machines (MEC202)	-----	3	0	0	3
4	MEM123P	Fluid Mechanics and Hydraulic Machines Lab. (MEC202P)	-----	0	0	2	1
5	MEM131	Kinematics of Machines (MEC204)	-----	3	1	0	4

6	MEM132	Manufacturing Technology	-----	3	0	0	3
7	MEM132P	Manufacturing Technology Laboratory	-----	0	0	2	1
8	MEM133	Thermal Engineering (MEC206)	MEM122	3	0	0	3
9	MEM133P	Thermal Engineering Laboratory (MEC206P)	-----	0	0	2	1
10	MEM141	Dynamics of Machines (MEC301)	MEM124	3	0	0	3
11	MEM141P	Dynamics of Machines Laboratory (MEC301P)	-----	0	0	2	1
12	MEM142	Design of Machine Elements (MEC206)	-----	3	1	0	4
13	MEM143	Heat and Mass Transfer (MEC304)	MEM122	3	0	0	3
14	MEM143P	Heat and Mass Transfer Laboratory (MEC304P)	-----	0	0	2	1

11) Multidisciplinary Minor in Manufacturing Engineering (5 Courses, 20 Credits) - (Category Code: MDM)

S#	Code	Name of subject (Matching code in B. Tech. (Mech.))	Pre-requisites	L	T	P	Credits
1	MEM221	Engineering Mechanics (MES101)	-----	3	1	0	4
2	MEM222	Engineering Materials (MEC105)	-----	3	0	0	3
3	MEM222P	Engineering Materials Laboratory (MEC105P)	-----	0	0	2	1
4	MEM231	Computer Aided Design and Manufacture	-----	3	0	0	3
5	MEM231P	Computer Aided Design and Manufacture Laboratory	-----	0	0	2	1
6	MEM232	Manufacturing Technology I (MEC205)	-----	3	0	0	3
7	MEM232P	Manufacturing Technology I Laboratory (MEC205P)	-----	0	0	2	1
8	MEM233	Manufacturing Technology II (MEC308)	MEM232	3	0	0	3
9	MEM233P	Manufacturing Technology II Laboratory (MEC308P)	-----	0	0	2	1
10	MEM241	Engineering Metrology	-----	3	0	0	3
11	MEM241P	Engineering Metrology Laboratory	-----	0	0	2	1
12	MEM242	Dies, Moulds & Tools Engineering (MEH422)	MES105 / MEM231 / MEM232	3	0	0	3
11	MEM242P	Dies, Moulds & Tools Engineering Laboratory (MEH422P)	-----	0	0	2	1
14	MEM243	Precision Manufacturing	-----	3	1	0	4

COURSE STRUCTURE

SEMESTER 1

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	BSC101	Engineering Chemistry	BSC	-----	3	0	0	3
2	BSC102	Mathematics I (Calculus & Linear Algebra)	BSC	-----	3	1	0	4
3	ESC101	Basic Electrical and Electronics Engineering	ESC	-----	3	0	0	3
4	MES101	Engineering Mechanics	ESC	-----	3	1	0	4
5	MES102	Engineering Graphics & Design Practice	ESC	-----	1	0	4	3
6	MES103	Workshop Practice	ESC	-----	0	0	2	1
7	BSC101P	Engineering Chemistry Laboratory	BSC	-----	0	0	2	1
8	ESC101P	Basic Electrical and Electronics Engineering Laboratory	ESC	-----	0	0	2	1
9	MAA101	Induction Programme	MAA	-----	3 Weeks			0
10	MAA102	Sports and Yoga / NCC / NSS	MAA	-----	0	0	2	0
				Total Credits			**20**	

SEMESTER 2

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	BSC103	Engineering Physics	BSC	-----	3	0	0	3
2	BSC104	Mathematics II (Differential Equations & Complex Analysis)	BSC	-----	3	1	0	4
3	HSM101	English Communication for Professionals	HSM	-----	2	0	0	2
4	MES104	Professional Ethics and Universal Human Values	HSM	-----	3	0	0	3
5	MES105	Engineering Materials	ESC	-----	3	0	0	3
6	MES106	Machine Drawing Practice	ESC	MES102	1	0	4	3
7	MAA103	Indian Knowledge System	MAA	-----	2	0	0	0
8	BSC103P	Engineering Physics Laboratory	BSC	-----	0	0	2	1
9	HSM101P	English Communication for Professionals Laboratory	HSM	-----	0	0	2	1
10	MES105P	Engineering Materials Laboratory	ESC	-----	0	0	2	1
11	MAA104	Sports and Yoga / NCC / NSS	MAA	-----	0	0	2	0
				Total Credits			**21**	

SEMESTER 3

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	MES201	Mathematics III (Transforms & Numerical Analysis)	BSC	-----	3	1	0	4
2	MEC201	Engineering Thermodynamics	CORE	-----	3	1	0	4
3	MEC202	Fluid Mechanics and Hydraulic Machines	CORE	-----	3	0	0	3
4	MEC203	Strength of Materials	CORE	MES101	3	0	0	3
5	MEC204	Kinematics of Machines	CORE	-----	3	1	0	4
6	MAA201	Environmental Science	MAA	-----	2	0	0	0
7	MEC202P	Fluid Mechanics and Hydraulic Machines Laboratory	CORE	-----	0	0	2	1
8	MEC203P	Strength of Materials Laboratory	CORE	-----	0	0	2	1
				Total Credits			**20**	

SEMESTER 4

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	MES202	Mathematics IV (Probability, Statistics & Quality Control)	BSC	-----	3	1	0	4
2	MES203	Programming for Problem Solving using Python	ESC	-----	3	0	0	3
3	ESC201	Applied Electrical and Electronics Engineering	ESC	ESC101	3	0	0	3
4	MEC205	Manufacturing Technology I	CORE	-----	3	0	0	3
5	MEC206	Thermal Engineering	CORE	MEC201	3	0	0	3
6	MAA202	Constitution of India	MAA	-----	2	0	0	0
7	MES203	Programming for Problem Solving using Python Laboratory	ESC	-----	0	0	2	1
8	ESC201	Applied Electrical and Electronics Engineering Laboratory	ESC	-----	0	0	2	1
9	MEC205	Manufacturing Technology I Laboratory	CORE	-----	0	0	2	1
10	MEC206	Thermal Engineering Laboratory	CORE	-----	0	0	2	1
11	-----	Multidisciplinary Minor I	MDM	To be opted from another department				
12	MEH22X	Honours Course I* (Plus MEH22XP as applicable)	HONS	As per the course	3	0	2	4
					3	1	0	
				Total Credits			**20 / 24***	

SEMESTER 5

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	MEC301	Dynamics of Machines	CORE	MEC204	3	0	0	3
2	MEC302	Design of Machine Elements	CORE	-----	3	1	0	4
3	MEC303	Metrology & Measurements	CORE	-----	3	0	0	3
4	MEC304	Heat and Mass Transfer	CORE	MEC201	3	0	0	3
5	MEC305	Manufacturing Automation	CORE	-----	3	0	0	3
6	MEC301P	Dynamics of Machines Laboratory	CORE	-----	0	0	2	1
7	MEC303P	Metrology & Measurements Laboratory	CORE	-----	0	0	2	1
8	MEC304P	Heat and Mass Transfer Laboratory	CORE	-----	0	0	2	1
9	MEP301	Summer Internship	PPS	-----	4 Weeks (Min.)			2
10	-----	Multidisciplinary Minor II	MDM	To be opted from another department				
11	MEH31X	Honours Course II* (Plus MEH31XP as applicable)	HONS	As per the course	3	0	2	4
					3	1	0	
				Total Credits		**21 / 25***		

SEMESTER 6

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	MEC306	Computer Aided Design	CORE	-----	3	0	0	3
2	MEC307	Computer Aided Manufacturing	CORE	-----	3	0	0	3
3	MEC308	Manufacturing Technology II	CORE	MEC205	3	0	0	3
4	MES301	Professional Development	HSM	-----	2	1	0	3
5	MEE3XX	Professional Elective I	PELEC	-----	3	0	0	3
6	MEO3XX	Open Elective I	OELEC	-----	3	0	0	3
7	MEC306P	Computer Aided Design Laboratory	CORE	-----	0	0	2	1
8	MEC307P	Computer Aided Manufacturing Laboratory	CORE	-----	0	0	2	1
9	MEC308P	Manufacturing Technology II Laboratory	CORE	-----	0	0	2	1
10	-----	Multidisciplinary Minor III	MDM	To be opted from another department				
11	MEH32X	Honours Course III* (Plus MEH32XP as applicable)	HONS	As per the course	3	0	2	4
					3	1	0	
				Total Credits		**21 / 25***		

SEMESTER 7

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	MES401	Innovation and Entrepreneurship	HSM	-----	3	0	0	3
2	MEC401	Operations Research	CORE	-----	3	0	0	3
3	MEC402	Internal Combustion Engines	CORE	MEC206	3	0	0	3
4	MEE4XX	Professional Elective II	PELEC	-----	3	0	0	3
5	MEE4XX	Professional Elective III	PELEC	-----	3	0	0	3
6	MEO4XX	Open Elective II	OELEC	-----	3	0	0	3
7	MEP401	Summer Internship	PPS	-----	4 Weeks (Min.)			2
8	-----	Multidisciplinary Minor IV	MDM	To be opted from another department				
9	MEH41X	Honours Course IV* (Plus MEH41XP as applicable)	HONS	As per the course	3	0	2	4
					3	1	0	
				Total Credits		**20 / 24***		

SEMESTER 8

S#	Code	Name of subject	Category	Pre-requisites	L	T	P	C
1	MEE4XX	Professional Elective IV	PELEC	-----	3	0	0	3
2	MEO4XX	Open Elective III	OELEC	-----	3	0	0	3
3	MEP402	Seminar	PPS	-----	0	0	4	2
4	MEP403	Mechanical Engineering Project	PPS	-----	0	0	18	9
5	-----	Multidisciplinary Minor V	MDM	-----	3	0	2	4
6	MEH42X	Honours Course V* (Plus MEH42XP as applicable)	HONS	As per the course	3	0	2	4
					3	1	0	
				Total Credits		**17 / 21***		

* ***These subjects / credits are applicable to Level 6 (Honours Course).***

SYLLABUS FOR REGULAR COURSES

Course code / Category	**BSC101 / Basic Sciences**				
Course title	**Engineering Chemistry**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**1**
Pre-requisites if any	**-----**				

Unit 1 Analytical techniques for engineers.

Role of materials in engineering fields - Qualitative and quantitative analysis - Emerging trends and applications of analytical techniques for engineering - Instrumental methods of analysis: principles and applications of UV-visible spectroscopy, IR spectroscopy and chromatography (GLC and HPLC) - Nuclear magnetic resonance and BET surface area analysis - Thermo-gravimetry: TGA - Microscopy: SEM and TEM.

Unit 2 Corrosion and material protection.

Introduction to corrosion and its impact on engineering materials - Mechanism and types / forms of corrosion - Factors that enhance corrosion and choice of parameters to mitigate corrosion - Corrosion prevention techniques - Advanced surface coatings and corrosion inhibitors - Case studies and real-world applications in corrosion prevention.

Unit 3 Electrochemical energy systems.

Electrode potential - Electrochemical series - Nernst equation and its applications - Characteristics of a battery - Classification of batteries - High energy electrochemical energy systems - Lithium-ion batteries: principle, construction, working, advantages and applications - Na-ion battery - New emerging fuel cells: working principles, advantages and applications - Solar cells: types Importance of silicon single crystal, polycrystalline and amorphous silicon solar cells - working principles, characteristics and applications - Green hydrogen technology.

Unit 4 Nanomaterials.

Nanomaterials classification - Quantum effects - Top-down and bottom–up approach - Synthesis methods: ball milling, RF sputtering, pulsed laser deposition, sol-gel technique and reduction method - Applications of nanomaterials - Fundamentals and fabrication of sensors and materials used in sensors - Fundamentals and fabrication of super capacitor and materials used in super capacitor.

Unit 5 Polymers.

Classification of polymers - Mechanism of polymerisation - Techniques of polymerization: bulk, solution, suspension and emulsion polymerization - Molecular weight of polymers - Number average and weight average molecular weight - Glass transition temperature and its significance - Structure-property relationship - Synthesis, properties and applications of commercially important polymers: polypropylene, PVC, Teflon, nylon, Bakelite and polyurethane - Functional polymers: conductive polymers, elastomers, biopolymer, polymer composites and industrial applications - Liquid crystalline polymers.

Textbooks / References.

1) Hobart Hurd Willard, Lynne Merritt, and John A. Dean, Instrumental Methods of Chemical Analysis, Wadsworth Publishing Company.
2) Gurdeep R. Chatwal, Instrumental Methods of Chemical Analysis, Himalaya Publishing House.
3) Jain and Jain, A Textbook of Engineering Chemistry, Dhanpat Rai Publications.
4) S. S. Dara, A Textbook of Engineering Chemistry, S. Chand Publications.
5) Shashi Chawla, A Textbook of Engineering Chemistry, Dhanpat Rai Publications, 2010.
6) Jianmin Ma, Battery Technologies: Materials and Components, John Wiley & Sons.
7) Charles P. Poole and Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons, 2003.
8) Ryan O' Hayre and Suk-Won Cha, Fuel Cell Fundamentals, John Wiley & Sons, 2016.
9) G. Odian, Principles of Polymerization, John Wiley & Sons, 2004.
10) F. W. Billmeyer, Textbook of Polymer Science, John Wiley & Sons, 2007.

Course code / Category	**BSC102 / Basic Sciences**				
Course title	**Mathematics I (Calculus & Linear Algebra)**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**1**
Pre-requisites if any	**-----**				

Unit 1 Matrices and linear algebra.

Matrices and vectors: addition, scalar multiplication and matrix multiplication - Linear systems of equations - Linear independence - Rank of a matrix - Determinants - Cramer's rule - Inverse of a matrix - Gauss elimination and Gauss-Jordan elimination - Eigenvalues and eigenvectors - Symmetric, skew-symmetric and orthogonal matrices - Eigen bases - Diagonalization - Inner product spaces - Gram-Schmidt orthogonalization - Vector space - Linear dependence of vectors, basis and dimension - Linear transformations (maps), range and kernel of a linear map, rank and nullity - Inverse of a linear transformation - Rank-nullity theorem - Composition of linear maps - Matrix associated with a linear map.

Unit 2 Differential calculus.

Rolle's theorem - Mean value theorems - Indeterminate forms and L' Hospital's rule - Maxima and minima - Expansions of function of one variable using Taylor's and Maclaurin's series - Asymptotes - Curve tracing - Limit and continuity of two variables - Partial and total derivatives - Chain rule - Jacobian - Taylor's theorem - Higher order derivatives - Maxima and minima of two variables - Method of Lagrange's multipliers.

Unit 3 Integral calculus.

Beta and Gamma functions - Evaluation of double integrals in Cartesian and polar coordinates - Change of order of integration - Evaluation of triple integrals in Cartesian, spherical and cylindrical coordinates - Change of variables - Applications to area, volume, surface area and centre of mass - Vector differentiation - Gradient, divergence and curl - Line integrals and arc length parameterization - Surface integral - Volume integral - Path independence - Statements and illustrations of theorems of Green, Stokes and Gauss - Applications.

Textbooks / References.

1) Erwin Kreyszig, Advanced Engineering Mathematics, 10e, Wiley Eastern Ltd.
2) Howard Anton and Chris Rorres, Elementary Linear Algebra, 10e, John Wiley & Sons.
3) K. D. Joshi, Calculus for Scientists and Engineers, CRC Press.
4) G. B. Thomas and R. L. Finney, Calculus and Analytic geometry, 9e, Pearson Reprint.
5) B. V. Ramana, Higher Engineering Mathematics, 11th Reprint, Tata McGraw-Hill, New Delhi.
6) D. Poole, Linear Algebra: A Modern Introduction, 2e, Brooks/Cole.
7) B. S. Grewal, Higher Engineering Mathematics, 36e, Khanna Publishers.
8) Serge Lang, Linear Algebra, 3e, Springer.
9) Gilbert Strang, Linear Algebra and its applications, 4e, Cengage Learning.
10) Sudhir Ghorpade and Balmohan Limaye, A course in Calculus and Real Analysis, 1e, Springer-Verlag, New York.

Course code / Category	**ESC101 / Basic Engineering Sciences**				
Course title	**Basic Electrical and Electronics Engineering**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**1**
Pre-requisites if any	**-----**				

Unit 1 Elementary concepts of electric circuits.

Concepts of DC electric circuits - Basic terminology including voltage, current, power, resistance and EMF - Resistances in series and parallel - Current and voltage division rules - Capacitors and inductors - V-I relations and energy stored - Ohm's and Kirchhoff's laws - Star-delta conversion (resistive networks only-derivation not required) - Problems - Analysis of DC electric circuits - Mesh current method - Matrix representation - Solution of network equations - Node voltage methods - Matrix representation - Solution of network equations by matrix methods - Numerical problems.

Unit 2 Elementary concepts of magnetic circuits.

Electromagnetic induction and AC fundamentals - Magnetic circuits - Basic terminology: MMF - field strength - flux density - reluctance - Comparison between electric and magnetic circuits - Series and parallel magnetic circuits with composite materials - Electromagnetic induction: Faraday's laws, problems - Lenz's law - Statically induced and dynamically induced EMFs - Self-inductance and mutual inductance - Coefficient of coupling - Alternating current fundamentals: generation of alternating voltages - Representation of sinusoidal waveforms: frequency, period, average, RMS values and form factor of waveforms - Numerical problems.

Unit 3 AC circuits.

Phasor representation of sinusoidal quantities - Trigonometric, rectangular, polar and complex forms - Analysis of simple AC circuits: purely resistive, inductive and capacitive circuits - Inductive and capacitive reactance - Concept of impedance - Average power factor - Analysis of RL, RC and RLC series circuits - Active, reactive and apparent power - Three phase AC systems: generation of three phase voltages - advantages of three phase systems - star and delta connections (balanced only) - relation between line and phase voltages - line and phase currents - Simple problems.

Unit 4 Introduction to semiconductor devices.

Evolution of electronics - Vacuum tubes to nano electronics - Resistors, capacitors and inductors (constructional features not required): types - specifications - Standard values and colour coding - PN junction diode: principle of operation - V-I characteristics - principle of avalanche breakdown - Bipolar junction transistors: PNP and NPN structures - Principle of operation, relation between current gains in CE, CB and CC, input and output characteristics of common emitter configuration.

Unit 5 Basic electronic circuits and instrumentation.

Rectifiers and power supplies - Block diagram description of a DC power supply - Working of a full-wave bridge rectifier and capacitor filter (no analysis) - Working of simple Zener voltage regulator - Amplifiers: block diagram of public address system - Circuit diagram and working of common emitter (RC coupled) amplifier with its frequency response - Concept of voltage divider biasing - Electronic instrumentation: block diagram of an electronic instrumentation system.

Unit 6 Digital electronics.

Introduction to number systems - Basic Boolean laws - Reduction of Boolean expressions and implementation with logic gates.

Textbooks / References.

1) D. P. Kothari and I. J. Nagrath, Basic Electrical Engineering, Tata McGraw Hill Co.
2) Floyd, Electronic Devices, 9e, Pearson Education.
3) R. J. Smith and R. C. Dorf, Circuits, Devices and Systems, 5e, John Wiley & Sons.
4) P. S. Dhogal, Basic Electrical Engineering, Vols. I & II, 42nd Reprint, McGraw Hill.

5) A. P. Malvino, D. P. Leach and Gowtham Sha, Digital Principles and Applications, 6e, Tata McGraw Hill Co.
6) Vincent Del Toro, Electrical Engineering Fundamentals, Prentice Hall India.

Course code / Category	**MES101 / Basic Engineering Sciences**				
Course title	**Engineering Mechanics**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**1**
Pre-requisites if any	**-----**				

Unit 1.

Introduction - Basic concepts of force, moment and couple - Equilibrium of coplanar force systems - Friction.

Unit 2.

Internal forces in members of Trusses and (Method of joints and Method of Sections) and Analysis of Frames (Method of Members).

Unit 3.

Properties of surfaces: centroid and moment of inertia of plane figures - Polar moment of inertia - Product of inertia - Principal axes - Principle of virtual work and applications.

Unit 4.

Kinetics of rectilinear motion and curvilinear motion of a particle - D'Alembert's principle - Linear momentum and impulse - Angular momentum - Work and energy - Impact.

Unit 5.

Rigid body motion: kinematics of rotation equation of motion of a rotating rigid body - Compound pendulum - Energy equations for rotating bodies - Plane motion: kinematics of plane motions - instantaneous centre of rotation - equations of plane motion of a rigid body and energy equations for plane motion - D'Alembert's principle for rotation and plane motion.

Textbooks / References.

1) R. C. Hibbeler, Engineering Mechanics - Statics, 14e, Prentice Hall.
2) R. C. Hibbeler, Engineering Mechanics - Dynamics, 14e, Prentice Hall.
3) F. P. Beer, E. R. Johnston, et al., Vector Mechanics for Engineers: Statics and Dynamics, 12e, McGraw-Hill Co.
4) S. Timoshenko, D. H. Young, J. V. Rao and Sukumar Pati, Engineering Mechanics, McGraw-Hill Co.
5) J. L. Meriam and L. G. Kraige, Engineering Mechanics - Statics, 8e, John Wiley and Sons.
6) J. L. Meriam and L. G. Kraige, Engineering Mechanics - Dynamics, 8e, John Wiley and Sons.
7) Bedford and W. Fowler, Engineering Mechanics - Statics and Dynamics, Pearson Publications.

Course code / Category	**MES102 / Basic Engineering Sciences**				
Course title	**Engineering Graphics and Design Practice**				
Scheme and credits	L	T	P	C	Semester
	1	**0**	**4**	**3**	**1**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Graphics as language for communication - Need for instruments, scaling and upkeep of instruments - Freehand lettering - Construction of certain common curves: ellipse, parabola, and hyperbola, cycloid and involute - Tangents to these curves.

Unit 2 Orthographic projections.

Need for orthographic projection - Preferring the first angle projection - Conversion of pictorial views into orthographic views - Dimensioning - IS codes.

Unit 3 Solid geometry.

Projections of solids: projection of simple solids, like cylinders, cones, prisms, pyramids, etc. with locations of specific lines or points on the surface - Sections of solids: need for sectioning - exercises with simple objects like prisms, pyramids and cones - true shape of sections.

Unit 4 Development and interpenetration of sheet metal components.

Development of simple surfaces and non-developable surfaces - Approximate solutions for sphere - Transition pieces - Application to sheet metal work - Interpenetration of simple solids like, prism-prism, cone-cylinder and cylinder-cylinder.

Unit 5 Isometric Projection.

Definition of isometric projection - Isometric scales - Simple exercises on isometric views - Perspective projection of prisms and pyramids by vanishing point method.

Unit 6 Overview of computer graphics.

Listing the computer technologies that impact on graphical communication - Demonstrating knowledge of theory of CAD software [such as: Menu System, Toolbars (Standard, Object Properties, Draw, Modify and Dimension), Drawing Area (Background, Crosshairs, Coordinate System), Dialog

boxes and windows, Shortcut menus (Button Bars), Command Line (where applicable) and Status Bar - Different methods of zoom as used in CAD - Select and erase objects - Isometric views of lines, planes, simple and compound solids.

Unit 7 CAD drawing: Customization, applying dimensions and annotations to drawings.

Setting up of drawing page and printer including scale settings, setting up of units and drawing limits - ISO and ANSI standards for coordinate dimensioning and tolerancing - Orthographic constraints, snap to objects manually and automatically - Producing drawings by using various coordinate input entry methods to draw straight lines - Applying various ways of drawing circles - Setting up and use of layers, layers to create drawings, create, edit and use customized layers - Changing line lengths through modifying existing lines (extend / lengthen) - Printing documents using the print command - Orthographic projection techniques - Drawing sectional views of composite right regular geometric solids and project the true shape of the sectioned surface - Drawing annotations - Computer-aided design (CAD) software modelling of parts and assemblies - Parametric and nonparametric solids, surfaces, and wireframe models - Part editing and two-dimensional documentation of models - Planar projection theory including sketching of perspective, isometric, multi-view, auxiliary, and section views - Spatial visualization exercises - Dimensioning guidelines - Tolerancing techniques - Dimensioning and scale multi-views of dwelling.

Textbooks / References

1) SP46 (2003), Engineering Drawing Practice for Schools and Colleges, Bureau of Indian Standards.
2) N. D. Bhatt, V. M. Panchal and P. R. Ingle, Engineering Drawing, Charotar Publishing House.
3) M. B. Shah and B. C. Rana, Engineering Drawing and Computer Graphics, Pearson Education.
4) B. Agrawal and C. M. Agrawal, Engineering Graphics, TMH.
5) K. L. Narayana and P. Kannaiah, Textbook on Engineering Drawing, SciTech Publishers.
6) H. R. Gopalakrishna, Engineering Drawing, Subhas Stores, Bengaluru.

Course code / Category	**BSC103 / Basic Sciences**				
Course title	**Engineering Physics**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**2**
Pre-requisites if any	**-----**				

Unit 1 Harmonic oscillation.

Simple harmonic motion - Damped and forced simple harmonic oscillator with examples - Damped harmonic oscillator - Heavy, critical and light damping - Amplitude and energy decay in a damped harmonic oscillator - Forced oscillation and resonance condition.

Unit 2 Wave optics.

Superposition of waves - Interference, thin-film interference and Newton's ring - Diffraction of light - Diffraction due to single slit and double slits - Unpolarized and polarized light - Polarization of wave - Production of polarized wave - Brewster's law - Malus' law - Double refraction - Retardation plate - Analysis of polarization.

Unit 3 Quantum mechanics.

Inadequacy of classical mechanics - Wave and particle duality of radiation - de Broglie concept of matter waves - Heisenberg's uncertainty principle - Schrödinger wave equation - Interpretation of wave function - Eigen values and Eigen functions - Superposition principle - Particle confined in one dimensional infinite square well potential.

Unit 4 Lasers.

Introduction to lasers - Characteristics of lasers - Spontaneous and stimulated emissions - Einstein's coefficients - Population inversion and lasing action - He-Ne laser and Semiconductor laser systems - Applications.

Unit 5 Fibre optics.

Snell's law-optical fibre - Principle and construction - Acceptance cone - Numerical aperture - Types of fibres - Fibre-optic communication principle - Fiber-optic sensors.

Unit 6 Physics of materials.

Crystalline and amorphous solids - System of crystals - Miller indices - Atomic radius - Coordination number - Atomic packing factor calculation - Bragg's law - Classical and quantum theory of electrical conductivity - Origin of band theory of solids - Semiconductors: extrinsic and intrinsic - concept of band gap - PN junction diode - Optical properties - Magnetism: types and properties - hard and soft magnetic materials and applications - Dielectric properties of materials - Superconductivity - types, Meissner effect and applications.

Textbooks / References.

1) David Halliday, Robert Resnik and Jearl Walker, Fundamentals of Physics: Electricity and Magnetism, 10e, Wiley India Pvt. Ltd.
2) W. Saslow, Electricity, Magnetism and Light, 1e, Elsevier, 2002.
3) S. Mahajan and S. R. Choudhury, Electricity, Magnetism and Electromagnetic Theory, Tata McGraw-Hill Pub. Co., 2017.
4) F. A. Jenkins and H. E. White, Fundamentals of Optics, McGraw-Hill Inc., 1981.
5) R. K. Gaur and S. L. Gupta, Engineering Physics, Dhanpat Rai Publications.
6) W. T. Silfvast, Laser Fundamentals, 2e, Cambridge University press, New York, 2004.
7) Charles Kittel, Introduction to Solid State Physics, 8e, John Wiley & Sons, NJ, USA, 2005.

Course code / Category	**BSC104 / Basic Sciences**				
Course title	**Mathematics II (Differential Equations and Complex Analysis)**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**2**
Pre-requisites if any	**-----**				

Unit 1 Ordinary differential equations.

Exact, linear and Bernoulli's equations - Euler's equations - Equations not of first degree: equations solvable for p - equations solvable for y - equations solvable for x - Clairaut's type - Second order linear differential equations with variable coefficients - Method of variation of parameters - Cauchy-Euler equation - Power series solutions - Legendre polynomials - Bessel functions of the first kind and their properties.

Unit 2 Complex variables - Differentiation.

Differentiation - Cauchy-Riemann equations - Analytic functions - Harmonic functions - Finding harmonic conjugate - Elementary analytic functions (exponential, trigonometric and logarithm) and their properties - Conformal mappings - Mobius transformations and their properties.

Unit 3 Complex variables - Integration.

Contour integrals - Cauchy-Goursat theorem (without proof) - Cauchy Integral formula (without proof) - Liouville's theorem and Maximum-Modulus theorem (without proof) - Taylor's series, zeros of analytic functions and singularities - Laurent's series - Residues: Cauchy residue theorem (without proof) - Evaluation of definite integral involving sine and cosine - Evaluation of certain improper integrals using the Bromwich contour.

Unit 4 Laplace transforms.

Laplace transform of standard functions, derivatives and integrals - Inverse Laplace transform - Convolution theorem - Periodic functions - Solution of ordinary differential equation and simultaneous equations with constant coefficients and integral equations by Laplace transform.

Unit 5 Partial differential equations.

Formation of partial differential equations by eliminating arbitrary constants and functions - Solution of first order equations - Four standard types - Lagrange's equation - Method of separation of variables.

Textbooks / References.

1) W. E. Boyce, R. C. DiPrima and D. B. Meade, Elementary Differential Equations and Boundary Value Problems, 9e, Wiley India.
2) Erwin Kreyszig, Advanced Engineering Mathematics, 9e, John Wiley & Sons, 2006.
3) D. Zill, W. S. Wright, and M. R. Cullen, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2011.
4) E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall India, 1995.
5) J. W. Brown and R. V. Churchill, Complex Variables and Applications, 7e, McGraw-Hill.
6) Ian N. Sneddon, Elements of Partial Differential Equations, Courier Corporation.

Course code / Category	**HSM101 / Humanities, Social Sciences and Management Sciences**				
Course title	**English Communication for Professionals**				
Scheme and credits	L	T	P	C	Semester
	2	**0**	**0**	**2**	**2**
Pre-requisites if any	**-----**				

Unit 1 Listening.

Barriers to listening: physical and psychological - steps to overcome them - Purposive listening practice - Active listening and anticipating the speaker - Use of technology in the professional world.

Unit 2 Speaking.

Fluency and accuracy in speech - Positive thinking - Kinds of thinking - Improving self-expression - Tonal variations - Listener oriented speaking - Group discussion practice - Interpersonal conversation - Developing persuasive speaking skills.

Unit 3 Reading.

Speed reading practice - Use of extensive readers - Trans-coding: verbal and nonverbal - Eye-reading practice - Analytical and critical reading practice - Introduction to ethics and values through case-study materials.

Unit 4 Writing.

Professional correspondence - Formal and informal letters - Argument writing practice - Perspectives in writing - Narrative writing - Different registers - Tone in formal writing - Summary writing practice - Introduction to reports.

Unit 5 Studying.

Reference skills - Use of dictionary, thesaurus, etc. - Importance of contents page, cover and back pages - Bibliography.

Textbooks / References.

1) Shirley Taylor, Communication for Business, Longman, New Delhi, 1999.
2) Robert Gannon, Best Science Writing: Readings and Insights, University Press, Hyderabad, 2000.
3) R. A. Boning, Multiple Reading Skills, McGraw-Hill, Singapore, 1990.
4) A. J. Harris and E. R. Sipay, How to Increase Reading Ability, Longman, New Delhi, 1990.

5) David Martin, Tough Talking, University Press, Hyderabad, 1994.

Course code / Category	**MES104 / Humanities, Social Sciences and Management Sciences**				
Course title	**Professional Ethics and Universal Human Values**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**2**
Pre-requisites if any	**-----**				

Unit 1 Engineering ethics.

Senses of engineering ethics - Moral issues - Types of inquiry - Moral dilemmas - Moral autonomy - Kohlberg's theory - Gilligan's theory - Consensus and controversy - Models of professional roles - Theories about right action - Self-interest - Customs and religion - Uses of ethical theories.

Unit 2 Engineering as social experimentation.

Engineering as experimentation - Engineers as responsible experimenters - Codes of ethics - A balanced outlook on law.

Unit 3 Safety, responsibilities, and rights.

Safety and risk - Assessment of safety and risk - Risk benefit analysis and reducing risk - Respect for authority - Collective bargaining - Confidentiality - Conflicts of interest - Occupational crime - Professional rights - Employee rights - Intellectual Property Rights (IPR) - Discrimination.

Unit 4 Global issues.

Multinational corporations - Environmental ethics - Computer ethics - Weapons development - Engineers as managers - Consulting engineers - Engineers as expert witnesses and advisors - Moral leadership - Code of conduct - Corporate Social Responsibility (CSR).

Unit 5 Human values.

Morals, values, and ethics - Integrity - Work ethics - Service learning - Civic virtue respect for others - Living peacefully - Caring - Sharing - Honesty - Courage - Valuing time - Cooperation - Commitment - Empathy - Self-confidence - Character - Spirituality - Introduction to Yoga and meditation for professional excellence and stress management.

Textbooks / References.

1) M. W. Martin and R. Schinzinger, Ethics in Engineering, Tata McGraw-Hill Co., New Delhi, 2003.
2) M. Govindarajan, S. Natarajan and V. S. Senthil Kumar, Engineering Ethics, Prentice Hall of India, New Delhi, 2004.
3) C. B. Fleddermann, Engineering Ethics, Pearson Prentice Hall, New Jersey, 2004.
4) C. E. Harris, M. S. Pritchard and M. J. Rabins, Engineering Ethics - Concepts and Cases, Thompson Wadsworth, United States, 2000.
5) E. G. Seebauer and R. L. Barry, Fundamentals of Ethics for Scientists and Engineers, Oxford University Press, Oxford, 2001.

Course code / Category	**MES105 / Basic Engineering Sciences**				
Course title	**Engineering Materials**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**2**
Pre-requisites if any	**-----**				

Unit 1 Crystallography and material characterization.

Crystalline and non-crystalline solids - Bonding in solids - Crystallography: basics, atomic radius, coordination number and atomic packing factor of BCC, FCC and HCP - Miller's indices - Polymorphism and allotropy - Solid solutions and intermetallic compounds - Laws of diffusion - Imperfection in solids: point defect, line defect, planar defect and volume defects - Material characterization: X-ray diffraction (XRD) - Bragg's law of diffraction - Scanning electron microscopy (SEM) - Transmission electron microscopy (TEM).

Unit 2 Phase diagrams, Ferrous and Non-ferrous alloys.

Phase diagrams: solidification of metals - phase rules - construction of phase diagram - binary isomorphous system - cooling curve of pure iron - Fe-Fe_3C equilibrium diagram - Eutectoid and Peritectic reactions - Ferrous alloys: classification of ferrous alloys - influence of alloying elements - Designation systems - Types of steels and cast iron - Typical compositions, properties and applications of ferrous alloys - Non-ferrous alloys: typical compositions, properties and applications of Aluminium, Copper, Titanium and Nickel and their alloys.

Unit 3 Strengthening mechanisms and heat treatment processes.

Strengthening mechanisms: dislocation and plastic deformation - mechanisms of strengthening in metals - Recovery, recrystallization, and grain growth - Dispersion strengthening and precipitation hardening - Heat treatment of steel: TTT diagram and CCT diagram - Heat treatment processes: annealing, normalizing, tempering and quenching - Jominy quench test - Case hardening: carburizing, nitriding, cyaniding, carbonitriding, flame hardening and induction hardening.

Unit 4 Mechanical properties of materials, failures and testing.

Mechanical properties: engineering material and their properties - compressive, shear and torsional deformation - Fracture and failure of materials: various types of fracture - brittle to ductile from low temperature to high temperature - Defects in materials - Deformation mechanisms - Failure mechanisms and influencing factors of ductile and brittle failure - Fatigue failure, creep failure and impact failure - Mechanical testing: universal testing machine - Stress–strain curve for ductile and brittle material - Hardness testing: Rockwell, Brinell's and Vicker's hardness tests - Impact testing: Charpy impact test and Izod impact test.

Unit 5 Polymer structures and composites.

Polymer structures: melting and glass transition temperatures - Polymer types - Forming techniques for plastics - Fabrication of elastomers, fibres and films - Composites: particle-reinforced composites, fibre-reinforced composites and structural composites.

Textbooks / References.

1) S. H. Avner, Introduction to Physical Metallurgy, 2e, Tata McGraw Hill Education Pvt. Ltd., 2009.
2) W. D. Callister Jr. and D. G. Rethwisch, Materials Science and Engineering: An Introduction, 9e, John Wiley & Sons Inc., 2013.
3) J. F. Shackelford and M. K. Muralidhara, Introduction to Materials Science for Engineers, 6e, Pearson Education, 2006.
4) P. R. Khangaonkar, An Introduction to Material Characterization, 1e, Penram International Publishing Pvt. Ltd., 2013.
5) M. F. Ashby, Materials Selection in Mechanical Design, 5e, Butterworth-Heinemann, 2017.
6) O. P. Khanna, A Textbook of Material Science & Metallurgy, 2e, Dhanpat Rai Publications, 2014.
7) K. G. Budinski and M. K. Budinski, Engineering Materials: Properties and Selection, 9e, Pearson, 2009.

Course code / Category	**MES106 / Basic Engineering Sciences**				
Course title	**Machine Drawing Practice**				
Scheme and credits	L	T	P	C	Semester
	1	**0**	**4**	**3**	**2**
Pre-requisites if any	**MES102**				

Unit 1 Standards.

Standardization - Code of practice for engineering drawing - BIS specifications - Welding symbols, riveted joints, keys and fasteners - Machining symbols - Surface finish indication - Guidelines to the selection of standard components like bolts, nuts, screws, keys, etc. - ISO and ANSI standards for coordinate dimensioning and tolerancing.

Unit 2 Dimensional and geometric tolerancing.

Limits and fits - Tolerancing of individual dimensions - Grades of tolerance - Standard tolerances - Specification of fits - Interchangeability - Selective assembly - Basic principles of geometric dimensioning and tolerancing - Functional and manufacturing datum - Preparation of production drawings and reading of part and assembly drawings.

Unit 3 Revisiting the CAD software.

Computer-aided design (CAD) software modelling of parts and assemblies - Parametric and nonparametric solids, surfaces, and wireframe models - Part editing and two-dimensional documentation of models - Planar projection theory including sketching of perspective, isometric, multi-view, auxiliary and section views - Spatial visualization exercises - Dimensioning guidelines - Tolerancing techniques.

Unit 4 Assembly drawing.

Preparation of assembled views (manual and CAD software) for shaft couplings (rigid and flexible), joints (cotter, knuckle and Hooke's), bearings (journal, footstep, thrust or collar), Plummer block, pulleys for flat belts, V-belts and ropes, engine parts (stuffing box, connecting rod, atomizer, spark plug and fuel injection pump), valves (stop valves, safety valves, relief valves and non-return valves) and machine tool components (drill jig, tail stock, tool post, tool head for shaping machine, machine vice and screw jack) - Preparation of bill of materials and tolerance data sheet.

Textbooks / References.

1) SP46 (2003), Engineering Drawing Practice for Schools and Colleges. Bureau of Indian Standards.
2) ASME Y14.5 (2018), Dimensioning and Tolerancing - Engineering Product Definition and Related Documentation Practices.
3) N. D. Bhatt and V.M. Panchal, Machine Drawing, 45e, Charotar Publishers, 2010.
4) N. D. Junnarkar, Machine Drawing, 1e, Pearson Education, 2004.
5) K. L. Narayana, P. Kannaiah and K. Venkata Reddy, Machine Drawing, 3e, New Age International Publishers.
6) S. T. Murthy, A Textbook of Computer Aided Machine Drawing, CBS Publishers, New Delhi, 2007.

Course code / Category	**MAA103 / Mandatory and Audit Courses**				
Course title	**Indian Knowledge System**				
Scheme and credits	L	T	P	C	Semester
	2	**0**	**0**	**0**	**2**
Pre-requisites if any	**-----**				

Unit 1 Bhāratīya civilization and development of knowledge system.

Genesis of the land - Antiquity of civilization - On the trail of lost river - Discovery of the Saraswatī river - The Saraswatī-Sindhu civilization - General structure of Vedic literature - Gurukul system of Vedic times (Aṣrama Dharma) - The Vedas - Main schools of philosophy - Ancient education system - Non-Vedic schools of philosophical systems (Cārvāka, Buddhist and Jain) - The Takṣaśilā University - The Nālandā University - Alumni - Knowledge export from Bhārata.

Unit 2 Arts and literature.

Art, music, and dance - Naṭarāja: a masterpiece of Bhāratīya art - Literature, life and works of Agastya, Vālmīki, Patañjali, Vedavyāsa, Caraka, Suśruta, Āryabhaṭa, Varāhamihira, Ādi Śaṅkarācārya, Bhāskarācārya - Components of a language - Paṇini's work on Sanskrit grammar - Phonetics in Sanskrit and the role of Sanskrit in natural language processing - The knowledge triangle: Prameya, Pramaṇa, and Saṃsaya.

Unit 3 Science, astronomy and mathematics.

Concept of matter, life and universe - Gravity - Sage Agastya's model of battery - Velocity of light - Aeronautics - Vedic Cosmology and modern concepts - Bhāratīya Kāla-gaṇanā - History and culture of Astronomy, Sun, Earth, Moon, and Eclipses - Indian Mathematics - Great Mathematicians and their contributions - Arithmetic operations - Geometry (Sulba Sutras) - Trigonometry - Concepts of Zero and Pi - Number system - Pythagoras theorem and Vedic Mathematics.

Unit 4 Engineering, technology and architecture.

Pre-Harappan and Sindhu valley civilization - Town planning and architecture - Temple architecture - Vastu sastra - Laboratory and apparatus - Dyes, paints, and cements - Glass and pottery - Metallurgy, metals, and metalworking technology (Copper, Gold, Zinc, Mercury, Lead, Silver, Iron and Steel).

Unit 5 Life, environment, health and social science.

Life science in plants - Anatomy - Agriculture - Ecology and environment - Health, wellness, and psychology - Āyurveda: integrated approach to healthcare, medicine, surgery, yoga, etc. - Governance and public administration - Ancient agricultural trends and practices.

Textbooks / References.

1) B. C. Chauhan, The Knowledge System of Bhārata.
2) S. Raha, et al., History of Science in India, National Academy of Sciences, India and The Ramakrishna Mission Institute of Culture, Kolkata.
3) B. Mahadevan, V. R. Bhat and R. N. N. Pravana, Introduction to Indian Knowledge System Concepts and Applications, PHI Learning.
4) Pradeep Kohle, et al., Pride of India - A Glimpse of India's Scientific Heritage, Samskrit Bharati.
5) Keshav Dev Verma, Vedic Physics, Motilal Banarsidass Publishers.
6) Suresh Soni, India's Glorious Scientific Tradition, Ocean Books Pvt. Ltd.

Course code / Category	**MES201 / Basic Sciences**				
Course title	**Mathematics III (Transforms & Numerical Analysis)**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**3**
Pre-requisites if any	**-----**				

Unit 1 Fourier series and Fourier transforms.

Fourier series: Dirichlet's conditions - Half range Fourier cosine and sine series - Parseval's relation - Fourier series in complex form - Harmonic analysis - Fourier transforms: Fourier cosine and sine transforms - Inverse transforms - Convolution theorem and Parseval's identity for Fourier transforms - Finite cosine and sine transforms.

Unit 2 Introduction to numerical computation, and Solution of algebraic and transcendental equations.

Introduction to numerical computation: representation of numbers - inherent errors - round-off errors - truncation errors - absolute, relative and percentage errors - accuracy of numbers - Solution of algebraic and transcendental equations: introduction - bisection method - method of false position - Newton Raphson's method - secant method - Muller's method - rate of convergence - Solution to systems of nonlinear equations.

Unit 3 Finite difference and interpolation.

Finite difference operators - Factorial notation - Divided differences - Finite difference interpolation - Newton's forward and backward difference interpolation formula - Central difference formula - Gauss forward and backward central differences formula - Stirling's formula - Bessel's interpolation formula - Newton's divided differences interpolation formula - Lagrange's polynomial interpolation formula - Spline interpolation - Cubic Splines - Choice of interpolation formula.

Unit 4 Curve fitting, numerical differentiation, and numerical integration.

Curve fitting: fitting linear equations - least-squares regression - fitting transcendental equations - fitting polynomial functions - Numerical differentiation: numerical differentiation based on equal interval interpolation - second order derivative - derivatives using Newton's formula and central differences formula - Derivatives using Lagrange's Interpolation formula and Newton's divided difference interpolation formula - Numerical integration: general quadrature formula - trapezoidal rule - Simpson's rule - Weddle's rule - Gaussian quadrature formula.

Unit 5 Solution of linear system of linear equations.

Direct methods: Gauss elimination method - identifying ill-conditioned system - Gauss Jordan method - Triangularization methods - Iterative methods: Jacobi Method and Gauss Seidel method - Comparisons of various methods.

Unit 6 Numerical solution of ordinary differential equations.

Taylor's series method - Euler's method - Modified Euler's method - Runge-Kutta formulas - Multistep methods: Adam-Moulton and Milne's methods.

Textbooks / References.

1) Erwin Kreyszig, Advanced Engineering Mathematics, 9e.
2) D. Zill, W. S. Wright and M. R. Cullen, Advanced Engineering Mathematics.
3) S. S. Sastry, Introductory Methods of Numerical Analysis.
4) E. Balagurusamy, Numerical Methods.
5) S. C. Chapra, Numerical Methods for Engineers.

Course code / Category	**MEC201 / Professional Core**				
Course title	**Engineering Thermodynamics**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**3**
Pre-requisites if any	**-----**				

Unit 1 Fundamentals of thermodynamics.

Thermodynamic system and control volume - Thermodynamics equilibrium, properties, states, processes and cycles, exact and inexact differentials - Definition and classification of thermodynamic work and heat - Displacement work and illustrations for simple processes - Electrical, magnetic, and shaft work - Zeroth law of thermodynamics - Temperature scales and thermometric property.

Unit 2 First law of thermodynamics.

First law for cyclic and non-cyclic processes - Concept of total energy E - Demonstration that E is a property - Various modes of energy - Internal energy and enthalpy - First law for a closed system undergoing a cycle and change of state - First law of thermodynamics for steady flow process - Steady flow energy equation applied to nozzle, boiler, turbine, compressor, pump, heat exchanger and throttling process.

Unit 3 Second law of thermodynamics.

Second law of thermodynamics: definitions of direct and reverse heat engines - Definitions of thermal efficiency and COP - Kelvin-Plank and Clausius statements - Definition of reversible process - Internal and external irreversibility - Carnot cycle - Corollary of Carnot theorem.

Unit 4 Entropy.

Clausius theorem - Property of entropy - Inequality of Clausius - Entropy change in an irreversible process - Principle of increase of entropy - Entropy change for non-flow and flow processes - Availability and irreversibility and exergy.

Unit 5 Pure substance.

Pure substances - p-V-T-surfaces - T-S and h-s diagrams - Mollier charts - Phase transformations - Triple point at critical state properties during change of phase - Dryness fraction - Clausius-Clapeyron equation.

Textbooks / References.

1) P. K. Nag, Engineering Thermodynamics, Tata McGraw-Hill, 1995.
2) R. E. Sonntag, C. Borgnakke and G. J. Van Wylen, Fundamentals of Thermodynamics, 6e, John Wiley & Sons, 2003.
3) J. B. Jones and R. E. Duggan, Engineering Thermodynamics, Prentice Hall of India, 1996.
4) P. Chattopadhyaya, Engineering Thermodynamics, Oxford University Press, 2010.
5) G. F. C. Rogers and Y. R. Mayhew, Engineering Thermodynamics - Work and Heat Transfer, 4e, Pearson, New Delhi, 2012.

Course code / Category	**MEC202 / Professional Core**				
Course title	**Fluid Mechanics and Hydraulic Machines**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Introduction to fluids - Hypothesis of continuum - Shear stress in a moving fluid - Properties of fluids - Pressure and head - Pascal's law - Variation of pressure vertically in a fluid under gravity - Equality of pressure at the same level in a static fluid - General equation for point-to-point variation of pressure due to gravity in a static fluid - Pressure measurements using elastic pressure transducers, force balance pressure gauge and electrical pressure transducers.

Unit 2 Static forces on surface and buoyancy.

Fluid statics - Action of fluid pressure on surface: resultant force and centre of pressure on a plane surface under uniform pressure - Resultant force and centre of pressure on a plane surface immersed in a liquid - Forces on a curved surface due to hydrostatic pressure - Buoyancy - Equilibrium of floating bodies - Stability of a submerged body - Stability of floating bodies - Metacentric height and its determination.

Unit 3 The energy equation and its application.

Momentum and fluid flow - Momentum equation for 2D and 3D flow along a streamline - Momentum correction factor - Euler's equation of motion along a streamline - Bernoulli's theorem - Kinetic energy correction factor - Pitot tube, venturi meter and orifice meter - Theory of small orifices discharging to atmosphere - Theory of large orifices - Rotameter - Elementary theory of notches and weirs - Flow in a curved path.

Unit 4 Dimensional analysis and similarities.

Dimensional analysis using Rayleigh's method, and Buckingham π-theorem - Similarities: geometric similarity, dynamic similarity, and kinematic similarity - Model testing and model laws - Undistorted and distorted models.

Unit 5 Viscous flow.

Reynolds number and Reynolds experiment - Flow of viscous fluid through circular pipe - Hagen Poiseuille formula - Flow of viscous fluid between two parallel fixed plates - Power absorbed in viscous flow through journal, footstep and collar bearing - Movement of piston in dash pot - Turbulent

flow: expression for coefficient of friction - Darcy-Weisbach equation - Moody diagram - Resistance of smooth and rough pipes - Velocity distribution in turbulent flow through pipes.

Unit 6 Flow through pipes.

Major energy losses - Minor energy losses - Hydraulic gradient and total energy lines - Pipes in series and parallel - Equivalent pipes - Power transmission through pipe - Flow through nozzle at the end of pipe - Water hammer in pipes - Compressible flow: basic equations for one dimensional compression - pressure wave propagation - sound velocity in fluid - Mach number - stagnation properties.

Unit 7 Hydraulic machines.

Euler equation for turbomachines - Velocity triangles - Centrifugal and axial flow pumps - Hydraulic turbines - Cavitation - Water hammer.

Textbooks / References

1) D. S. Kumar, Fluid Mechanics and Fluid Power Engineering, S. K. Kataria & Sons.
2) R. K. Bansal, Fluid Mechanics and Hydraulic Machines, Laxmi Publications.
3) Frank M. White, Fluid Mechanics, McGraw Hill Publishing Company Ltd.
4) R. W. Fox and A. T. McDonald, Introduction to Fluid Mechanics, 10e, John Wiley & Sons.
5) Y. A. Cengel and John Cimbala, Fluid Mechanics Fundamental and applications, 3e, Tata McGraw-Hill Education.
6) S. K. Som, G. Biswas and S. Chakraborty, Introduction to Fluid Mechanics and Fluid Machines, 3e, Tata McGraw-Hill Education.

Course code / Category	**MEC203 / Professional Core**				
Course title	**Strength of Materials**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**MES101**				

Unit 1 Fundamentals.

Analysis of stress: Introduction to stress tensor - Cauchy's stress equation - 3D-Equation of equilibrium (Cartesian coordinates) - Plane stress transformation (analytical and Mohr's circle method) - Principal stresses - Maximum in-plane shear stress - Strain: Deformation in the neighbourhood of a point - State of strain at a point - Compatibility conditions - Plane strain transformation (analytical and Mohr's circle method) - Mechanical properties of materials: Stress-strain behaviour of ductile and brittle materials - Elasticity - Hooke's law - Strain energy - Poisson's ratio - Yield strength, ultimate strength, toughness, ductility, and relations between the elastic constants.

Unit 2 Analysis of members under loading.

Axial loading: Elastic deformation of an axially loaded member - Principle of superposition - Statically indeterminate axially loaded member - Thermal stresses - Stress concentration - Torsion: Torsion of general prismatic section solid bars - Torsion problems for circular section - Statically indeterminate torque-loaded members - Thin-walled tubes having closed cross sections - Bending: Shear force and bending moment diagrams for various loading conditions - Flexural formula - Straight beam (symmetric and unsymmetric bending) - Curved beams.

Unit 3 Buckling of columns.

Critical load - Columns having diverse types of supports - Secant formula - Design of columns for concentric and eccentric loading.

Unit 4 Energy methods.

Principle of virtual work - Castigliano’s theorem applied to trusses and beams.

Unit 5 Advanced topics.

Combined loading: superposition principle for bars and beams under combined axial, shear and bending loads - Pressure vessels: thick and thin-walled pressure vessels subjected to internal and external pressure - Transverse shear: shear in straight members - Shear formula - Deflection of beams: slope and displacement by integration method, moment of area method, and method of superposition.

Textbooks / References.

1) R. C. Hibbeler, Mechanics of Materials, 8e, Pearson Asia, 2010.
2) E. P. Popov, Engineering Mechanics of Solids, 2e, Pearson India, 2015.
3) S. Crandall, N. Dahl, T. Lardner, R. Archer, N. Cook, F. A. McClintock, E. Rabinowicz, G. S. Reichenbach and M. S. Shiva Kumar, An Introduction to the Mechanics of Solids, 3e, McGraw-Hill Education, 2017.
4) William Nash, Strength of Materials, 4e, McGraw Hill Education, 2017.
5) F. P. Beer, E. R. Johnston Jr., J. T. DeWolf, D. F. Mazurek, and S. Sanghi, Mechanics of Materials, 8e, McGraw Hill, 2020.
6) R. Subramanian, Strength of Materials, 2e, Oxford Higher Education, 2010.
7) James M. Gere and Stephen P. Timoshenko, Mechanics of Materials, 4e, CBS Publisher, 1996.

Course code / Category	**MEC204 / Professional Core**				
Course title	**Kinematics of Machines**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**3**
Pre-requisites if any	**-----**				

Unit 1 Mechanisms.

Classification of links, pairs, and degree of freedom - Mobility of mechanisms - Kinematic inversions of four bar chain and slider crank - Mechanical advantage - Transmission angle - Description of some common mechanisms - Quick return mechanism - Straight line generators (Peaucellier, Hart, Watt, Roberts straight line motion) - Universal coupling - Motor car steering.

Unit 2 Velocity and acceleration.

Displacement, velocity, and acceleration analysis of simple mechanisms - Graphical velocity analysis using instantaneous centres - Kennedy's theorem - Angular velocity theorem - Velocity and acceleration analysis using loop closure equation - Kinematics analysis of simple mechanisms - Slider crank mechanism dynamics - Quick return mechanism - Coincident points - Velocity and acceleration image - Coriolis component of acceleration.

Unit 3 Kinematics synthesis of mechanism.

Number synthesis - Kinematics synthesis - Graphical methods of dimensional synthesis for four bar mechanism - Introduction to motion and path generation.

Unit 4 Cam and follower mechanism.

Classification of cams and followers - Terminology and definitions - Displacement diagrams - Uniform velocity, parabolic, simple harmonic, and cycloidal motions - Derivatives of follower motion-specified contour, cams-circular and tangents cams - Pressure angle and undercutting - Sizing of cams, graphical and analytical disc cam profile synthesis for roller and flat face followers.

Unit 5 Gears and gear trains.

Involute and cycloidal gear profiles - Gear parameters - Fundamental law of gearing and conjugate action, spur gear, arc and path of contact - Contact ratio and interference / undercutting - Helical gears - Simple, compound and epicyclic gear train kinematics.

Textbooks / References.

1) S. S. Ratan, Theory of Machines, 1e, McGraw Hill Education India Private Limited, 2017.
2) Ashok G. Ambekar, Mechanism and Machine Theory, 1e, PHI Learning, 2007.
3) Thomas Bevan, Theory of Machines, 3e, Pearson Education India, 2009.
4) W. L. Cleghorn and Nikolai Dechev, Mechanisms of Machines, 2e, Oxford University Press, 2014.
5) A. Ghosh and A. K. Mallick, Theory of Mechanism and Machines, Affiliated East-West Pvt. Ltd, New Delhi.

Course code / Category	**MAA201 / Mandatory and Audit Courses**				
Course title	**Environmental Science**				
Scheme and credits	L	T	P	C	Semester
	2	**0**	**0**	**0**	**3**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Concept and scope of environment science - Components of environment, environmental segment and their importance.

Unit 2 Ecology.

Ecosystem and its characteristics features - Structure and function of forest ecosystem, grassland ecosystem, desert ecosystem and aquatic ecosystem - Ecological balance and consequences of imbalance.

Unit 3 Atmosphere.

Atmospheric composition - Energy balance - Climate, weather, depletion of ozone layer, greenhouse effect, acid rain, particles, ions and radicals in the atmosphere - Chemical and photochemical reactions in the atmosphere.

Unit 4 Air pollution and control.

Air pollutants: sources and effect of air pollutants - primary and secondary pollutants - photochemical smog - fly ash - inorganic and organic particulate matter - Air quality standards - Sampling, monitoring and control measures for pollutants.

Unit 5 Water pollution and control.

Aquatic environment - Water pollution: sources and their effect - lake and ground water pollution - eutrophication - water quality standard and water pollution control measures - Wastewater treatment.

Unit 6 Land pollution.

Lithosphere - Composition of soil - Acid, base and ion exchange reactions in soil - Soil erosion, landslides, desertification, pollutants (municipal, industrial, commercial, agricultural, hazardous solid wastes) - Origin and effects - Collection and disposal of solid wastes, recovery and conversion methods.

Unit 7 Noise pollution.

Noise classification and its sources - Effects and measurement - Noise pollution hazards - Standards and noise pollution control.

Textbooks / References.

1) G. M. Master, Introduction to Environmental Engineering and Science, Pearson Education.

2) B. J. Nebel, Environment Science, Prentice Hall Inc.
3) E. P. Odum, Ecology: The link between the natural and social sciences. IBH Publishing Company.
4) B. K. Sharma, Environmental Chemistry, Krishna Prakashan Media, Meerut.
5) A. Kaushik and C. P. Kaushik, Perspectives in Environmental studies, New Age International Publication.

Course code / Category	**MES202 / Basic Sciences**				
Course title	**Mathematics IV (Probability, Statistics & Quality Control)**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**-----**				

Unit 1 Random variables.

Discrete and continuous random variables - Moments - Moment generating functions - Probability distributions: Binomial, Poisson, Normal and Hypergeometric - Joint probability distributions - Marginal probability distributions - Conditional probability distributions - Functions of a random variable.

Unit 2 Two-dimensional random variables.

Joint probability distributions - Marginal probability distributions - Conditional probability distributions - Covariance - Correlation and linear regression - Transformation of random variables - Central limit theorem (for independent and identically distributed random variables).

Unit 3 Tests of significance.

Population and sample - Sampling distributions - Tests for single mean, proportion and difference of means (large and small samples) - Tests for single variance and equality of variances - χ^2-test for goodness of fit - Independence of attributes - Non-parametric tests - Test for randomness and rank-sum test (Wilcoxon test).

Unit 4 Design of experiments.

Completely randomized design - Randomized block design - Latin square design - 2^2 factorial design - Taguchi's robust parameter design.

Unit 5 Statistical quality and process control.

Statistical quality control: Deming's, Crosby's and Juran's philosophies - Tools for continuous quality improvement: pareto diagrams - Flowcharts - Cause effect diagrams - Scatter plots - Multivariable charts - Failure mode and effects criticality analysis - Statistical process control: basics of control charts - Control charts of variables and control charts for attributes - Process capability analysis - Acceptance sampling plans.

Textbooks / References

1) J. S. Milton and J. C. Arnold, Introduction to Probability and Statistics, 4e, Tata McGraw-Hill, New Delhi.
2) R. A. Johnson and C. B. Gupta, Miller and Freund's Probability and Statistics for Engineers, 8e, Pearson Education.
3) J. L. Devore, Probability and Statistics for Engineering and the Sciences, Thomson Brooks/Cole, International Student Edition, New Delhi.
4) Douglas C. Montgomery and George C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons.
5) Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists, Academic Press.
6) Amitava Mitra, Fundamentals of Quality Control and Improvement, 3e, Wiley Student Edition.

Course code / Category	**MES203 / Basic Engineering Sciences**				
Course title	**Programming for Problem Solving using Python**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction to Python.

Structure of a Python program - Functions, interpreter shell and indentation - Identifiers and keywords - Literals and strings - Basic operators - Data types, variables, expressions and statements - Input and output statements - Assignment statements - Strings and string operations - Control structures: loops and decision - Mutable and immutable structures.

Unit 2 Modularization and object-oriented programming.

Standard and user-written modules - Defining functions - Functions and arguments - Classes - Abstract classes - Inheritance - Data encapsulation - Polymorphism - Operator overloading - Databases and database programming.

Unit 3 Data structures and data visualization.

Arrays, lists, sets, tuples and dictionary - String manipulations - Basic searching and sorting using iteration and recursion - Data visualization using graphical objects like point, line, histogram, sine and cosine curves and 3D objects - Graphical user interfaces - An example GUI - The root component - Adding a button, entry widgets, text widgets and check buttons.

Unit 4 Exception handling and file handling.

Reading and writing text and structured files - File handling modes - Reading files - Writing and appending to files - Error processing - Exception raising and handling - Multiple exceptions.

Unit 5 Introduction to scientific Python.

NumPy, Matplotlib, Pandas and Scikit-learn - Programming in Python for typical Mechanical Engineering problems.

Textbooks / References.

1) Allen B. Downey, Think Python: How to Think Like a Computer Scientist, Shroff O'Reilly Publishers.
2) Guido van Rossum and Fred L. Drake Jr, An Introduction to Python - Revised and updated for Python 3.2, Network Theory Ltd.
3) Martin C. Brown, Python, The Complete Reference, Tata McGraw-Hill.

Course code / Category	**ESC201 / Basic Engineering Sciences**				
Course title	**Applied Electrical and Electronics Engineering**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**ESC101**				

Unit 1.

Single phase induction motors and universal motors - Applications - Synchronous motors: principle of operation, starting and applications.

Unit 2.

Three-phase induction motor - Cage and slip ring motors - Torque slip characteristics - Equivalent circuits - Starting and speed control of induction motors - Applications.

Unit 3.

Electric drive for general factory, textile mill and cement mill - Pumps, blowers, hoists, traction, etc. - Group and individual drives - Choice of motors for various applications - Drive characteristics and control of drives.

Unit 4.

Introduction to operational amplifiers - Applications in control circuits - Combinational logic - Representation of logic functions - SOP and POS forms - K-map representations - Minimization using K-maps - Simplification and implementation of combinational logic - Multiplexers and demultiplexers.

Unit 5.

Introduction to microprocessors and micro-controllers - Control systems: introduction - Block diagram reduction - Routh-Herwitz criterion-based stability analysis - Implementation of control logics to drives.

Textbooks / References.

1) V. K. Mehta and Rohit Mehta, Principles of Electrical Machines, S. Chand and Co., 2006.
2) G. K. Dubey, Fundamentals of Electric drives, Narosa Book Distributors Pvt. Ltd , 2e, 2012.
3) Ramesh S. Gaonkar, Microprocessor Architecture Programming and Applications with 8085, Penram Intl. Publishing, 6e, 2013.
4) Morris Mano and Michael D. Ciletti, Digital Design, Pearson Education, 4e, 2008.
5) B. L. Theraja, A Textbook of Electrical Technology, Vol. 2, S. Chand and Co.,23e, 2007.
6) Vincent Del Toro, Electrical Engineering Fundamentals, PHI, 2e, 2009.
7) V. Subrahmanyan, Thyristor Control of Electric Drives, Tata McGraw Hill, 1e.

Course code / Category	**MEC204 / Professional Core**				
Course title	**Manufacturing Technology I**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Importance of manufacturing - Selection of materials and manufacturing processes - Planning for manufacturing - Global competitiveness of manufacturing - Fundamentals of materials, their behaviour and manufacturing properties.

Unit 2 Metal casting processes.

Introduction to patterns and foundry process - Types of sands - Sand binders and different additives - Sand testing - Melting furnaces for ferrous and non-ferrous metals such as Cupola, Induction furnace, Arc furnace and Resistance furnace - Introduction to the sand casting process - Pattern design - Green sand moulding - Microstructure in castings - Cooling curves, heat transfer and solidification time - Gating design - Fluidity - Other casting processes: Die casting, squeeze casting, centrifugal casting, investment casting and continuous casting - Casting defects.

Unit 3 Metal forming processes.

Introduction to forming processes - Basic structure of metals and heat treatment - Plastic deformation and yield criteria - Dependence of stress-strain diagram on strain rate and temperature - Idealized stress-strain curves - Flow curve - Hot and cold working of metals - Conventional forming processes: rolling, forging, extrusion and wire drawing - Slab analysis for force estimation - Forming dies and tools - Effect of friction and lubrication - Forming defects - Nonconventional forming processes: electromagnetic, hydraulic and explosive forming - Superplastic deformation.

Unit 4 Sheet metal processes.

Introduction and classification - Shearing processes - Bending processes - Stretch forming - Deep drawing - Spinning - Sheet metal formability - High velocity and high energy rate forming.

Unit 5 Welding processes.

Introduction - Types of joints - Weld specifications - Symbols - Conventional fusion welding processes: gas welding, shielded metal arc welding, gas metal arc welding, submerged arc welding and gas tungsten arc welding - Physics of arc welding - Metal transfer in arc welding - Power sources - Heat flow in welds - Welding thermal cycle - TT curves - Generalized heat flow equation - Other welding processes: solid-state welding and high energy density beam welding processes - Design of weld joints - Weld defects - Weld quality and destructive and non-destructive testing.

Unit 6 Polymer fabrication methods.

Injection moulding - Compression moulding - Transfer moulding - Thermoforming - Composite fabrication methods, viz., compression moulding, vacuum moulding, prepreg fabrication and filament winding - Powder metallurgy and its applications.

Textbooks / References.

1) A. Ghosh and A. K. Mallik, Manufacturing Science, Wiley Eastern, 2010.
2) P. N. Rao, Manufacturing Technology: Foundry, Forming and Welding, Tata McGraw Hill, 2017.
3) M. P. Groover, Introduction to Manufacturing Processes, Wiley, 2011.
4) S. Kalpakjian and S. R. Schmid, Manufacturing Processes for Engineering Materials, Pearson Education, 6th Edition, 2016.
5) H. A. Youssef, H. A. El-Hofy and M. H. Ahmed, Manufacturing Technology: Materials, Processes and Equipment, CRC Press.

Course code / Category	**MEC205 / Professional Core**				
Course title	**Thermal Engineering**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC201**				

Unit 1.

Fuel and Combustion - Introduction to solid, liquid and gaseous fuels - Stoichiometry - Exhaust gas analysis - First law analysis of combustion reactions - Heat calculations using enthalpy tables - Adiabatic flame temperature.

Unit 2.

Vapor power cycles: Rankine cycle with superheat, reheat and regeneration - Energy analysis - Super-critical and ultra-super-critical Rankine cycles - Analysis of steam turbines - Velocity and pressure compounding of steam turbine.

Unit 3.

Gas power cycles - Classification of IC engines - Working of SI and CI engines - Two and four stroke engines - Air standard Otto, Diesel and Dual cycles - Brayton cycle - Effect of reheat, regeneration and intercooling -Combined gas and vapor power cycles.

Unit 4.

Compressible flow - Basics of compressible flow - Stagnation properties - Isentropic flow of a perfect gas through a nozzle - Chocked, subsonic and supersonic flows - Normal shocks - Use of ideal gas tables for isentropic flow and normal shock flow - Flow of steam and refrigerant through nozzle.

Unit 5.

Refrigeration and air conditioning systems - Vapour compression refrigeration cycle - Effect of super heat and sub cooling - Psychrometric processes - Properties of dry and wet air - Use of psychrometric chart - Processes involving heating/cooling and humidification / dehumidification - Dew point - Working principles and concept of RSHF, GSHF and ESHFC.

Unit 6.

Reciprocating compressors - Staging of reciprocating compressors - Optimal stage pressure ratio - Effect of intercooling - Minimum work for multistage reciprocating compressors.

Textbooks / References.

1) P. K. Nag, Basic and Applied Thermodynamics, 2e, Tata McGraw-Hill, 2009.
2) P. L. Ballaney, Thermal Engineering, Khanna Publishers, 2005.
3) R. S. Khurmi and J. K. Gupta, Thermal Engineering, S Chand and Co., 2006.
4) M. J. Moran, H. N. Shapiro, D. D. Boettner and M. B. Bailey, Principles of Engineering Thermodynamics, 8e, Wiley, New Delhi, 2015.
5) H. I. H. Saravanamuttoo, G. F. C. Rogers and H. Cohen, Gas Turbine Theory, 5e, Pearson, New Delhi, 2003.
6) C. P. Arora, Refrigeration and Air Conditioning, Tata McGraw Hill, 1994.

Course code / Category	**MAA202 / Mandatory and Audit Courses**				
Course title	**Constitution of India**				
Scheme and credits	L	T	P	C	Semester
	2	**0**	**0**	**0**	**4**
Pre-requisites if any	**-----**				

Unit 1.

The preamble - Citizenship - Fundamental rights and duties.

Unit 2.

The union, the states and the union territories - Role of Parliament and Legislatures in federal setup.

Unit 3.

Law and Justice - Judiciary system.

Unit 4.

Place of official languages and education pertinent to concurrent list - Perspectives of Indian issues on trade and commerce - Role of Parliament to impose restriction of trade, commerce and intercourse.

Unit 5.

Human rights and protection of human rights.

Textbooks / References.

1) Magbook, Indian Polity and Governance, Arihant Experts.
2) Ministry of Law And Justice, Legislative Department, Official Languages Wing, Government of India, The Constitution of India.
3) S. K. Kapoor, Human Rights.

Course code / Category	**MEC301 / Professional Core**				
Course title	**Dynamics of Machines**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5**
Pre-requisites if any	**-----**				

Unit 1 Mechanism force analysis.

Piston effort - Crank pin effort - Crank effort - Dynamic force analysis in slider crank mechanism - Inertia force and torque in reciprocating engines - Dynamically equivalent systems - Turning moment diagram - Flywheels.

Unit 2 Friction and brakes.

Friction: types, angle of repose and angle friction - Axial force and friction movement in pivots and collars - Friction between lubricated surfaces - Friction clutches - Brakes: band and block brakes - Internal expanding shoe brakes - Effect of braking - Braking of vehicles - Types of dynamometers.

Unit 3 Governors and gyroscopes.

Governors: types of governors - stability and isochronism - sensitiveness - hunting - Governor effort and power - Effect of friction - Gyroscopes: gyroscopic effect on aeroplanes and naval ships - Stability of an automobile and two-wheelers - Rigid disk fixed at an angle to the rotating shaft.

Unit 4 Balancing.

Static and dynamic balancing - Balancing of reciprocating masses, locomotives, 2-stroke and 4-stroke inline engines - Balancing of machines.

Unit 5 Vibrations.

Free and forced vibration of single-degree-of-freedom systems - Vibration isolation - Effect of damping - Resonance - Critical speeds of shafts.

Textbooks / References.

1) S. S. Rattan, Theory of Machines, 1e, McGraw Hill Education India Private Limited, 2017.
2) Ashok G. Ambekar, Mechanism and Machine Theory, 1e, PHI Learning, 2007.
3) A Ghosh, Theory of Mechanisms Machines, 1e, East West, 2008.
4) Thomas Bevan, Theory of Machines, 3e, Pearson Education India, 2009.
5) R. L. Norton, Kinematics and Dynamics of Machinery, 1e, McGraw Hill Education, 2017.

Course code / Category	**MEC302 / Professional Core**				
Course title	**Design of Machine Elements**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**5**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Design considerations and philosophy - Design procedure - Stress concentration - Factor of safety - Review of failure theories for static and dynamic loading (including fatigue failure).

Unit 2 Design of joints.

Design of riveted joints, threaded fasteners, pre-loaded bolts and welded joints.

Unit 3 Design of shafts and couplings.

Design of flange coupling - Keys - Design of solid and hollow shafts under combined bending torsion and axial load static and fatigue loadings.

Unit 4 Design of bearings and transmission elements.

Analysis and design of sliding and rolling contact bearings - Design of flat belt, V-belt, and chain drives - Design of transmission elements: spur, helical, and bevel gear using beam strength and wear strength.

Unit 5 Design of springs, clutches, and brakes.

Design of helical compression, tension, torsional and leaf springs - Design of a single plate, multiple friction clutches, band brakes and shoe brakes.

Textbooks / References.

1) V. B. Bhandari, Design of Machine Elements, McGraw-Hill International.
2) D. Deutschman, W. J. Michels and C. E. Wilson, Machine Design Theory and Practice, Macmillan, 1992.
3) M. F. Spotts, Design of Machine Elements, Prentice-Hall India, 1994.
4) R. L. Norton, Mechanical Design - An Integrated Approach, Prentice Hall, 1998

Course code / Category	**MEC303 / Professional Core**				
Course title	**Metrology and Measurements**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Standards - Calibration - Terminologies used in measurement - Errors in measurement - Uncertainty in measurement - Limits, fits and tolerances - Interchangeability and selective assembly.

Unit 2 Linear, angular and form measurements.

Linear measuring instruments - Comparators - Gauges and design of gauges - Angular measuring instruments: bevel protractor, clinometers, angle gauges, spirit levels and sine bar - Alignment telescope - Autocollimator - Angle Dekkor - Form measurement (straightness, flatness and roundness).

Unit 3 Screw thread, gear and surface metrology.

Metrology of screw threads - Metrology of gears - Measurement of surface finish.

Unit 4 Advanced metrology.

Interferometry principles and applications - Laser interferometers - Coordinate measuring machines: basic concepts and types - Constructional features - Probes - Accessories - Applications - Basic concepts and elements of machine vision systems - Introduction to Nanometrology.

Unit 5 Measurement of power, flow and temperature.

Measurement of force, torque, pressure, power: mechanical, pneumatic, hydraulic and electrical type instruments - Flow measurement: Venturi meter, orifice meter, rotameter and Pitot tube - Temperature measurement: bimetallic strip, thermocouples and electrical resistance thermometer.

Textbooks / References.

1) J. F. W. Galyer and C. R. Shotbolt, Metrology for Engineers, Cassel London.
2) I. C. Gupta, Engineering Metrology, Dhanpat Rai Publications.
3) R. K. Jain, Engineering Metrology, Khanna Publishers.
4) D. J. Whitehouse, Handbook of Surface and Nanometrology, IOP Publishing.
5) G. R. Cogorno, Geometric Dimensioning and Tolerancing for Mechanical Design, 3e, McGraw-Hill Publishing Co.
6) R. J. Hocken and P. H. Pereira, Coordinate Measuring Machines and Systems, 2e, CRC Press.
7) E. O. Doebelin, Measurement Systems - Applications and Design, 4e, McGraw-Hill Publishing Co.

Course code / Category	**MEC304 / Professional Core**				
Course title	**Heat and Mass Transfer**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5**
Pre-requisites if any	**MEC201**				

Unit 1 Fundamentals.

Modes of heat transfer - Effect of temperature on thermal conductivity of solids, liquids and gases - Conduction: Fourier's law - one dimensional steady state heat conduction in simple geometries - Plane wall-cylinder and sphere-composite walls - Critical thickness of insulation - Thermal contact resistance - Heat generation in plane wall, cylinder and sphere - Transient conduction - Lumped heat capacity analysis - Biot number.

Unit 2 Convection.

Boundary layer theory - Newton's law of cooling - Conservation equations of mass, momentum and energy for laminar flow over a flat plate and turbulent flow over a flat plate - Flow over cylinders - Internal flows: natural convection - Blasius solution for laminar boundary layer.

Unit 3 Radiation.

Thermal radiation - Laws of radiation - Black and grey bodies - Shape factor - radiation exchange between surfaces - Radiation shields.

Unit 4 Heat exchangers.

Classification - Heat exchanger analysis - LMTD for parallel and counter flow exchangers - Condenser and evaporator - Overall heat transfer coefficient - Fouling factor - Correction factors for multi pass arrangement - Effectiveness and number of transfer unit for parallel and counter flow heat exchangers.

Unit 5 Heat transfer from extended surfaces.

Types of fins - heat flow through rectangular fin and infinitely long fin - fins insulated at the tip and fins losing heat at the tip - efficiency and effectiveness of fins.

Unit 6 Boiling and condensation.

Pool boiling regimes and correlations - Nusselt's theory - Film-wise and dropwise condensation - Condensation over surfaces.

Textbooks / References.

1) P. K. Nag, Heat and Mass Transfer, 2e, Tata McGraw-Hill, 2007.
2) T. L. Bergman, A. S. Lavine, F. P. Incropera and D. P. Dewitt, Fundamentals of Heat and Mass Transfer, 7e, John Wiley & Sons, 2011.
3) J. P. Holman, Heat Transfer, 10e, Tata McGraw-Hill, 2010.
4) M. N. Ozisik, Heat Transfer - A Basic Approach, McGraw-Hill, 1985.
5) Y. A. Cengel, Heat Transfer - A Practical Approach, 2e, McGraw-Hill, 2002.
6) R. C. Sachedva, Fundamentals of Heat and Mass Transfer, 4e, New Age International, 2012.

Course code / Category	**MEC305 / Professional Core**				
Course title	**Manufacturing Automation**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5**
Pre-requisites if any	**-----**				

Unit 1.

Introduction - Overviews, principles and application of hydraulic, pneumatic and electric controls systems.

Unit 2.

Hydraulic systems - Hydraulic components - Pressure-flow-direction controls valves - Proportional, servo and cartridge (logic) valves - Accumulator - Accessories - Hydraulic components symbols - Design and application of hydraulic circuits of machine tools and presses - Mobile hydraulic.

Unit 3.

Pneumatic systems - Pneumatic components - Pressure-flow-direction controls valves - Pneumatic components symbols - Design and application of pneumatic circuits of machine tool.

Unit 4.

Semi automats - Automats - Transfer lines - Automatic assembly - Transfer devices and feeders - Classifications and applications - Job orienting and picking devices - Setting of automats and transfer lines.

Unit 5.

Introduction to mechatronics - Mechatronics systems - Microprocessors and their applications - Sensors and principles - Programmable logic controllers (PLCs) - Examples of mechatronics systems.

Textbooks / References.

1) M. J. Pinches and J. G. Ashby, Power Hydraulics, Prentice Hall.
2) D. A. Pease and J. J. Pippenger, Basic Fluid Power, Prentice Hall.
3) E. O. Doebelin, Measurement Systems - Applications and Design, 4e, McGraw-Hill Publishing Co.
4) W. Bolton, Mechatronics, 3e, Addison Wesley.
5) Geoffrey Boothroyd, Assembly Automation and Product Design.

Course code / Category	**MEC306 / Professional Core**				
Course title	**Computer Aided Design**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**6**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Product life cycle management - Need and scope of computer-aided design - Hardware: CAD workstation, memory types, input devices, display devices, hard-copy devices, hardware integration and networking - Software: graphics standards - Database structures for graphic modelling - Database coordinate systems - Software modules.

Unit 2 Computer graphics.

Transformations: translation, scaling, rotation, reflection and concatenation - Orthographic and perspective projections of geometric models - Scan conversion algorithms: DDA algorithm, Bresenham's line algorithm, Midpoint circle algorithm and ellipse generating algorithm - Visual realism: back

face removal, Z-buffer, depth sort and ray tracing algorithms - Graphics aids: geometric modifiers, names, layers, colours, grids, groups, dragging and rubber banding and clipping.

Unit 3 Geometric modelling.

Geometric models - Requirements of geometric modelling - Types of models and their limitations and applications - Wireframe models: wireframe entities, curve representation methods, line, circle, ellipse, parabola, hyperbola, Hermite cubic spline curve, Bezier curve, B-spline curve and rational curve - Surface models: surface entities and their representation methods - Plane surface, ruled surface, surface of revolution, tabulated cylinder, Bezier surface, B-spline surface and Coons patch - Solid models: solid entities, regularized set operations, half-space, B-Rep and constructive solid geometry (CSG).

Unit 4 CAD/CAM data exchange.

Shape-based format - Product-based format - Standard for exchange of product model data - Drawing exchange format - Dimensional measurement interface specification - Initial Graphics Exchange Specification (IGES) standard - STL files.

Unit 5 Finite element modelling and analysis.

Basic concepts of the finite element method - Steps in finite element analysis of physical systems - Finite element analysis of 1-D problems, like spring, bar, truss and beam elements - Development of elemental stiffness equations and their assembly, solution and post-processing.

Textbooks / References.

1) P. N. Rao, CAD/CAM: Principles and Applications, 3e, McGraw Hill Education, 2017.
2) Ibrahim Zeid and R Sivasubramanian, CAD/CAM: Theory and Practice, 2e, McGraw Hill Education, 2009.
3) Donald D. Hearn and M. Pauline Baker, Computer Graphics, C Version, 2e, Pearson Education India, 2002.
4) H. H. Lee, Finite Element Simulations with ANSYS Workbench 2023: Theory, Applications, Case Studies, 1e, SDC Publications, 2023.
5) Sham Tickoo, Finite Element Analysis with ANSYS Workbench 2022 R1: A Tutorial Approach, 1e, BPB Publications, 2023.

Course code / Category	**MEC307 / Professional Core**				
Course title	**Computer Aided Manufacturing**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**6**
Pre-requisites if any	**-----**				

Unit 1 Basics of numerical control (NC).

NC systems: concepts - basic components - advantages and disadvantages - NC machine tools - Economics of NC - Some mathematical elements for NC - Computer control in NC - CNC - DNC - Adaptive control - Control of NC machines - NC system devices such as stepper motors, encoders, etc. - Interpolators: hardware and software interpolation.

Unit 2 NC machining.

Point to point and continuous path machining - NC Programming: G and M Codes, and APT programming.

Unit 3 Computer-aided process planning (CAPP).

Role of process planning in CAD/CAM Integration - CAPP: development, benefits, model and architecture - CAPP approaches: variant, generative and hybrid process planning systems - CAPP systems: CAM-I, D-CLASS and CMPP - Criteria in selecting a CAPP system.

Unit 4 Computer-aided inspection.

Engineering tolerances: need for tolerances - limits and fits - tolerance accumulation - surface quality - Geometric tolerances - Tolerancing practices in design, drafting and manufacturing - Tolerance analysis and synthesis - Computer aided quality control - Contact and Non-contact inspection methods.

Unit 5 Reverse engineering.

Scope and tasks of reverse engineering - Domain analysis - Process duplicating - Tools for reverse engineering - Developing technical data - Digitizing techniques - Construction of surface and solid models - Characteristic evaluation - Software and applications - CMM feature capturing - Reverse engineering data management - Renewable software components - Recycling real-time embedded software - Design of experiments to evaluate the reverse engineering tools - Rule-based detection for reverse engineering user interface.

Textbooks / References.

1) I. Zeid and R. Sivasubramanian, CAD/CAM Theory and Practice, Revised First Special Indian Edition, Tata Mc Graw Hill Co., 2007.
2) I. Zeid, Mastering CAD/CAM, Special Indian Edition, Tata McGraw Hill Co., 2007.
3) L. Wills, Reverse Engineering, Kluwer Academic Press, 1996.
4) D. R. Honra, Coordinate Measurement and Reverse Engineering, American Gear Manufacturers Association.

Course code / Category	**MEC308 / Professional Core**				
Course title	**Manufacturing Technology II**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**6**
Pre-requisites if any	**MEC205**				

Unit 1 Introduction to metal cutting and machine tools.

Orthogonal and oblique metal cutting - Forces in machining - Merchant's analysis of metal cutting process - Types of chips and mechanism of chip formation - Thermal aspects: sources of heat generation - effects of temperature - cutting temperature determination using analytical / experimental methods - methods of controlling cutting temperature - Single-point and multi-point cutting tools: tool geometry - significance of various angles of single point turning tools - ASA system - Orthogonal Rake System (ORS) - Normal Rake System (NRS) - Conversions between ASA and ORS - Cutting tool materials: desirable properties of tool materials - Indexable inserts and coated tools - Cutting fluids: functions, characteristics, types and their selection - Tool wear, tool life, surface finish and machinability.

Unit 2 Machine tools.

Classification and specifications of machine tools - Functional principles of machine tools - Conventional machine tools: features and characteristics - Machine tool power drives.

Unit 3 Turning machines.

Centre lathe: constructional features, specification and operations - Taper turning - Thread cutting - Special attachments - Machining time and power estimation - Capstan and turret lathes - Tool layout - Automatic lathes: semi-automatic, single spindle, Swiss type and automatic screw type - Multi-spindle automats.

Unit 4 Reciprocating, milling and gear cutting machines.

Reciprocating machine tools: shaper, planer and slotter - Types and operations - Hole making: drilling, reaming, boring and tapping - Milling: types of milling cutter - attachments - machining time calculations - Gear cutting, forming and generation - Gear milling, gear hobbing and gear shaping.

Unit 5 Abrasive processes and broaching.

Grinding wheel: specifications and selection - Types of grinding: cylindrical grinding, surface grinding, centreless grinding and internal grinding - Micro finishing methods - Typical applications - Concepts of surface integrity - Broaching machines - Broach construction - Push, pull, surface and continuous broaching machines.

Unit 6 Advanced machining techniques.

Overview of non-conventional machining processes - Working principles of common non-conventional machining processes - Micromachining - Wafer machining.

Textbooks / References.

1) A. Ghosh and A. K. Mallik, Manufacturing Science, Wiley Eastern.
2) Roy A. Lindberg, Processes and Materials of Manufacture, 4e, PHI/Pearson Education.
3) P. N. Rao, Manufacturing Technology: Metal Cutting and Machine Tools, Tata McGraw-Hill, New Delhi.
4) Richerd R. Kibbe, John E. Neely, Roland O. Merges and Warren J. White, Machine Tool Practices, Prentice Hall of India.
5) HMT, Production Technology, Tata McGraw-Hill, New Delhi.
6) S. K. Hajra Choudhury and A. K. Hajra Choudhury, Elements of Workshop Technology, Vol. II, Media Promoters and Publishers.
7) Geofrey Boothroyd, Fundamentals of Metal Machining and Machine Tools, McGraw-Hill Publishing Co.
8) P. C. Pandey and H. S. Shan, Modern Machining Processes, Tata McGraw-Hill Publishing Co.
9) B. L. Juneja and G. S. Sekhon, Fundamentals of Metal Cutting and Machine Tools, New Age International Publishers.

Course code / Category	**MES301 / Humanities, Social Sciences and Management Sciences**				
Course title	**Professional Development**				
Scheme and credits	L	T	P	C	Semester
	2	**1**	**0**	**3**	**6**
Pre-requisites if any	**-----**				

Unit 1 Self-analysis.

Introduction - Who am I? - SWOT analysis - Self-introspection - Johari window: knowing the unknown can bring self-confidence and self-esteem.

Unit 2 Attitude.

Factors influencing attitude - Influence of attitude on behaviour - Thumb impression activity - Challenges and lessons from attitude - Synergy between knowledge, skill and attitude - Personal, social and professional etiquettes.

Unit 3 Motivation and goal setting.

Motivation: motivational factors - I am good at - Self-image - Self-talk - Tapping and tuning inner voice - Self-motivation - Intrinsic and extrinsic motivators - Goal setting: wish list - SMART goals - Short, long and life-time goals - Goal tree - Goal poster - Blueprint for success - 5W1H - Time management - Value of time - Test your time management skill - Weekly planner - TODO list - Prioritizing work - Time management matrix.

Unit 4 Interpersonal skills and leadership.

Interpersonal skills: gratitude - Being thankful - Secret of happiness - Satin ribbon activity - Stages of dependence - Understanding the integration of leadership, networking and teamwork - Assessing interpersonal skills - Situation analysis - Importance of teamwork - Teamwork activity - Leadership: skills needed for a good leader - Types of leadership style - Assessment of leadership skills - Wheel of leadership.

Unit 5 Curriculum vitae (CV) and video profiling.

Curriculum vitae: importance of building a winning CV - Orientation to placement preparation - Do's and Don'ts of CV - Inputs on LinkedIn profiling - Preparation of an impressive CV - Video profile: instructions to present an appealing self-introduction video - Sample video profile screening - Presentation of self-introduction video for assessment.

Unit 6 Group discussion and Interview skills.

Group discussion (GD): what is GD? - Why GD? - Types of GD - SPELT topics - Do's and Don'ts of GD - Skills assessed / parameters: knowledge, body language, communication, team skills, time management and assertiveness - Mock GD - GD Assessment - Interview skills: what is a structured interview? - Preliminary preparation - Do's and Don'ts of an interview - Sample interview video projection - Discussion of frequently asked questions in the interview - Personal interview assessment with constructive feedback.

Unit 7 Decision making.

Importance of decision making - Impact of decision in life - Weighing positives and negatives - Process and practical way of decision making.

Textbooks / References.

1) Soft Skills, Career Development Centre, Green Pearl Publications.
2) Carnegie Dale, How to win Friends and Influence People, New York: Simon & Schuster.
3) Thomas A Harris, I am ok, You are ok , New York-Harper and Row.
4) Anand Ganguly, Group Discussion for Admissions and Jobs", Pustak Mahal Publications.
5) Gerald M. Phillips and Douglas J. Pedersen, Group Discussion: A Practical Guide to Participation and Leadership, Waveland Press.
6) Susan Hodgson, Brilliant Answers to Tough Interview Questions, Pearson Publications.

Course code / Category	**MES401 / Humanities, Social Sciences and Management Sciences**				
Course title	**Innovation and Entrepreneurship**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7**
Pre-requisites if any	**-----**				

Unit 1 Design thinking and innovation.

Design thinking for startups - Design thinking principles and processes - Define the problem using design thinking principles and validate problem - Generation of ideas - Idea generation techniques and evaluating creative ideas - Identify problem worth solving - Sharpen your problem pitch - Out-of-the-box thinking - Possibility of innovation - Creative thinking - Torrance test for creating thinking - Lateral thinking - Creativity challenge.

Unit 2 Entrepreneurship.

Defining entrepreneurship - Concepts and emerging trends in entrepreneurship (domain specific) - Understanding the unique opportunities - Why be an entrepreneur? - Entrepreneurship in Indian scenario and its role in economic development - Success stories of entrepreneurs (domain specific) - Entrepreneurial style assessment tool - Developing the entrepreneurial mindset - Attributes and skills - Recognizing your sweet spot for starting up - Principles of effectuation - Myths about entrepreneurship - Types of entrepreneurs - Entrepreneur vs intrapreneur - Role of entrepreneurial teams.

Unit 3 Customer, markets and creating a sustainable differentiation.

Differentiate between a customer and a consumer - Who is your customer and what is your segment - Customer job, pains, and gains using value proposition canvas - Build solution using value proposition canvas - Market estimation - TAM, SAM and SOM - Competitive analysis - Minimum viable product - Build - Measure - Learn - Differentiate between solution demo and MVP - How to validate MVP? - Achieve a product - Market fit.

Unit 4 Business model, business planning and go to market strategies.

Introduction to business model - Business plans - Lean approach - 9 block lean canvas model - Financial feasibility: costs, revenue streams, pricing and financial projections - Key financial metrics using financial template - Managing growth and targeting scale - Unit economics - Selecting the right channel - Introduction to digital marketing and tools - Branding strategy.

Unit 5 Funding strategy.

Sources of funds: debt and equity - Map the start-up lifecycle to funding options - Build an Investor ready pitch deck.

Textbooks / References

1) R. D. Hisrich, M. P. Peters and D. A. Shepherd, Entrepreneurship, 10e, McGraw-Hill Education, 2017.
2) E. Ries, The Lean Startup: How Today's Entrepreneurs use Continuous Innovation to Create Radically Successful Businesses, Crown Business, 2011.
3) S. G. Blank, and B. Dorf, The Startup Owner's Manual: The Step-by-Step Guide for Building a Great Company, K&S Ranch, 2012.
4) R. Roy, Indian Entrepreneurship: Theory and Practice, Oxford University Press, New Delhi, 2017.
5) J. S. Chandan and S. S. Rana, Entrepreneurship Development and Management, McGraw Hill Education, New Delhi, 2019.

Course code / Category	**MEC401 / Professional Core**				
Course title	**Operations Research**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7**
Pre-requisites if any	**-----**				

Unit 1 Linear programming.

Overview of operations research - Introduction to linear programming - Solution to linear programming problems: Graphical, simplex, and Big M methods - Multiple optimal solutions of linear programming problems - Degeneracy in linear programming problems - Infeasible and unbounded solutions of linear programming problems - Principle of duality in linear programming problems - Solution to linear programming problems by dual simplex method - Two-phase method of linear programming problem - Economic interpretation of linear programming problems - Sensitivity analysis.

Unit 2 Transportation problems.

Introduction - Methods of finding initial basic feasible solution: North-west corner method, least cost method, and Vogel's approximation method - Methods for finding optimal solutions for transportation problems - Multiple optimal solutions - Unbalanced transportation problems - Degeneracy - Solution of profit maximization transportation problems - Post optimality analysis in transportation problems.

Unit 3 Assignment problems.

Introduction - Hungarian method for solution of assignment problems - Multiple optimal solutions - Solution of unbalanced assignment problems - Solution of maximization of assignment problems.

Unit 4 Integer programming problems.

Introduction - Solution to integer programming problems by cutting-plane algorithm and branch-and-bound technique.

Unit 5 Sequencing problems.

Introduction - Processing of two jobs through two machines - Processing of n jobs through two machines - Processing of n jobs through three machines.

Unit 6 Game theory.

Introduction - Two-persons, zero sum games - Pure and mixed strategies - Rules of dominance - Solution methods without saddle point.

Unit 7 Queuing theory.

Introduction - Single channel queuing theory - Single Channel Poisson Arrivals with Exponential Service Times, Infinite Population (M/M/1 : ∞ / FCFS) - Single Server Finite queue (M/M/1 : N/FCFS).

References / Textbooks.

1) D. S. Hira and P. K. Gupta, Operations Research, S. Chand Publishers.
2) J. K. Sharma, Operations Research: Theory and Applications.
3) H. A. Taha, Operations Research, PHI Limited, New Delhi.

Course code / Category	**MEC402 / Professional Core**				
Course title	**Internal Combustion Engines**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7**
Pre-requisites if any	**MEC206**				

Unit 1 Introduction to internal combustion (IC) engines.

Principle of working - Basic engine types - Components of IC engines - Classification and nomenclature - Working and comparison of 2- and 4-stroke Petrol and Diesel engines - Valve timing diagrams - Actual and fuel-air cycles for SI and CI engines - Analysis of air standard cycles (Otto, Diesel and Dual).

Unit 2 Combustion in SI and CI engines.

Classification of IC engine fuels - Carburetion - Air-fuel ratio requirement - Analysis of a simple carburettor - Combustion stages in SI and CI engine - Theories of normal and abnormal combustion in SI and CI engines.

Unit 3 Fuel supply systems in SI and CI engines.

Fuel ignition and injection systems - Injection pumps and nozzles - Ignition: Battery, magneto, and electronic ignition systems - Supercharging, turbocharging, and scavenging.

Unit 4 Engine performance.

Lubrication and cooling - Engine lubrication systems - Cooling systems - Performance, testing and measurement - Heat balance.

Unit 5 Alternative fuels and emission control.

Alternative fuels for SI and CI engines - Air requirement - Emissions - Main pollutants in SI and CI engines - Soot formation and oxidation - Emission control measures for SI and CI engines.

Textbooks / References.

1) V. Ganesan, Internal Combustion Engines, Tata McGraw Hill Book Co., 2003.
2) John B. Heywood, Internal Combustion Engine Fundamentals, Tata McGraw Hill Book Co., 2002.
3) M. L. Mathur and R. P. Sharma, A Course in Internal Combustion Engines, Dhanpat Rai Publications, New Delhi, 2000.
4) E. F. Obert, Internal Combustion Engine and Air Pollution, International Textbook Publishers, 2001.

SYLLABUS FOR PROFESSIONAL ELECTIVES

Course code / Category	**MEE301 / Professional Elective**				
Course title	**Additive Manufacturing**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**-----**				

Unit 1 Introduction to additive manufacturing (AM).

Classification of AM processes (VAT photopolymerization, material jetting, binder jetting, extrusion process, powder bed fusion process, direct energy deposition process and sheet metal deposition) - AM generic process chain - Applications of AM: biomedical applications, rapid tooling, automotive applications, etc. - Introduction to CAD models (surface and solid models) - AM data formats: STL format - STL file problems - STL file repair - Introduction to other translators (IGES file, HP/GL file, CT fata, SLC file, CLI file, RPI file and LEAF file) - Slicing algorithms: staircase effect - uniform and adaptive slicing algorithms for tessellated and solid CAD models.

Unit 2 Materials.

Polymers: polymers for powder, liquid and filament - properties and process-specific consolidation mechanisms - Metals: commonly used alloys, printability issues (affinity for atmosphere constituents, high reflectivity and thermal conductivity, residual stress, and microstructure) - Ceramics: types of ceramic part production (direct or single-step and indirect) process - Issues, challenges and potential in ceramic AM - Multi-materials: functionally graded materials, polymer composites and metal composites - Smart materials: brief introduction to smart materials in AM.

Unit 3 Metal additive manufacturing processes.

Fusion processes: energy sources - consolidation mechanisms - important process parameters (energy source-, scan-, feedstock- and temperature-related parameters) - Solid-state metal AM: fundamentals of binder jetting - metal extrusion AM - ultrasonic consolidation - additive friction stir deposition - cold spray AM - Case study on any one of the topics: AM of Titanium alloys, AM of Nickel-base superalloys, AM of steels, AM of Copper and Copper alloys, AM of Aluminium alloys.

Unit 4 Micro additive manufacturing.

Brief description - Challenges of microscale AM: direct ink writing / jetting process, laser-based curing, heating and trapping processes - Energy induced deposition and hybrid processes.

Unit 5 Quality issues and post-processing.

Defects and their causes in polymer and metal additive manufactured parts - In-line process monitoring of powder-bed fusion and directed-energy deposition processes - Surface post-treatment (material removal, no material removal and coating) - Heat treatment - Hot isostatic pressing.

Textbooks / References.

1) S. Kumar, Additive Manufacturing Processes, 1e, Springer.
2) I. Gibson, D. Rosen and B. Stucker, Additive Manufacturing Technologies, 2e, Springer New York.
3) C. K. Chua, K. F. Leong, and C. S. Lim, Rapid Prototyping Principles and Applications, 3e, World Scientific Publishing Co.
4) A. Bandyopadhyay and S. Bose, Additive Manufacturing, 2e, CRC Press.
5) N. Hopkinson, R. J. M. Hauge and P. M. Dickens, Rapid Manufacturing: An Industrial Revolution for the Digital Age, John Wiley & Sons.
6) S. Joshi, R. P. Martukanitz, A. R. Nassar and P. Michaleris, Additive Manufacturing with Metals, 1e, Springer Nature Switzerland AG.
7) Y. Shi, C. Yan, Y. Zhou, J. Wu, Y. Wang, S. Yu and C. Ying, Materials for Additive Manufacturing, 1e, Academic Press.

Course code / Category	**MEE302 / Professional Elective**				
Course title	**C++ Programming for Mechanical Engineers**				
Scheme and credits	L	T	P	C	Year
	2	**0**	**2**	**3**	**3**
Pre-requisites if any	**-----**				

Unit 1 Fundamentals.

The history of C++ - Data types: built-in, user-defined, derived and enumerated data types - Constants and variables - Symbolic constants - Dynamic initialization of variable - Reference variables - Storage classes: auto, static, extern and register variables - Operators: arithmetic, relational, logical, assignment and conditional operators - Control structures: if-else, nested if-else, while, do-while, for, break, continue, switch and goto statements.

Unit 2 Arrays, structures and functions.

Arrays: one dimensional and multidimensional arrays - static and dynamic arrays - processing of arrays - arrays and strings - Structures: defining a structure - accessing the members of structures - self-referential structures - Functions: function declaration - function definition - calling of functions - Passing arguments to functions: passing constants, passing values, passing arrays, reference arguments, structures as arguments and default arguments - Returning values from functions: return statement - returning structures - return by reference - Inline functions - Function overloading.

Unit 3 Object-oriented programming (OOP).

Overview of OOP - Basic concepts, benefits and applications - OOP languages - Objects and classes: defining the class and its members - Making an outside function inline, nesting of member function, array as class member, structure and classes - Constructor and destructor: null and default constructors - parameterized constructors - constructor with default arguments - copy constructors - class destructors - Memory allocation: memory allocation for objects, new and delete operator, static data member, static member functions and object as function argument.

Unit 4 Inheritance and polymorphism.

Inheritance: types of inheritance - function overriding - Constructor in derived class - Access specifiers: public, private and protected - Polymorphism: dynamic polymorphism - virtual functions - Abstract classes - Static polymorphism: operator keyword - overloading the unary and binary operators using operator function - Friend functions - Friend class - Overloading binary operators using friend function.

Unit 5 Pointers, file handling and applications in Mechanical Engineering.

Pointers: introduction - declaration of pointers - pointer operators - pointer to arrays, functions and objects - arrays of pointers - this pointer - pointer to derived classes - passing functions to other functions - File handling in C++ - Programming for solving typical Mechanical Engineering problems.

Textbooks / References.

1) E. Balagurusamy, Object Oriented Programming with C++, Tata McGraw-Hill Co.
2) Bjarne Stroustrup, The C++ Programming Language, Addison-Wasley.
3) Robert Lafore, Object Oriented Programming in C++, Galgotia Publications.

Course code / Category	**MEE303 / Professional Elective**				
Course title	**Computational Methods in Mechanical Engineering**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**MES201**				

Unit 1 Introduction and mathematical foundations.

Introduction: role of computational methods in engineering problem solving (e.g., stress analysis, heat transfer simulations, etc.) - Advantages and limitations of computational approaches - Programming fundamentals (using chosen software): basic syntax, data types, control flow statements, and functions - Error analysis: rounding errors, truncation errors and propagation of errors - Importance of accuracy and precision in computations - Mathematical foundations for numerical methods: review linear algebra concepts (matrices, vectors and determinants).

Unit 2 Root finding algorithms.

Nonlinear equation systems: classification of roots (real vs. complex, single vs. multiple) - graphical methods for root visualization applied to mechanical engineering problems (e.g., buckling analysis of beams) - Iterative root finding methods: bisection method, fixed-point iteration, Newton-Raphson method and secant method - Convergence analysis and error estimation - Applications of root finding in mechanical engineering: finding natural frequencies of vibrations - calculating critical loads for buckling.

Unit 3 Linear algebra and interpolation.

Gaussian elimination - LU decomposition applied to solve systems of linear equations arising in mechanical engineering (e.g., truss analysis, finite element method) - Matrix inversion techniques for calculating displacements, forces and other mechanical engineering quantities - Iterative methods for solving linear systems: Jacobi iteration and Gauss-Seidel iteration with examples in mechanical engineering (e.g., solving heat transfer problems) - Convergence analysis of iterative methods - Curve fitting and interpolation: polynomial regression, Lagrange interpolation, spline interpolation for fitting experimental data or complex geometries.

Unit 4 Numerical differentiation and integration.

Numerical differentiation: finite difference methods for approximating displacement, velocity, and acceleration derivatives in mechanical systems - Numerical integration: trapezoidal rule, Simpson's rule and Gaussian quadrature - Error analysis and truncation error considerations - Applications of numerical differentiation and integration: examples from various mechanical engineering disciplines (e.g., solving differential equations for dynamic systems, calculating fluid flow rates, heat transfer across a surface, calculating areas, volumes, and other engineering quantities).

Unit 5 Introduction to ordinary differential equations.

Classification of ODEs - Initial value problems (IVPs) - Boundary value problems (BVPs) - Single-step methods for solving ODEs: Euler's method and Runge-Kutta methods - Multistep methods for solving ODEs: Adams-Bashforth methods and Adams-Moulton methods - Applications of ODE solvers in engineering: modelling and simulation of dynamic systems (e.g., control systems, mechanical vibrations).

Textbooks / References.

1) S. Chapra and R. Canale, Numerical Methods for Engineers, 6e, McGraw-Hill.
2) S. P. Venkateshan and P. Swaminathan, Computational Methods in Engineering, 1e, Academic Press.
3) W. Xu, Y. Guo and M. M. Rana, Fundamentals of Computational Methods for Engineers, 1e, Bentham Science Publishers.
4) Y. Jaluria, Computer Methods for Engineering with MATLAB® Applications, 2e, CRC Press.
5) Q. Kong, T. Siauw and A. Bayen, Python Programming and Numerical Methods: A Guide for Engineers and Scientists, 1e, Academic Press.
6) K. H. Grote and E. Antonsson, Springer Handbook of Mechanical Engineering, 1e, Springer Berlin, Heidelberg.

Course code / Category	**MEE304 / Professional Elective**				
Course title	**Data Analytics and Machine Learning**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**MES203**				

Unit 1 Basic concepts.

Data-driven decision making: descriptive, predictive and prescriptive analytics techniques - Challenges in data-driven decision making and future - Data types and representations: structured and unstructured data, cross-sectional, time series and panel data - Data measurement scales: nominal scale, ordinal scale, interval scale and ratio scale - Population and sample - Learning from data: introduction to types of data learning paradigms, learning workflow and applications in manufacturing.

Unit 2 Statistical foundations.

Basic concepts of probability - Bayes' theorem - Chebyshev's theorem - Random variables - Probability density and cumulative distribution functions - Descriptive statistics: measures of central tendency (mean - median - mode) - measures of dispersion (variance - standard deviation), measures of skewness and kurtosis - Inferential statistics: confidence intervals - statistical tests (T-test - χ^2-test test - ANOVA - Pearson correlation coefficient) - Hypothesis testing: null and alternative hypothesis - one-tailed and two-tailed tests - Type I and Type II errors - power of the hypothesis test.

Unit 3 Introduction to supervised learning.

Regression analysis (linear regression, logistic regression), Classification algorithms (decision trees, support vector machines).

Unit 4 Introduction to unsupervised learning.

Unsupervised learning: K-means clustering - Principal Component Analysis (PCA).

Unit 5 Deep learning.

Introduction to deep Learning, convolutional neural networks and recurrent neural networks.

Textbooks / References.

1) U. Dinesh Kumar, Business Analytics, The Science of Data-driven Decision Making, 1e, Wiley.
2) K. Murphy, Machine Learning: A Probabilistic Perspective, 1e, MIT Press.
3) J. Jose, Introduction to Machine Learning,1e, Khanna Book Publishing Company.
4) G. James, D. Witten, T. Hastie, R. Tibshirani and J. Taylor, An Introduction to Statistical Learning: with Applications in Python, 1e, Springer.
5) S. K. Jayasingh, P. Sahu and S. K. Jena, Introduction to Machine Learning, 1e, Taran Publication.
6) G. Rebala, A. Ravi and S. Churiwala, An Introduction to Machine Learning, 1e, Springer Nature Switzerland AG.

Course code / Category	**MEE305 / Professional Elective**				
Course title	**Fluid Machinery**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**MEC202**				

Unit 1 Impact of jets and impulse turbines.

Classification of fluid machines and devices - Application of momentum and moment of momentum equation to flow through hydraulic machinery, Euler's fundamental equation - Introduction to hydrodynamic thrust of jet on a fixed and moving surface (flat and curved) - Classification of turbines - Impulse turbines: constructional details - velocity triangles - power and efficiency calculations - Governing of Pelton wheel.

Unit 2 Reaction turbines.

Francis and Kaplan turbines - Constructional details - Velocity triangles - Power and efficiency calculations - Degree of reaction - Draft tube - Cavitation in turbines - Principles of similarity - Unit and specific speeds - Performance characteristics - Selection of water turbines.

Unit 3 Centrifugal pumps.

Classifications of centrifugal pumps - Vector diagram - Work done by impellor - Efficiencies of centrifugal pumps - Specific speed - Cavitation and separation - Performance characteristics.

Unit 4 Positive displacement and other pumps.

Reciprocating pumps theory - Slip - Indicator diagram - Effect of acceleration - Air vessels - Comparison of centrifugal and reciprocating pumps - Performance characteristics.

Unit 5 Hydraulic devices.

Hydraulic accumulator - Hydraulic intensifier - Hydraulic press - Hydraulic crane - Hydraulic lift - Hydraulic ram - Hydraulic coupling - Hydraulic torque converter - Air lift pump - Jet pump.

Textbooks / References.

1) J. Lal, Hydraulic Machines, Metropolitan Book Co. Pvt. Ltd.
2) K. Subramanya, Hydraulic Machines, Tata McGraw Hill Co.
3) D. S. Kumar, Fluid Mechanics and Fluid Power Engineering, S. K. Kataria & Sons.
4) M. M. Das, Fluid Mechanics and Turbo machines, PHI.
5) A. Esposito, Fluid Power with Applications, Pearson Publication.
6) P. N. Modi and S. M. Seth, Fluid Mechanics and Hydraulic Machines, Standard Book House.
7) V. P. Vasandani, Hydraulic Machines: Theory and Design, Khanna Publishers.

Course code / Category	**MEE306 / Professional Elective**				
Course title	**Fracture Mechanics**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**MES105 / MEC203 / BSC102**				

Unit 1 Introduction.

Stress-strain equation - Biaxial and triaxial stress states - Plane conditions - Equilibrium equations - Airy's stress function - Airy's power series - Theoretical strength - Stress concentration factor - Griffith crack theory - Strain energy release rate - Grain size refinement.

Unit 2 Linear elastic fracture mechanics.

Modes of loading - Westergard's stress function - Far-field boundary condition - Near-field boundary condition - Specimen geometries - Through the thickness centre crack - Elliptical cracks - Part through thumbnail surface flaw - Leak before break criterion - Radial crack around cylinder - Fracture control - Plane stress vs plane strain - Principle of superposition.

Unit 3 Crack tip elasticity and the energy principle.

Crack tip stress state - Irwin's approximation - Dugdale's approximation - Crack opening displacement - The shape of the elastic zone - Von-Mises yielding criterion - Tresca yielding criterion - Energy release rate - Linear compliance - Nonlinear crack growth - Traction forces - Load and displacement control - Crack resistance curves - The J-integral - Tearing modulus.

Unit 4 Plastic fracture mechanics and mixed mode fracture mechanics.

J-controlled crack growth - HRR field equations - Semi empirical approach - Near-field J-integral - Far-field J-integral - Engineering approach - The constant h1 - Elastic state of stresses - Strain energy release rate: Mode I and II - Fracture angle: Mode I and III - Principal stress criterion - Strain energy density factor - Crack branching.

Unit 5 Fatigue crack growth and creep fracture.

Cyclic stresses - Fatigue crack initiation - Fatigue crack growth rate - Fatigue life calculations - Crack growth rate diagram - Weldments - Surface fracture appearances - Mixed-mode loading - Growth rate measurements and corrosion fatigue - Creep: mechanism and stages - Cavity nucleation - Vacancy accumulation - Grain boundary sliding - Dislocation pile-up - Growth: grain boundary diffusion-controlled - surface diffusion-controlled.

Textbooks / References.

1) T. L. Anderson, Fracture Mechanics - Fundamentals and Applications, 3e, CRC Press, 2005.
2) R. W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 4e, John Wiley, 1995.
3) M. Janssen, J. Zuidema and R. Wanhill, Fracture Mechanics, 2e, Spon Press, 2004.
4) M. F. Kanninen and C. H. Popelar, Advanced Fracture Mechanics, Oxford University Press, 1985.
5) David Broek, Elementary Engineering Fracture Mechanics, 3e, Martinus Nijhoff Publishers, 1984.
6) A. P. Boresi and R. J. Schmidt, Advanced Mechanics of Materials, 6e, John Wiley, 2003.

Course code / Category	**MEE307 / Professional Elective**				
Course title	**Industrial Robotics**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**-----**				

Unit 1.

Introduction to robotics: definitions - motivation - historical development - basic structure - classification - workspace - grippers - serial manipulator - parallel manipulator - Specification of robots - Selection of robots based on the application.

Unit 2.

Robot arm kinematics and dynamics: frame transformation - D-H parameters - forward kinematics - inverse kinematics - Lagrange formulation - Newton-Euler formulation for RR and RP manipulators.

Unit 3.

Trajectory generation: Cartesian scheme - Joint space scheme.

Unit 4.

Teaching methods: manual teaching - lead-through teaching - Robot programming language and systems such as VAL programming.

Unit 5.

Sensing: range sensing - proximity sensing - touch sensors - force and torque sensing - Robot vision: low-level vision - higher-level vision - Control schemes: position control - force control.

Unit 6.

Hands-on practice: motor control microcontroller - sensor data acquisition and operation of industrial robots - Application of robots in production systems - Robots used in welding, machine tools, material handling, assembly operations, parts sorting and parts inspection.

Textbooks / References.

1) R. C. Gonzalez, K. S. Fu and C. S. G. Lee, Robotics: Control, Sensing, Vision and Intelligence, Tata Mc-Graw Hill.
2) John Craig, Introduction to Robotics Mechanics and Control, Pearson Education.
3) M. P. Groover, Industrial Robots - Technology Programmes and Applications, McGraw Hill , New York, USA.

Course code / Category	**MEE308 / Professional Elective**				
Course title	**Sensors and Applications**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**ESC202**				

Unit 1 Strain and pressure measurement.

Resistance strain gauge - Piezoelectric pressure gauge - Electronic circuits for strain gauge - Load cells - Interferometer - Fibre-optic methods - Pressure gauges: aneroid capacitance pressure gauge - ionization gauge - Using the transducers for applications.

Unit 2 Motion sensors.

Capacitor plate sensor - Inductive sensors - LVDT accelerometer systems - Rotation sensors - Drag cup devices - Piezoelectric devices - Rotary encoders.

Unit 3 Light radiation.

Colour temperature - Light flux - Photo sensors - Photomultiplier - Photo resistor and photoconductors - Photodiodes - Phototransistors - Photovoltaic devices - Fibre-optic applications - Light transducer - Solid-state transducers - Liquid crystal devices.

Unit 4 Heat and temperature.

Bimetallic strip - Bourdon temperature gauge - Thermocouples - Resistance thermometers - Thermistors - PTC thermistors - Bolometer - Pyroelectric detector.

Unit 5 Electronic sensors.

Proximity detectors: inductive and capacitive, ultrasonic and photo beam detectors - Reed switch - Magnet and Hall-effect units - Doppler detectors - Liquid level detectors - Flow sensors - Smoke sensors.

Textbooks / References.

1) E. O. Doebelin, Measurement Systems: Application and Design , McGraw Hill, 5e, 2004.
2) J. P. Holman, Experimental Methods for Engineers, 7e, McGraw Hill, USA, 2001.
3) I. R Sinclair, Sensors and Transducers, 3e, Newnes Publishers, 2001.
4) J. G. Webster, Measurement Instrumentation and Sensors Handbook, CRC Press, 1999.
5) R. G. Seippel, Transducers, Sensors and Detectors, Reston Publishing Company, USA, 1983.

Course code / Category	**MEE401 / Professional Elective**				
Course title	**Automobile Engineering**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Vehicle structure and engines.

Types of automobiles - Vehicle construction and different layouts - Chassis, frame and body - IC engines: components function and materials.

Unit 2 Engine auxiliary systems.

Fuel supply system - Starting system - Ignition system - Electronic injection for SI - Electronic fuel injection system - Mono-point and Multi-point injection systems - Turbo chargers and superchargers.

Unit 3 Transmission systems.

AWD and 4WD transmission - Clutch-types and construction - Gear boxes: manual and automatic - gear shift mechanisms - overdrive - transfer box - fluid flywheel - torque converter - propeller shaft - slip joints - universal joints - differential and rear axle.

Unit 4 Steering, brakes and suspension.

Steering geometry and types of steering gear box - Power steering - Types of front axles - Wheel alignment - Braking systems: types and construction - antilock braking system (ABS) and traction control - pneumatic and hydraulic braking systems - Suspension systems.

Unit 5 Alternative fuels and emission control.

Use of natural gas - Liquefied petroleum gas - Biodiesel and hydrogen in automobiles - Exhaust emission control - Electric and hybrid vehicles.

Textbooks / References.

1) Kirpal Singh, Automobile Engineering, Vol. 1 & 2, Standard Publishers, 7e,1997, New Delhi.
2) K. K. Jain and R. B. Asthana, Automobile Engineering, Tata McGraw Hill Publishers, New Delhi, 2002.
3) T. K. Garrett, K. Newton and W. Steeds, Motor Vehicle, 13e, Butterworth Heinemann Publishers, 2000.

4) M. W. Stockel and M. T. Stockel, Automotive Mechanics Fundamentals, The Good Heart - Will Cox Company Inc., USA, 1978.
5) H. Heisler, Advanced Engine Technology, SAE International Publications, USA,1998.
6) V. Ganesan, Internal Combustion Engines, 3e, Tata McGraw-Hill Co., 2007.
7) W. H. Crouse and D. L. Anglin, Automotive Mechanics, 10e, Tata McGraw-Hill Publishing Company Ltd., 2004.

Course code / Category	**MEE402 / Professional Elective**				
Course title	**Biofluid Mechanics**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Conservation laws of fluid mechanics - Introduction to physiological systems.

Unit 2.

Circulatory biofluid mechanics - Circulation in heart, blood and lymphatic vessels.

Unit 3.

Blood properties - Models for blood flow.

Unit 4.

Steady flow in tubes - Pulsatile flow in a rigid tubes and elastic tubes.

Unit 5.

Respiratory biofluid mechanics - Air flow in the lungs - Mechanics of breathing - Gas exchange and transport - Flow and pressure measurement techniques in human body.

Textbooks / References.

1) C. R. Ethier, Introductory Biomechanics: From Cells to Organisms, Cambridge University Press.
2) L. Waite and J. Fine, Applied Biofluid Mechanics, McGraw Hill Co.
3) K. B. Chandran, S. E. Rittgers and A. P. Yoganathan, Biofluid Mechanics: The Human Circulation, 2e, CRC Press.

Course code / Category	**MEE403 / Professional Elective**				
Course title	**Biomechanics**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction to biomechanics.

Basic terminology and concepts - Vibration exciters, control systems, motion sensors and transducers - Mechanical properties of soft tissues, bones and muscles.

Unit 2 Biomechanics of tissues and structures of the musculoskeletal system.

Introduction, structure and function of musculoskeletal system - Connective tissues - Biomechanics of bone - Biomechanics of articular cartilage, tendons and ligaments, peripheral nerves and spinal nerve roots and skeletal muscle.

Unit 3 Biomechanics of joints.

Knee - Hip - Foot and ankle - Lumbar spine - Cervical spine - Shoulder - Elbow - Wrist - Hand.

Unit 4 Biomechanics of human motion.

Linear kinematic and kinetic aspects of human movement - Angular kinematic and kinetic aspects of human movement - Equilibrium and human moment - Biomechanics of gait.

Unit 5 Measurements, modelling and analysis.

Joint motion - Human motion analysis system - Applied electromyography - Intradiscal pressure measurement - Intrabdominal measurement - Force platform system - Whole body vibration measurement - Measurement of body segment and physical properties - Anthropometric data for biomechanical studies in industry - Planar static biomechanical models - Static 3D modelling - Dynamic biomechanical models - Special purpose biomechanical models - Anatomy and biomechanics of manual handling - Prevention of manual handling injuries in the workplace - Design of manual handling tasks, carrying and postural stability - Discomfort analysis: RULA, REBA and Corlett Bishop's body mapping - Vibration on human body: whole body vibration - hand transmitted vibration - segmental vibration - vibration exposure criteria.

Textbooks / References.

1) S. J. Hall, Basic Biomechanics, 5e, McGraw Hill Inc.
2) J. D. Humphrey and S. L. Delange, An Introduction to Biomechanics: Solids and Fluids, Analysis and Design, Springer-Verlag.
3) M. Nordin and V. H. Frankel, Basic Biomechanics of the Musculoskeletal System, Lippincott Williams and Wilkins.
4) N. Özkaya, D. Leger, D. Goldsheyder and M. Nordin, Fundamentals of Biomechanics: Equilibrium, Motion and Deformation, Springer Verlag.

5) C. W. De Silva, Vibration and Shock Handbook, Taylor & Francis.
6) D. B. Chaffin and G. B. J. Andersson, Occupational Biomechanics, John Wiley & Sons.

Course code / Category	**MEE404 / Professional Elective**				
Course title	**Composite Materials and Structures**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Introduction to composite materials - Classification: polymer matrix composites, metal matrix composites, ceramic matrix composites, carbon-carbon composites and particulate matrix composites - Basic terminology - Lamina - Laminates - Stacking sequence - Recycling of composites - Application of composites - Strength and stiffness advantages - Weight advantage.

Unit 2.

Review of strain, stress and strain energy - Generalizes Hooke's law for anisotropic, monoclinic, orthotropic and transversely isotropic material for three dimensions and reduction to plain stress and plane strain conditions - Stress-strain relations to plain stress and plane strain conditions - Tsai-Wu and Tsai-Hill failure criteria.

Unit 3.

Mechanical behaviour lamina - Determination of E_1, E_2, γ_{12} and G_{12} - Elasticity approach - Bounding techniques of elasticity - Exact solution - Elasticity solution with contiguity - Halpin-Sai equation - Tensile and compressive strength in fibre direction.

Unit 4.

Macro mechanical behaviour of lamina - Lamina stress-strain vector - Classical laminated plate theory - Stress-strain variation in laminates - Resultant laminate force and moment vectors - Stiffness of symmetric and antisymmetric and unsymmetric laminates - Classical lamination theory - First order shear deformation theory.

Unit 5.

Governing equation for bending, buckling and vibration of laminated plates - Deflection of simply supported laminated plates under distributed load - The vibration of simply supported specially orthotropic plates.

Textbooks / References.

1) R. M. Jones, Mechanics of Composite Materials, 2e, Taylor & Francis, 2014.
2) R. F. Gibson, Principles of Composite Material Mechanics, 2e, McGraw-Hill, 1994.
3) M. W. Hyer, Stress Analysis of Fiber-Reinforced Composite Materials, McGraw-Hill, 1998.
4) I. M. Daniel and O. Ishai, Engineering Mechanics of Composite Materials, Oxford University Press, 2007.
5) P. K. Mallick, Reinforced Composites: Materials, Manufacturing and Design, Marcel Dekker, Inc., 1993.
6) J. C. Halpin, Primer on Composite Materials Analysis, Technomic Publishing Co., 1984.

Course code / Category	**MEE405 / Professional Elective**				
Course title	**Computer Aided Inspection**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC303**				

Unit 1 Fitting techniques for computational metrology.

Fitting substitute geometries: linear and nonlinear least square fitting (line, plane, circle, sphere and cylinder) - Algorithms for minimum zone fitting (line, plane and circle).

Unit 2 Computational surface metrology.

Measurement of surface finish in 2D and 3D: various parameters - Filtering: history of filtering - different filters in 2D - filtering in time and frequency domains - filtering in 3D - Advanced filtering techniques.

Unit 3 Interferometry and laser metrology.

Interferometers: light sources - scales and gratings - optical flats - use of interferometers for calibration of height standards, etc. - Laser metrology: laser light source - laser interferometer - laser alignment telescope - laser micrometer - Applications in online and in-process measurements.

Unit 4 Coordinate measuring machines (CMMs).

Types of CMMs - Major hardware elements - Hard probing and soft probing - CMM software - Performance evaluation - Environmental control - Accuracy enhancement - Applications of CMMs - Integration of CMM and data logging in computers.

Unit 5 Vision-based measurements.

Introduction to image acquisition and processing - Shape identification - Edge detection - Normalization - Greyscale correlation - Template techniques - Interfacing robot and image processing systems - Applications of vision systems for the measurement of surface roughness, tool wear, lengths and diameters, and sorting and counting of objects.

Unit 6 Advanced topics.

Metrology of micro-machined parts - Micro-holes and topography measurements - Nano metrology - Developments in micro and nano metrology - - Statistical evaluation of data using computers.

Textbooks / References.

1) B. Muralikrishnan and J. Raja, Computational Surface and Roundness Metrology, Springer-Verlag London Ltd.
2) R. J. Hocken and P. H. Pereira, Coordinate Measuring Machines and Systems, 2e, CRC Press.
3) Meadows, J. D., Geometric Dimensioning and Tolerancing, Marcel Dekker, Inc., New York.
4) T. Yoshizawa, Handbook of Optical Metrology: Principles and Applications, 2e, CRC Press.
5) D. J. Whitehouse, Handbook of Surface and Nanometrology, 2e, CRC Press.

Course code / Category	**MEE406 / Professional Elective**				
Course title	**Computer Integrated Manufacturing**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC306 / MEC307**				

Unit 1 Introduction to CIM and automation.

Evolution of CIM: historical perspective of manufacturing - automation levels - benefits of CIM - CIM concepts: introduction to manufacturing systems - elements of a CIM system - data flow in CIM - Manufacturing models and metrics: production systems (discrete, continuous) - performance measures (productivity, lead time, quality) - Industry 4.0 overview: key technologies (IoT, big data, cloud computing) and its impact on manufacturing.

Unit 2 Computer-Aided Design (CAD) and Manufacturing (CAM).

Introduction to CAD: 2D and 3D modelling concepts - geometric modelling techniques (parametric and feature-based) - Introduction to CAM: principles of CAM - computer-aided process planning (CAPP) - integration with CAD - CNC technology: CNC machining concepts - CNC machine components (controller, drives and actuators) - types of CNC machines.

Unit 3 Advanced manufacturing systems.

Flexible Manufacturing Systems (FMS): basic concepts - components (workstations, material handling systems and control systems) - benefits and applications - Robotics: robot anatomy (manipulators, end effectors and sensors) - robot programming - Computer-Aided Process Planning (CAPP): benefits - types of CAPP systems (variant and generative) - integration with CAD/CAM - Additive Manufacturing: key technologies, materials and applications in prototyping and production.

Unit 4 Data management and communication in CIM.

Manufacturing Information Systems (MIS): role of MIS in CIM - data acquisition and storage - enterprise resource planning (ERP) - Industrial Networking: communication protocols for CIM - factory automation networks - Data security and standards: security concerns in CIM systems - data encryption - industrial automation standards.

Unit 5 Future of CIM.

Smart manufacturing concepts: Cyber-Physical Systems (CPS) - Industrial Internet of Things (IIoT) - digital twins - Big data analytics in manufacturing: data collection, processing and analysis for process optimization and predictive maintenance - Cloud computing in CIM: cloud-based manufacturing, scalability and remote monitoring - Emerging trends: Artificial intelligence (AI) in manufacturing, Collaborative robots (cobots), and future directions of CIM.

Textbooks / References.

1) M. P. Groover, Automation, Production Systems and Computer-Integrated Manufacturing, 4e, Prentice Hall, 2007.
2) A. Weatherall, Computer Integrated Manufacturing: From Fundamentals to Implementation, 1e, Butterworth-Heinemann, 2013.
3) X. Xu, Integrating Advanced Computer-aided Design, Manufacturing and Numerical Control, 1e, Information Science Reference, 2009.
4) P. Radhakrishnan, Computer Numerical Control Machines and Computer Aided Manufacture, 2e, New Academic Science Ltd., London, 2018.
5) K. Schwab, Fourth Industrial Revolution, 1e, Penguin, 2017.
6) A. Azizi, and R. V. Barenji, Industry 4.0: Technologies, Applications and Challenges, 1e, Springer Verlag, Singapore, 2023.

Course code / Category	**MEE407 / Professional Elective**				
Course title	**Cryogenics**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Insight on cryogenics - Properties of cryogenic fluids - Material properties at cryogenic temperatures.

Unit 2.

Carnot liquefaction cycle - FOM and yield of liquefaction cycle - Inversion curve - Joule Thomson effect - Linde Hampson cycle - Precooled Linde Hampson cycle - Claudes cycle - Dual cycle

Unit 3.

Binary mixtures - T-C and H-C diagrams - Principle of rectification - Rectification column analysis - McCabe Thiele method - Adsorption systems for purification.

Unit 4.

JT cryocoolers - Stirling cycle refrigerators - GM cryocoolers - Pulse tube refrigerators - Regenerators used in cryogenic refrigerators - Cryogenic Dewar constructive and design - Cryogenic transfer lines - Vacuum pumps and types - Instrumentation to measure flow-level and temperature.

Unit 5.

Applications of cryogenics in space programs - Superconductivity - Cryo-metallurgy - Medical applications.

Textbooks / References.

1) Mamata Mukhopadhyay, Fundamentals of Cryogenic Engineering, Prentice Hall of India.
2) Randall F. Barron, Cryogenic Systems, Oxford University Press.
3) Thomas M. Flynn, Cryogenic Engineering, Marcel Dekker.

Course code / Category	**MEE408 / Professional Elective**				
Course title	**Design for Manufacturing and Assembly**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC205 / MEC306 / MEC203 / MEE301**				

Unit 1 Basic concepts.

Implementation of concurrent engineering - Issues involved in introducing DFMA - DFMA principles and techniques - Commercial DFMA packages - Requirements for new generation DFMA systems - Knowledge-based approaches to DFMA - Interfacing CAD and DFMA systems.

Unit 2 Component design - Machining considerations.

Introduction to machining: recommended materials for machinability - design recommendations - Design for tuning: process description - typical characteristics and applications - suitable materials - design recommendations - Design for drilling: introduction - suitable materials - design recommendations - recommended tolerances - Design for milling: process description - characteristics and applications of milled parts - design recommendations - dimensional factors and tolerances - Design for planning, shaping and slotting: process description - design recommendations - Design for broaching: process description, typical characteristics of broached parts - suitable materials - design recommendations.

Unit 3 Component design - Casting considerations.

Sand casting: typical characteristics of a sand cast part - design recommendations - Investment casting: introduction - steps in investment casting - design considerations - typical characteristics and applications - Die casting: introduction - advantages and disadvantages of die casting process - applications - suitable material consideration - general design considerations - specific design recommendations - Injection moulding: introduction - typical characteristics of injection moulded parts - effect of shrinkage - suitable materials - design recommendations - Design for powder metal processing: introduction - typical characteristics and applications - limitations - design recommendations.

Unit 4 Design for additive manufacturing.

Introduction to additive manufacturing (AM) - DFMA concepts and objectives - AM unique capabilities - Exploring design freedoms - Design tools for AM - Part orientation - Removal of supports.

Unit 5 Introduction to assembly.

The assembly process: characteristics and applications - Example of common assembly - Economic significance of assembly - General taxonomies of assembly operation and systems - Assembling a product - Design for assembly: introduction - design consideration - Design for fasteners: introduction - Design recommendation for fasteners.

Textbooks / References.

1) J. Lesko, Industrial Design, Materials and Manufacture Guide, John Wiley and Sons, Inc.
2) G. E. Dieter and L. C. Schmidt, Engineering Design, 4e, McGraw-Hill Co., New York.
3) G. Boothroyd, P. Dewhurst and W. Knight, Product Design for Manufacture and Assembly, 2e, CRC Press.
4) O. Molloy, S. Tilley and E. A. Warman, Design for Manufacturing and Assembly, 1e, Chapman & Hall, London.

Course code / Category	**MEE409 / Professional Elective**				
Course title	**Fluid Power Control**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1.

What is fluid power? - Applications and advantages - Components of hydraulic and pneumatic systems - Desired properties of hydraulic fluids - Advantages of mineral oil over water - Definitions of pressure, head, force, density, specific gravity, kinematic viscosity, dynamic viscosity, compressibility, etc. - Pascal's law - Analysis of simple hydraulic jack - Mechanical advantage - Continuity equation - Hydraulic power of a cylinder.

Unit 2.

Hydraulic Pumps - Positive displacement pumps: constructional features, working principle and volumetric capacity of external gear pump, vane pump, axial piston pump and radial piston pump.

Unit 3.

Hydraulic actuators: constructional features of single- and double-acting hydraulic cylinders - Mounting and cushioning of cylinders - Applications of cylinder through mechanical linkages - Force, velocity and power from a cylinder - Hydraulic motors: torque, power and flow rate - Hydraulic valves: direction control valves - Operation and graphical symbol of 3-way and 4-way valves - Modes of activation of valves - Operation and graphical symbols of check, pressure relief, pressure reducing, unloading and flow control valves - ANSI symbols for hydraulic components - Analysis of hydraulic circuits: single and double acting cylinder controls - regenerative circuit - pump unloading circuit - double pump hydraulic system - cylinder synchronization circuit - speed control of a hydraulic motor - circuit to lift and hold heavy load - automatic sequencing of two cylinders.

Unit 4.

Advantages and disadvantages of pneumatic systems compared to hydraulic systems - Constructional details and operation of a reciprocating compressor - Working principle and use of filter, pressure regulator, lubricator and silencer - Symbols of different pneumatic components - Compressed air distribution system in a plant - Drawing pneumatic circuits for different operations.

Unit 5.

Use of electrical devices to control fluid circuits - Function of electrical devices like pushbutton switches, limit switches, pressure switches, solenoids, relays and timers and their symbols - Ladder diagrams - Study of following circuits using electrical control devices: control of a solenoid actuated cylinder using one limit switch, reciprocation of a cylinder using pressure / limit switches, and two-cylinder sequencing circuit using two limit switches.

Textbooks / References.

1) Ilango and Soundararajan, Introduction to Hydraulics and Pneumatics, 2e, PHI.
2) A. Esposito, Fluid Power with Applications, 6e, Pearson Prentice Hall.
3) S. R. Majumdar, Pneumatic Systems: Principles and Maintenance, Tata McGraw-Hill.
4) E. C. Fitch, Jr, Fluid Power and Control Systems, McGraw-Hill Book Co.
5) Banks and Banks, Industrial Hydraulics, Prentice Hall.

Course code / Category	**MEE410 / Professional Elective**				
Course title	**Gas Dynamics & Jet Propulsion**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC206**				

Unit 1 Basic concepts.

Energy and momentum equations of compressible fluid flows - Stagnation states - Mach waves and Mach cone - Effect of Mach number on compressibility - Isentropic flows: isentropic flow through variable area ducts.

Unit 2 Isentropic flow.

Nozzles, diffusers, compressors and turbines - Use of gas tables - Flow through ducts: flow through constant area ducts with heat transfer (Rayleigh flow) and friction (Fanno flow) - Variation of flow properties - Use of tables and charts - Generalized gas dynamics.

Unit 3 Normal and oblique shocks.

Governing equations - Variation of flow parameters across the normal and oblique shocks - Prandtl Meyer relations - Expansion of supersonic flow - Use of tables and charts - Applications.

Unit 4 Jet propulsion.

Theory of jet propulsion - Thrust equation - Thrust power and propulsive efficiency - Operation principle - Cycle analysis and use of stagnation state performance of ram jet, turbojet, turbofan and turbo-prop engines - Aircraft combustors.

Unit 5 Space propulsion.

Types of rocket engines - Propellants - Ignition and combustion - Theory of rocket propulsion - Performance study - Staging - Terminal and characteristic velocity - Applications - Space flights.

Textbooks / References.

1) S. M. Yahya, Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, 5e, New Age International Publishers, 2016.
2) P. Balachandran, Fundamentals of Compressible Fluid Dynamics, PHI Learning India Private Ltd., 2009.
3) J. D. Anderson Jr., Modern Compressible Flow with Historical Perspective, 2/e, McGraw Hill Publishing Co., 1990.
4) A. H. Shapiro, Dynamics and Thermodynamics of Compressible Fluid Flow - Volume I, John Wiley, New York, 1953.

Course code / Category	**MEE411 / Professional Elective**				
Course title	**Heat Treatment Technology**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MES105**				

Unit 1 Introduction.

Iron-Carbon equilibrium diagram - Effect of alloying elements on properties of steels - Decomposition of austenite - Diffusion controlled and diffusion less transformations - Nucleation and growth of phases - Types and application of heat treatment methods in manufacturing industries.

Unit 2 Transformations.

Pearlitic and bainitic transformations - Mechanism of martensitic transformations - Determination of grain size - TTT and CCT curves.

Unit 3 Heat treatment processes.

Hardening - Tempering - Annealing - Normalizing - Surface hardening - Carburizing - Nitriding - Electron beam hardening - Laser hardening - Application of plasma in heat treating - Heat treatment of tool and alloy steels - Heat treatment of cast iron - Heat treatment of weldments.

Unit 4 Thermo-mechanical treatment.

Heat treatment of non-ferrous metals and alloys - Theory of age-hardening - Heat treatment defects in castings, forgings and weldments and their remedial measures - Automation and computerization of heat treating process and equipment - Controlling heat treating furnace atmosphere.

Unit 5 Heat treatment of engineering steels.

Heat treatment of general engineering steels: stainless steel, Hadfield steel, spring steels, bearing steels, tool steels, HSLA steels, maraging steels and dual phase steels - Heat treatment of non-ferrous metals and alloys: brasses - bronzes - Al and Mg alloys - Heat treatment defects and their rectification - Advances in heat treatment technology.

Textbooks / References.

1) T. V. Rajan, C. P. Sharma and A. Sharma, Heat Treatment: Principles and Techniques, PHI Learning Private Limited.
2) Vijendra Singh, Heat Treatment of Materials, Standard Publishers Distributors, Delhi.
3) S. H. Avner, Introduction to Physical Metallurgy, McGraw Hill Education (India) Pvt Ltd.
4) C. R. Brooks, Heat Treatment, Structure and Properties of Non Ferrous Alloys, ASM International.
5) R. E. Reed Hill, Physical Metallurgy Principles, Affiliated East West Press.

Course code / Category	**MEE412 / Professional Elective**				
Course title	**Machine Tools Design**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC203 / MEC204 / MEC301 / MEC302 / MEC308**				

Unit 1 Introduction to machine tool drives and mechanisms.

Introduction - Working and auxiliary motions in machine tools - Parameters defining working motions of machine tools - Machine tool drives - Selection of electric motors - Rotary and translatory hydraulic drives - Mechanical transmission and its elements: elementary transmission for transmitting rotary motion - elementary transmission for transforming rotary motion into translatory - devices for intermittent motion - reversing and differential mechanisms - General requirements of machine tool design.

Unit 2 Mechanical drives for providing rotational movements.

Basic principles - Stepped and stepless output - Requirements for layout of a stepped drive - Selection of range of spindle speeds - Range ratio and speed ratio - Principle of stepped regulation - Saw diagram - Comparison of different series: AP, GP and Logarithmic - Kinematic advantage of GP series - Analysis of productivity loss - Standard values of GP ratio - Number of steps in speed range - Rules for layout of gearboxes having sliding cluster - Types of structure diagram - Feasibility of structural forms - Ray diagram - Decision making for best ray diagram of a gear box - Design of shafts - Strength of gear tooth: determination of modules - Design of gear box - Classification of speed boxes - Classification of feed boxes - Stepless regulation of speed and feed rates: hydraulic, electrical and mechanical.

Unit 3 Design of machine tool structures.

Functions of machine tool structures and their requirements - Design criteria for machine tool structures - Materials of machine tool structures - Profiles of machine tool structures - Basic design procedure of machine tool structures: design for strength - design for stiffness - Design of beds - Design of lathe bed - Design of columns - Design of housings, bases, tables and rams.

Unit 4 Design of guideways.

Functions and types of guideways - Types of slideways - Types of antifriction ways - Design of slideways - Shapes of slideways - Materials of slideways - Methods of adjusting clearances in slideways - Design criteria and calculations for slideways: design of slideways for wear resistance - design of slideways for stiffness - Guideways operating under liquid friction conditions - Design of hydrodynamic slideways - Design of aerostatic slideways - Design of anti-friction guideways.

Unit 5 Design of spindles and spindles supports.

Functions and spindle unit and requirements - Materials of spindles - Effect of machine tool compliance on machining accuracy - Design calculations of spindles - Deflection of spindle axis due to bending - Deflection of spindle axis due to compliance of spindle supports - Optimum spacing between spindle supports - Deflection due to compliance of the tapered joint - Antifriction bearings: preloading of antifriction bearings - Sliding bearings - Sleeve bearings - Hydrodynamic journal bearings - Multiple wedge bearings - Hydrostatic journal bearings - Air lubricated bearings.

Unit 6 Vibration of machine tools and dynamic rigidity.

Definitions - Static stiffness - Dynamic rigidity - Dynamic stability - Introduction of machine tool vibration - Effects of vibration - Free motion of single degree of freedom system - Free damped vibration - Under damped forced vibration - Dynamic magnification factor - Maximizing and minimizing real receptance - Harmonic response locus - Sources of vibration - Machine tool chatter - Self-excited vibration and dynamic stability - Analysis of single degree of freedom chatter - Elimination of vibration: damping - isolating vibrations - dynamic absorber with damping - viscous damper - other methods of reducing instability in machine tools.

Textbooks / References.

1) N. K. Mehta, Machine Tool Design and Numerical Control, McGraw-Hill.
2) A. Bhattacharyya and G. C. Sen, Principles of Machine Tools, New Central Book Agency.
3) N. Acherkan (Ed.), Machine Tool Design, Mir Publications, Moscow.

Course code / Category	**MEE413 / Professional Elective**				
Course title	**Materials Characterization Techniques**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Light microscopy: optical principles - image formation - resolution - effective magnification - brightness and contrast - instrumentation - steps to improve depth of field - specimen preparation - imaging modes - bright field and dark field imaging - phase-contrast microscopy - polarized-light - Confocal microscopy: working principles.

Unit 2.

X-ray diffraction methods: X-ray radiation - generation of X-rays - X-ray absorption - theoretical background of diffraction - diffraction geometry - Bragg's law - reciprocal lattice - diffraction intensity - X-ray diffractometry - Samples and data acquisition: sample preparation - acquisition and treatment of diffraction data - distortions of diffraction spectra.

Unit 3.

Transmission Electron Microscopy: instrumentation - electron sources - thermionic emission gun - field emission gun - electromagnetic lenses - specimen stage - specimen preparation - pre-thinning - final thinning - electrolytic thinning - Scanning Electron Microscopy: instrumentation - optical arrangement - signal detection - detector - probe size and current - contrast formation - electron-specimen interactions - specimen preparation - preparation for micro composition examination.

Unit 4.

Spectroscopy: introduction - Ultraviolet-visible light (UV-vis) spectroscopy: principle - sample preparation - basic instrumentation - applications - Infrared spectroscopy: basic theory - sample preparation - instrumentation - applications - Fourier Transform spectrometry: principle - applications - Raman spectroscopy: principle - instrumentation - applications - Anger electron spectroscopy: principle - instrumentation - applications.

Unit 5.

Thermal analysis: common characteristics - thermal events - enthalpy change - instrumentation - experimental parameters - Differential thermal analysis and differential scanning calorimetry: working principles - experimental aspects - sample requirements - baseline determination - effects of scanning rate - measurement of temperature and enthalpy change - thermogravimetry.

Textbooks / References.

1) Yang Leng, Materials Characterization Techniques, 2e, John Willey and Sons, 2013.
2) P. K. Mitra, Characterization of Materials,1e, PHI Learning Pvt. Ltd, 2014.
3) Li Lin, Ashok Kumar and Sam Zhang, Materials Characterization Techniques, CRC Press, 2008.
4) B. D. Cullity and R. S. Stock, Elements of X-Ray Diffraction, Prentice-Hall, 2001.
5) P. E. J. Flewitt and R K Wild, Physical Methods for Materials Characterization, IOP Publishing, 2003.
6) W. W. Wendlandt, Thermal Analysis, John Willey & Sons, 1986.

Course code / Category	**MEE414 / Professional Elective**				
Course title	**Material Handling Systems & Equipment**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Materials handling equipment.

Introduction to material handling equipment - Classification of material handling equipment - Applications and their selection - Types of materials and loads - Objectives, principles, and selection parameters of materials handling equipment.

Unit 2 Design of hoists.

Design of hoisting equipment: wire and hemp rope, and drums - Load handling attachments - Design of hooks: forged hooks and eye hooks - Crane grabs - Grabbing attachments - Hoist components and their types.

Unit 3 Conveyors.

Classification of conveyors - Layout of flat belt conveyor - Methods of feeding and discharge - Types of conveyor belts - Types of pulleys - Idlers - Take-up device - Belt sag - Frictional resistance and belt tension at various point along conveyor path.

Unit 4 Elevators.

Types of elevators - Traction drum elevator - Hydraulic elevator - Bucket elevator and its types.

Unit 5 Other material handling systems.

Industrial robots - Automated guided vehicles (AGV) systems - Automated storage and retrieval systems (ASRS).

Textbooks / References.

1) N. Rudenko, Material Handling Equipment, MIR Publishers, Moscow, 1969.
2) M. Alexandrov, Materials Handling Equipment, MIR Publishers, Moscow, 1981.
3) A. Spivakovsky and V. Dyachkov, Conveyors and Related Equipment, Peace Publishers, Moscow.
4) ASME, Materials Handling Handbook, Wiley-Interscience, 1985.
5) A. Spivakovsky and V. Dyachkov, Conveying Machines, Volume I and II, MIR Publishers, Moscow, 1985.
6) M. P. Groover, Industrial Robots - Technology Programmes and Applications, McGraw Hill , New York, USA.
7) M. P. Groover, Automation Production Systems and Computer- Integrated Manufacturing, Pearson Education, New Delhi, 2001.
8) PSG Tech., Design Data Book, Kalaikathir Achchagam, Coimbatore, 2003.

Course code / Category	**MEE415 / Professional Elective**				
Course title	**Mechanical Behaviour & Testing of Materials**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Elastic and plastic deformation - Stress-strain relationship - Plastic deformation of metallic materials - Mohr's circle - Yielding criterion - Von Misses and maximum-shear stress / Tresca yielding criterion - Failure criteria under combined stresses.

Unit 2.

Elements of theory of plasticity - Dislocation theory - Properties of dislocation - Stress fields around dislocations - Elementary dislocation interactions - Application of dislocation theory to work hardening and strengthening mechanisms.

Unit 3.

Engineering stress-strain curve - True stress-strain curve - Instability in tension - Stress distribution at the neck - Ductility measurement - Effect of strain rate and temperature on flow properties - Testing machines - Tensile properties of important materials.

Unit 4.

Introduction to hardness and hardness testing - Brinell, Vickers and Rockwell hardness tests - Meyer hardness - Analysis of indentation by an indenter - Relationship between hardness and the flow curve - Microhardness tests - Hardness conversion - Hardness at elevated temperatures - Introduction to torsion - Torsional stresses for large plastic strains - Types of torsion failures torsion test vs. tension test - Hot torsion testing.

Unit 5.

Introduction to fatigue testing - Practice and evaluation - Fatigue crack growth - Low cycle and high cycle fatigue - Introduction to creep - Stress rupture testing - Creep data extrapolation - Fatigue-creep interactions - Super plasticity.

Textbooks / References.

1) William F. Hosford, Mechanical Behaviour of Materials, Cambridge University Press, New York, USA, 2005.
2) Marc A. Meyers and Krishan Kumar Chawla, Mechanical Behaviour of Materials, 2e, Cambridge University Press, New York, USA, 2008.
3) D. W. A. Rees, Basic Engineering Plasticity, Elsevier India, New Delhi, 2008.
4) C. Lakshmana Rao and Abhijit P. Deshpande, Modelling of Engineering Materials, Ane Books Pvt. Ltd., New Delhi, India, 2010.
5) John D. Verhoeven, Fundamentals of Physical Metallurgy, Wiley, 1975.
6) G. E. Dieter, Mechanical Metallurgy, 3e, McGraw-Hill Co., 1989.
7) Donald R. Askeland and Pradeep P. Phule, The Science and Engineering of Materials, 4e, Thomson, Singapore, 2003.
8) Robert E. Reed-Hill, Physical Metallurgy Principles, 2e, East-West Press Pvt. Ltd, New Delhi, 2008.

Course code / Category	**MEE416 / Professional Elective**				
Course title	**Mechatronics and Industrial Automation**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**ESC202**				

Unit 1 Fundamental concepts of industrial automation.

Definition of automation - Reasons for automating - Types of production and types of automation - Automation strategies - Levels of automation.

Unit 2 Transfer lines and automated assembly.

General terminologies - Analysis of transfer lines without storage - Partial automation - Automated flow lines with storage buffers - Automated assembly: design for automated assembly - types of automated assembly systems - part feeding devices - analysis of multi-station assembly machines - AS/RS - RFID system - AGVs - Modular fixturing - Flow line balancing.

Unit 3 Pneumatic controls.

Components: filter - lubricator - regulator - Constructional features - Types of cylinders - Control valves for direction, pressure and flow - Air motors - Air hydraulic equipment - Pneumatic control system design: general approach to control system design - symbols and drawings - schematic layout - travel step diagram - circuits - Control modes: program control - sequence control - cascade method - Karnaugh-Veitch mapping.

Unit 4 Programmable logic controllers.

Basic structure - Input / output programming - Timers - Relays - Counters - Analogue input / output - Interfacing with PC - Pneumatic sequencing - Control problem using PLC.

Unit 5 Programmable automation.

Computer numerical control (CNC): basic theory - advantages of numerical control - open and closed loop systems - classification of CNC machine tools - Drive system for CNC machine tools.

Unit 6 Robotic systems.

Basic structure of a robot - Robot end effectors - Classification of robots - Accuracy, resolution and repeatability of a robot - Drives and control systems – Mechanical components of robots - Sensors and vision systems: transducers and sensors-tactile sensors - proximity sensors and range sensors - vision systems - Robot motion control and robot programming.

Unit 7 Design of mechatronic systems.

Stages in design - Traditional and mechatronic design - Possible design solutions: Case studies: pick and place robot - engine management system.

Textbooks / References.

1) M. P. Groover, Automation Production Systems and Computer- Integrated Manufacturing, Pearson Education, New Delhi, 2001.
2) Wemer Depper and Kurt Stoll, Pneumatic Application, Kemprath Reihe, Vogel Buch Verlag Wurzburg, 1987.
3) W. Bolton, Mechatronics, 2e, Pearson Education, 1999.
4) Steve F. Krar, Computer Numerical Control Simplified, Industrial Press, 2001.
5) M. P. Groover, Industrial Robots - Technology Programmes and Applications, McGraw Hill , New York, USA. 2000.
6) Rolf Isermann, Mechatronic Systems Fundamentals, Springer, 2003.
7) John W. Webb and Ronald A. Reis, Programmable Logic Controllers, Prentice Hall, Inc., 1999.
8) Mark W. Spong and Seth Hutchinson, Robot Modelling and Control, Wiley-India Pvt. Ltd., 2006.

Course code / Category	**MEE417 / Professional Elective**				
Course title	**Metal Forming Technology**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC205**				

Unit 1 Metallurgical aspects of metal forming.

Mechanics of plastic deformation - Effects of temperature, strain rate, microstructure and friction in metal forming - Yield criteria and their significance - Classification of metal forming processes, advantages and limitations - Stress strain relations in elastic and plastic deformation - Concept of flow stresses - Deformation mechanisms - Hot and cold working processes and their effect on mechanical properties.

Unit 2 Rolling.

Terminology of rolled products - types of rolling mills - deformation zone in rolling, neutral point, angle of bite, forward slip, roll flattening and rolling variables - hot rolling and cold rolling - rolling of blooms billets - elementary roll pass design - Forces and geometrical relationships in rolling - Defects in rolled products.

Unit 3 Forging.

Introduction and classification - operation and principle of forging processes and equipment - methods of forging - open and close die forging processes - defects - structure and properties of forged products - Force analysis in forging - Other related processes like cold heading, rotary swaging, coining, embossing and roll forging.

Unit 4 Extrusion.

Classification of extrusion processes - direct and indirect extrusion - impact extrusion - hydrostatic extrusion - extrusion equipment - hot extrusion - cold extrusion - extrusion ratio - process variables - Lubrication and defects in extrusion - Derivation of extrusion pressure - Extrusion of tubing - Production of seamless pipe and tubing.

Unit 5 Drawing.

Introduction and classification - Wire drawing, rod drawing, tube drawing and deep drawing - Analysis of wire drawing process and load calculations.

Unit 6 Sheet metal forming.

Principle - process parameters - equipment and application of spinning, stretch forming, plate, V-and edge bending, curling, ironing, roll bending, metal spinning, press brake forming, explosive forming, hydro forming, electrohydraulic forming and magnetic pulse forming processes - High velocity forming of sheet metals and high energy rate forming.

Textbooks / References.

1) B. L. Juneja, Fundamentals of Metal Forming Processes, New Age International Publishers.
2) G. W. Rowe, Introduction to Industrial Mechanical Working Process, CBS Publishers, New Delhi.
3) G. E. Dieter, Mechanical Metallurgy, McGraw-Hill Co.
4) T. Altan. Metal Forming: Fundamentals and Applications, ASM Series in Metal Processing.
5) ASM, Metal Forming Handbook.
6) B. Avitzur, Metal Forming: Processes and Analysis, Tata McGraw-Hill.

Course code / Category	**MEE418 / Professional Elective**				
Course title	**Micro and Nano Manufacturing**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC205**				

Unit 1 Introduction.

Introduction to micro and nano-manufacturing - Miniaturization and its applications - Micro-manufacturing classification - Micromachining concepts and significance - Theory of micromachining: chip formation and size effect in micromachining.

Unit 2 Micro-manufacturing.

LIGA - Micro-stereolithography - Micro-turning - Micro-drilling - Micro-milling - Diamond turning - Electric discharge micromachining - Ultrasonic micromachining - Laser beam micromachining - Focused ion beam micromachining - Abrasive flow finishing - Magnetic abrasive finishing - Magnetorheological finishing - Magnetorheological abrasive flow finishing - Magnetic float polishing - Hybrid finishing processes - Chemo-mechanical polishing - Electro-discharge grinding - Electrolytic in-process dressing grinding.

Unit 3 Nano-fabrication methods.

Overview - Top-down and bottom-up approaches - Fabrication, properties, and application of one-dimensional and two-dimensional nanostructured materials - Stereolithography - SLS - FDM - SGC - LOM - 3D printing - Surface modification techniques: sputtering, CVD, PVD, plasma spraying, diffusion coatings and pulsed layer deposition.

Unit 4 Micro and nano finishing processes.

Introduction - Magnetorheological finishing (MRF) processes - Magneto-rheological abrasive flow finishing (MRAFF) processes: principle, equipment and applications - force analysis for MRAFF process - Magnetic float polishing (MFP) - Elastic emission machining (EEM) - Ion beam machining (IBM) - Chemical mechanical polishing (CMP): principle, equipment and applications.

Unit 5 Metrology of micro and nano parts.

Optical microscopy, white light interferometry, micro CMM, scanning probe microscopy, scanning electron microscope, transmission electron microscope and atomic force microscope.

Textbooks / References.

1) V. K. Jain, Introduction to Micromachining, Narosa Publishing House.
2) V. K. Jain, Micro Manufacturing Processes, CRC Press.
3) N. Taniguchi, Nano Technology, Oxford University Press.
4) N. P. Mahalik, Micro-manufacturing and Nanotechnology.
5) M. J. Jackson, Micro and Nano-manufacturing, Springer.

Course code / Category	**MEE419 / Professional Elective**				
Course title	**Non-destructive Testing**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Overview of NDT.

NDT versus mechanical testing - Overview of NDT methods for the detection of manufacturing defects as well as material characterisation - Relative merits and limitations - Various physical characteristics of materials and their applications in NDT - Visual inspection: unaided and aided.

Unit 2 Surface NDT methods.

Liquid penetrant testing: principles, types and properties of liquid penetrants - developers - advantages and limitations of various methods - testing procedure - interpretation of results - Magnetic particle testing: theory of magnetism - inspection materials - magnetisation methods - interpretation and evaluation of test indications - Principles and methods of demagnetization - Residual magnetism.

Unit 3 Thermography and eddy current testing.

Thermography: principles - contact and non-contact inspection methods - techniques for applying liquid crystals - advantages and limitations - infrared radiation and infrared detectors - instrumentation and methods - applications - Eddy current testing: generation of eddy currents - properties of eddy currents - eddy current sensing elements - probes - instrumentation - types of arrangement - applications - advantages and limitations - interpretation / evaluation.

Unit 4 Ultrasonic testing and acoustic emission.

Ultrasonic testing: principle - transducers - transmission and pulse-echo method - straight and angle beams - instrumentation - data representation - A, B and C-scans - phased array ultrasound - Time-of-flight diffraction - Acoustic emission technique: principle, parameters and applications.

Unit 5 Radiography.

Principle - Interaction of X-Ray with matter - Imaging: film and film less techniques - Types and use of filters and screens - Geometric factors - Inverse square law - Characteristics of films: graininess, density, speed, contrast and characteristic curves - Penetrometers - Exposure charts - Radiographic equivalence - Fluoroscopy - Xero-radiography - Computed radiography - Computed tomography.

Textbooks / References.

1) Baldev Raj, T. Jayakumar and M. Thavasimuthu, Practical Non-destructive Testing, Narosa Publishing House.
2) Ravi Prakash, Non-destructive Testing Techniques, New Age International Publishers, 1e.
3) ASM Metals Handbook, Vol. 17, Non-destructive Evaluation and Quality Control, American Society of Metals, Metals Park, Ohio, USA.
4) C. J. Hellier, Handbook of Non-destructive Evaluation, McGraw Hill, New York.
5) ASNT, NDT Handbook, Volumes 1 - 7, American Society for Non Destructive Testing, Columbus, Ohio.
6) Paul E. Mix, Introduction to Non-destructive Testing: A Training Guide, 2e, Wiley & Sons, New Jersey.

Course code / Category	**MEE420 / Professional Elective**				
Course title	**Non-traditional Machining Processes**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Need for non-traditional machining processes - Classification of non-traditional machining processes based on energy, mechanism, source of energy, transfer media and process - Process selection based on physical parameters, shapes to be machined, process capability and economics - Overview of all processes.

Unit 2 Mechanical processes.

Ultrasonic machining: principle - transducer types - concentrators - abrasive slurry - process parameters - tool feed mechanism - advantages and limitations - applications - Abrasive jet machining: process - principle - process variables - material removal rate - advantages and limitations - applications - Water jet machining: principle - process variables - advantages and limitations - applications - Abrasive water jet machining process.

Unit 3 Electrical discharge machining.

Electrical discharge machining: mechanism of metal removal - dielectric fluid - flushing methods - electrode materials - spark erosion generators - electrode feed system - material removal rate - process parameters - tool electrode design - tool wear characteristics of spark eroded surfaces - advantages and limitations - applications - Electrical discharge wire cut and grinding: principle - wire feed system - advantages and limitations - applications.

Unit 4 Chemical and electrochemical machining.

Chemical machining: fundamentals - principle - classification and selection of etchants - chemical milling, engraving and blanking - advantages and limitations - applications - Electrochemical machining: electro-chemistry of process - electrolytes - electrolyte and their properties - material removal rate - tool material - tool feed system - design for electrolyte flow - process variables - advantages and limitations - applications - Electrochemical grinding: honing, cutting off, deburring and turning.

Unit 5 High energy machining process.

Electron beam machining: principle - generation and control of electron beam - advantages and limitations - applications - Laser beam machining: principle - solid and gas laser application - thermal features of laser beam machining - advantages and limitations - applications - Ion beam

machining: equipment - process characteristics - material removal rate - advantages and limitations - applications - Plasma arc machining: principle - gas mixture - types of torches - process parameters - advantages and limitations - applications.

Textbooks / References.

1) P. C. Pandey and H. S. Shan, Modern Machining Process, Tata McGraw-Hill Publishing Company Limited, New Delhi.
2) V. K. Jain, Advanced Machining Process, Allied Publishers Private Limited.
3) A. Bhattacharyya, New Technology, The Institution of Engineers (India).
4) HMT, Production Technology, Tata McGraw-Hill Publishing Company Limited, New Delhi.
5) H. E. Hofy, Advanced Machining Processes, McGraw-Hill Co.
6) James Brown, Advanced Machining Technology Handbook, 1e, McGraw Hill, New Delhi.
7) G. F. Benedict, Advanced Manufacturing Processes, 2e.
8) P. C. Pandey, Advanced Methods of Machining, 2e, Chapman and Hill, New York, 2011.

Course code / Category	**MEE421 / Professional Elective**				
Course title	**Optimization Techniques for Engineering Design**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Fundamentals of optimization and introduction to MATLAB.

Optimization problem formulation - Optimality criteria - Introduction to MATLAB programming - Optimization toolbox.

Unit 2 Unconstrained optimization.

Univariate optimization - Elimination methods - Interpolation based methods - Multivariate direct search - Gradient-based methods for unconstrained optimization.

Unit 3 Constrained optimization.

Constrained optimization formulations - Optimality criteria - Multivariate KKT conditions - Direct search methods - Gradient-based methods for constrained optimization.

Unit 4 Non-traditional algorithms for global optimization.

Simulated annealing - Genetic algorithms - Particle swarm optimization.

Unit 5 Multi-objective optimization.

Basic concepts - Graphical solution - Analytical methods - Non-traditional methods.

Textbooks / References.

1) K. Deb, Optimization for Engineering Design: Algorithms and Examples, Prentice Hall India Learning Private Limited.
2) S. S. Rao, Engineering Optimization - Theory and Practice, New Age Publishers.
3) J. S. Arora, Introduction to Optimum Design, Elsevier India Pvt. Ltd.
4) K. Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley Student Edition.

Course code / Category	**MEE422 / Professional Elective**				
Course title	**Power Plant Engineering**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC206**				

Unit 1.

Fuel and combustion - Introduction to solid, liquid and gaseous fuels - Energy and power - Energy scenario - Steam power plants: classification of steam power plants - layout of modern coal based steam power plant - steam power plant cycle - supercritical boiler - fluidized bed combustion (FBC) boiler - fuel handling - ash handling - chimney draught - coal handling and coal properties - high pressure boilers - performance of boilers - boiler mountings and accessories - steam turbines.

Unit 2.

Gas turbine plant: introduction - classification of gas turbine plant - construction and layout - principle of working open and closed cycle gas turbine - advantages and disadvantages - combined cycle power plants.

Unit 3.

Classification of hydro-plants - Hydraulic turbines - Hydel plant controls- Problem solving - Principles of nuclear energy - Thermal fission reactors and power plants - Fast breeder reactors.

Unit 4.

Solar thermal energy - Direct energy conversion - Wind energy - Geothermal energy - Energy from oceans - Photo-voltaic conversion.

Unit 5.

Energy, economic and environmental issues of power plants - Power tariff types - Load distribution parameters - Load curve - Instrumentation in power plant - Economics of power generation - Environmental aspects of power generation.

Textbooks / References.

1) S. C. Arora and S. Domkundwar, Power Plant Engineering, Dhanpat Rai & Sons, New Delhi.
2) P. K. Nag, Power Plant Engineering, Tata McGraw Hill, New Delhi.
3) A. W. Culp Jr, Principles of Energy Conversion, McGraw Hill Inc., New York.
4) A. V. Desai, Non-conventional Energy, Wiley Eastern Limited, New Delhi.
5) R. K. Rajput, Power Plant Engineering, Laxmi Publications, New Delhi.
6) K. K. Ramalingam, Power Plant Engineering, SciTech Publication Pvt. Ltd.
7) M. M. El-Wakil, Power Plant Technology, McGraw-Hill Book Co.
8) J. H. Rust, Nuclear Power Plant Engineering, Haralson Pub. Co.
9) P. J. Potter, Power Plant Theory & Design, Kreiger Publishing Co.

Course code / Category	**MEE423 / Professional Elective**				
Course title	**Production Planning and Control**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Definitions - Objectives of production planning and control - Functions of production planning and control - Elements of production control - Types of production - Organization of production planning and control - Internal organizations department.

Unit 2 Forecasting.

Importance - Types of forecasting and their uses - General principles of forecasting techniques - Qualitative methods and quantitative methods.

Unit 3 Inventory management.

Functions inventory - Relevant inventory cost - ABC analysis - VED Analysis - EOQ model - Inventory control systems - P-systems and Q-systems - Introduction to MRP and ERP - LOB (line of balance) - JIT inventory - Japanese concepts.

Unit 4 Routing.

Routing procedure - Route sheets - Bill of materials - Factors affecting routing - Schedule: definition - difference with loading - Scheduling polices - Standard scheduling methods: job shop - flow shop - Line balancing - Aggregate planning: methods for aggregate planning - chase planning - expediting - control aspects.

Unit 5 Dispatching.

Activities of dispatcher - Dispatching procedure - Follow-up: definition - reasons for existence of functions - types of follow-ups - Applications of computer in production planning and control.

Textbooks / References.

1) K. C. Jain and L. N. Agarwal, Production Planning and Control, 6e, Khanna Publishers, 2008.
2) M. Mahajan, Production Planning and Control, Dhanpat Rai & Co., 2010.
3) R. Paneerselvam, Production & Operations Management, 2e, PHI Publications, 2006.
4) E. S. Baffa and R. K. Sarin, Modern Production & Operation Management, 8e, Wiley, 2009.
5) O. P. Khanna, Industrial Engineering and Management, Dhanpat Rai & Co., 2009.
6) S. D. Sharma, Operations Research, Kedarnath Ramnath Publishers, 1996.

Course code / Category	**MEE424 / Professional Elective**				
Course title	**Programmable Logic Controllers**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**ESC202**				

Unit 1 PLC hardware.

Introduction - Internal architecture - IEC standard - Input / output devices - Signal conditioning serial and parallel communications - Standards and protocols - Distributed control - Network standards - Industrial communication systems.

Unit 2 Ladder and functional programming.

Ladder diagrams - Logic functions - Internal relays - Latching - Functional blocks - Application of timers and counters.

Unit 3 Subroutines and data handling.

Jump and call - Subroutines - Shift registers - Data handling - Arithmetic functions - Closed loop controls - Applications.

Unit 4 Designing PLC systems.

Program development - Safety systems - Commissioning - Fault detection - Documentation.

Unit 5 Applications of PLC.

Material handling applications - Automatic control of warehouse door - Automatic lubricating oil supplier - Conveyor belt motor control - Automatic car washing machine - Bottle label detection - Process control application - Industrial case studies.

Textbooks / References.

1) W. Bolton, Programmable Logic Controllers, 6e, Elsevier.
2) F. D. Petruzella, Programmable Logic Controllers, McGraw Hill Book Co.
3) J. W. Webb and R. A. Reis, Programmable Logic Controllers: Principles and Applications, Prentice Hall of India Ltd.
4) W. I. Fletcher, An Engineering Approach to Digital Design, Prentice Hall of India Ltd.
5) C. H. Roth Jr, Fundamentals of Logic Design, 6e, Jaico Publishing House, New Delhi.

Course code / Category	**MEE425 / Professional Elective**				
Course title	**Refrigeration & Air-conditioning**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC206**				

Unit 1 Introduction.

Basic definitions of refrigeration and air-conditioning - History of refrigeration - Natural and artificial refrigeration methods - Techniques to produce low temperatures - Applications of refrigeration - Refrigerants: classification - nomenclature - desirable properties - selection.

Unit 2 Air refrigeration.

Air refrigeration cycles: reversed Carnot cycle - Bell-Coleman cycle analysis - Various methods of aircraft refrigeration: analysis, merits and demerits.

Unit 3 Vapor compression refrigeration system (VCRS).

Ideal VCRS cycle (working, analysis and limitations) - Standard VCRS (working and analysis) - Methods to improve performance of VCRS - Multi-stage VCRS - Cascade refrigeration.

Unit 4 Components of refrigeration systems.

Compressors: positive displacement (reciprocating and rotary) compressors - dynamic (centrifugal and axial) compressors - Condensers and evaporators (both natural and forced convection type) - Expansion devices and other components of the system.

Unit 5 Vapor absorption systems.

Working and analysis - Absorbent-refrigerant combinations: water-ammonia systems - water-lithium bromide system - Modified version of aqua-ammonia system with rectifier and analyser assembly.

Unit 6 Other refrigeration systems.

Brief discussion on steam-jet refrigeration system, vortex tube refrigeration system, thermoelectric refrigeration system and magnetic refrigeration system.

Unit 7 Psychrometry.

Classification of air-conditioning systems - ASHRAE nomenclature - Applications of air-conditioning - Psychrometry - Air-water vapor mixtures - Psychrometric properties - Psychrometric or air-conditioning processes - Psychrometric chart.

Unit 8 Air-conditioning systems.

Classification of air-conditioning systems - Psychrometry of air-conditioning systems - Thermal comfort (definition and psychrometric properties for thermal comfort) - Mathematical analysis of air-conditioning systems - Cooling and heating load estimation - Ventilation.

Textbooks / References.

1) S. Singh, Refrigeration and Air conditioning, Khanna Publishers.
2) S. Domkundwar, Refrigeration and Air conditioning, Dhanpat Rai Publications.
3) W. B. Gosney, Principles of Refrigeration, Cambridge University Press.
4) W. F. Stoecker and J. W. Jones, Refrigeration and Air conditioning, Tata McGraw Hill.
5) C. P. Arora, Refrigeration and Air conditioning, 2e, Tata McGraw Hill.
6) T. H. Kuehn, J. W. Ramsey and J. L. Threlkeld, Thermal Environmental Engineering, 3e, Prentice Hall.

Course code / Category	**MEE426 / Professional Elective**				
Course title	**Reverse Engineering**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEC306**				

Unit 1 Introduction to reverse engineering and geometric form.

Definition - Uses - The generic process - Phases - Computer-aided reverse engineering - Surface and solid model reconstruction - Dimensional measurement - Prototyping.

Unit 2 Material characteristics, part durability and life limitation.

Alloy structure equivalency - Phase formation and identification - Mechanical strength - Hardness - Part failure analysis - Fatigue - Creep and stress rupture - Environmentally induced failure.

Unit 3 Material identification and process verification.

Material specification - Composition determination - Microstructure analysis - Manufacturing process verification.

Unit 4 Data processing, part performance and system compatibility.

Statistical analysis - Data analysis - Reliability and the theory of interference - Weibull analysis - Data conformity and acceptance - Data report - Performance criteria - Methodology of performance evaluation - System compatibility.

Unit 5 Acceptance, legality and industrial applications of reverse engineering.

Legality of reverse engineering - Patent - Copyrights - Trade secret - Third-party materials - Reverse engineering in automotive industry, aerospace industry and medical device industry.

Textbooks / References.

1) Donald R. Honsa, Co-ordinate Measurement and Reverse Engineering, American Gear Manufacturers Association.
2) P. Aiken, Data Reverse Engineering, McGraw-Hill.
3) T. J. Biggerstaff, Design Recovery for Maintenance and Reuse, IEEE Corp.
4) Katheryn A. Ingle, Reverse Engineering, McGraw-Hill.
5) Linda Wills, Reverse Engineering, Kluver Academic Publishers.
6) S. Rugaban, White Paper on Reverse Engineering, Technical Report, Georgia Inst. of Technology.

Course code / Category	**MEE427 / Professional Elective**				
Course title	**Supply Chain Management**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Strategic framework to analyse supply chains.

Understanding the supply chain management - Decision phases in a supply chain - Process views of a supply chain: push / pull and cycle views - Supply chain performance: achieving strategic fit and scope - Supply chain drivers and metrics.

Unit 2 Supply chain network design.

Factors influencing distribution network design - Design options for a distribution network - Online sales - Factors influencing network design decisions - Framework for network design decisions - Models for facility location and capacity allocation - Risk management in global supply chains.

Unit 3 Demand forecasting in supply chain.

Role of forecasting in a supply chain - Components of a forecast and forecasting methods - Models for forecasting: time series - causal methods - Accuracy of forecasts - Risk management in forecasting.

Unit 4 Aggregate planning and inventories in supply chain.

Aggregate planning: role of aggregate planning in supply chains - aggregate planning strategies - Inventory: types of inventories - Cycle inventory: estimating cycle inventory related costs in practice - Economies of scale to exploit fixed costs and quantity discounts - Managing uncertainty in a supply chain - Determining the appropriate level of safety inventory.

Unit 5 Transportation and coordination in supply chain.

Modes of transportation and their performance characteristics - Design options for a transportation network - Trade-offs in transportation design - Tailored transportation - Coordination in supply chain: lack of supply chain coordination and the bullwhip effect - obstacles to coordination in a supply chain - managerial levers to achieve coordination.

Textbooks / References.

1) D. K. Agrawal, Textbook of Logistics and Supply Chain Management, MacMillan, 2015.
2) Sunil Chopra and Peter Meindl, Supply Chain Management - Strategy, Planning and Operation, 6e, Pearson Education Asia, 2016.
3) Janat Shah, Supply Chain Management - Text and Cases, Pearson Education South Asia, 2016.

Course code / Category	**MEE428 / Professional Elective**				
Course title	**Surface Engineering**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MES105 / MEC205 / MEC308 / BSC101**				

Unit 1 Basics of surface properties.

The surface state - Structural state of a surface - Topographic state of a surface - Atomic-scale topographic state - Micrometer-scale topographic state - Experimental techniques - Surface energy and surface energy measurements - Tribology-surface degradation - Wear: types of wear - adhesive, abrasive, oxidative, corrosive, erosive and fretting wear - Galling - Spalling - Impact wear brinelling - Roles of friction and lubrication - Corrosion: types, passivity, mechanism of growth and break down of passive film - Corrosion control.

Unit 2 Surface cleaning.

Surface pretreatment of metallic and electronic materials - Mechanical cleaning polishing - Chemical cleaning: acid, alkaline, acetone and carbon tetra chloride cleaning - Alumina and diamond polishing - Degreasing - Ultrasonic cleaning.

Unit 3 Surface coating techniques.

Principle and parameters of electrodeposition - Faraday's laws of electrodeposition - Electrodeposition of copper, nickel, chromium and gold for industrial use - Electrophoretic deposition - Organic coating paints: requirements of good paints - constituents of paints - function - formulation of durable paint - Enamel coating - Special paints - Heat resistant and fire retardant paints - Electroless coating - Conversion coating - Powder coating.

Unit 4 Advanced surface modification process.

PVD - CVD - Ion beam process - Ion beam assisted vapour deposition - Ion implantation - Reactive ion sputtering coating - Electron beam process - Electron beam assisted vapour deposition - Laser assisted surface modification - Laser alloying - Laser melting - Laser ablation - Laser sprayed deposit - Direct metal deposition by laser - Plasma electrolytic deposition - Cladding - Sol-gel deposition - Thermal spraying.

Unit 5 Standards for surface engineering measurements.

Terminology - Laboratory accreditation - Sampling - Surface finish evaluation - Bare and coated materials - Product quality standards for specific coating process - Conversion coatings - Galvanized coatings - Electrodeposited coatings - Vapor deposited coatings - Standards - ASTM standards for measurement of surface treated materials - Depth, thickness, hardness and friction co-efficient.

Textbooks / References.

1) R. Chattopadhyay, Advanced Thermally Assisted Surface Engineering Processes, Kluwer Academic Publishers.
2) T. S. Sudarshan, Surface Modification Technologies - An Engineer's Guide, Marcel-Dekker, Inc.
3) K. G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall.
4) A. Mathews, Advanced Surface Coatings: A Handbook of Surface Engineering, Spinger.
5) M. G. Hocking, Metallic and Ceramic Coatings, John Wiley.
6) K. N. Strafford, P. K. Datta and J. S. Gray, Surface Engineering Practice, Processes, Ellis Harwood.

Course code / Category	**MEE429 / Professional Elective**				
Course title	**Sustainable Manufacturing**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction to sustainable manufacturing.

Concepts of sustainability and sustainable development - Need for sustainable development - Components of sustainability: social, economic, and environmental dimensions - Linkages between technology and sustainability - Sustainable manufacturing scope, need, and benefits - Relation between lean and sustainable manufacturing - Green manufacturing.

Unit 2 Tools and techniques.

Environmental consciousness - Quality function deployment - Design for environment - R3 and R6 cycles - Design for disassembly - Design for recycling - Eco-friendly product design methods - Environmental impact assessment methods and standards.

Unit 3 Sustainability assessment.

Sustainability assessment: concept models and various approaches - Product sustainability and risk / benefit assessment - Corporate and social responsibility.

Unit 4 Sustainable characteristics.

Sustainable characteristics of manufacturing processes - Interactions between energy and technology and their implications for the environment and sustainable development - Energy efficiency analysis of manufacturing processes - Sustainability analysis and scope of sustainable manufacturing centres.

Unit 5 Sustainable product design.

Sustainable product design - Principles of life cycle assessment - Product life cycle assessment - Introduction to sustainable manufacturing related software packages.

Textbooks / References.

1) N. Arun Nambiar, Sustainable Manufacturing, CRC Press.
2) S. Vinodh, Sustainable Manufacturing: Concepts, Tools, Methods and Case Studies, CRC Press.
3) M. Singh, T. Ohji and R. Asthana, Green and Sustainable Manufacturing of Advanced Materials, 1e, Elsevier.

4) G. Seliger, Marwan M. K. Khraisheh and I. S. Jawahir, Advances in Sustainable Manufacturing, Springer.
5) G. Atkinson, S. Dietz and E. Neumayer, Handbook of Sustainable Manufacturing, Edward Elgar Publishing Limited.
6) P. Lawn, Sustainable Development Indicators in Ecological Economics, Edward Elgar Publishing Limited.
7) D. Rodick, Industrial Development for the 21st Century: Sustainable Development Perspectives, New York.

SYLLABUS FOR OPEN ELECTIVES

Course code / Category	**MEO301 / Open Elective**				
Course title	**Artificial Intelligence in Manufacturing**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**MES203**				

Unit 1 Introduction to Artificial Intelligence (AI).

Definitions of intelligence and artificial intelligence - Human mental capabilities: association, stereotyping, reasoning and vision - Artificial intelligence: components, scope and application areas.

Unit 2 AI Languages.

Programming with PROLOG - Simple programs.

Unit 3 Expert systems.

Knowledge-based or expert systems: definition, structure, characterization and justification - Knowledge sources - Expert - Knowledge acquisition and representation - Knowledge base - Interference strategies: forward and backward chaining.

Unit 4 Expert systems tools and applications.

Expert system building tools or shells - Typical examples of shells - Expert system software for manufacturing applications in CAD, CAPP, MRP, adaptive control, robotics, process control, fault diagnosis, failure analysis, process selection, group technology, etc.

Unit 5 Artificial Neural Networks, Fuzzy Logic and Genetic Algorithms.

Concepts of artificial neural networks, fuzzy logic and genetic algorithms - Manufacturing applications of neural networks, fuzzy logic and genetic algorithms - Applications in tool selection, process selection, part classification, inventory control, process planning, etc. using PROLOG and Python.

Textbooks / References.

1) W. F. Clocksin and C. S. Mellish, Programming in PROLOG, Narosa Publishing House, New Delhi.
2) Guido van Rossum and Fred L. Drake Jr, An Introduction to Python - Revised and updated for Python 3.2, Network Theory Ltd.
3) J. C. Giarratano and G. D. Riley, Expert Systems - Principles and Programming, Cengage Learning, New Delhi.
4) N. P. Padhy, Artificial Intelligence and Intelligent Systems, Oxford University Press, New Delhi.
5) S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Logic and Genetic Algorithms, PHI Learning Private Limited, New Delhi.

Course code / Category	**MEO302 / Open Elective**				
Course title	**Industrial Engineering & Management**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**-----**				

Unit 1 Introduction to management.

Entrepreneurship and organization - Nature and importance of management - Functions of management - Taylor's scientific management theory - Fayol's principles of management - Maslow's theory of human needs - Douglas McGregor's Theory X and Theory Y - Herzberg's two-factor theory of motivation - Systems approach to management - Leadership styles - Social responsibilities of management.

Unit 2 Designing organizational structures.

Departmentation and decentralization - Types of organization structure - Line organization - Line and staff organization - Functional organization - Committee organization - Matrix organization - Virtual Organization - Cellular organization - Team structure - Boundary less organization - Inverted pyramid structure - Lean and flat organization structure and their merits, demerits and suitability.

Unit 3 Operations management.

Objectives - Product design process - Process selection - Types of production system (Job, Batch and Mass production) - Plant location factors - Urban and rural sites comparison - Types of plant layouts - Design of product layout - Line balancing (RPW method) - Value analysis: definition - types of values - objectives-phase of value analysis - Fast diagram.

Unit 4 Work study.

Introduction: definition - objectives - steps in work study - Method study: definition - objectives - steps of method study - Work measurement: purpose - types of study - stopwatch methods - steps - key rating - allowances - standard time calculations - work sampling - Statistical quality control: variables - attributes, Shewart control chart for variables - X chart - R chart - Attributes - Defective - Defect charts for attributes - p chart, c chart (simple problems) - Acceptance sampling - Single sampling and double sampling plans - OC curves.

Unit 5 Job evaluation.

Methods of job evaluation - simple routing objective systems classification method - factor comparison method - point method - benefits of job evaluation and limitations - Project management: Network Analysis - Programme Evaluation and Review Technique (PERT) - Critical Path Method (CPM) - Identifying critical path - Probability of completing the project within given time - Project cost analysis - Project crashing (simple problems).

Textbooks / References.

1) O. P. Khanna, Industrial Engineering and Management, Dhanpat Rai Publishers.

2) K. C. Jain and L. N. Agarwal, Production Planning Control and Industrial Management, Khanna Publishers.
3) R. Paneerselvam, Production and Operations Management, 2e, PHI Publications.
4) A. K. Mukhopadhyay, Value Engineering: Concepts, Techniques and Applications, SAGE Publishing.
5) S. C. Sarma and T. R. Banga, Industrial Engineering and Management, Khanna Publishers.
6) R. D. Reid and N. R. Sanders, Operations Management, 4e, Wiley & Sons.
7) R. M. Barnes, Motion and Time Study, John Wiley & Sons.
8) N. V. S. Raju, Industrial Engineering and Management, Cengage Learning.

Course code / Category	**MEO303 / Open Elective**				
Course title	**Maintenance Engineering & Management**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**3**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Fundamentals of maintenance engineering - Maintenance engineering its importance in material and energy conservation - Inventory control - Productivity - Safety - Pollution control - Safety regulations - Pollution problems - Human reliability.

Unit 2 Maintenance management.

Types of maintenance strategies - Planned and unplanned maintenance - Breakdown - Preventive and predictive maintenance and their comparison - Computer-aided maintenance - Maintenance scheduling - Spare parts management - Inventory control - TPM.

Unit 3 Tribology in maintenance.

Friction, wear and lubrication - Friction and wear mechanisms - Prevention of wear - Types of lubrication mechanisms - Lubrication processes - Lubricant types: general and special purpose - Additives - Testing of lubricants - Degradation of lubricants - Seals and packing.

Unit 4 Machine health monitoring.

Condition-based maintenance - Signature analysis - Oil analysis - NDT - Vibration, noise and thermal signatures - Online and offline techniques - Instrumentation and equipment used in machine health monitoring - Instrumentation in maintenance - Signal processing, data acquisition and analysis - Application of intelligent systems - Database design.

Unit 5 Reliability, Availability and Maintainability (RAM).

Introduction to RAM - Failure mechanism - Failure data analysis - Failure distribution - Reliability of repairable and non-repairable systems - Improvement in reliability - Reliability testing - Reliability prediction - Utilization factor - System reliability by Monte Carlo simulation technique.

Textbooks / References.

1) Krishnan Gopal and S. K. Banerji, Maintenance and Spare Parts Management, PHI.
2) R. C. Mishra and K. Pathak, Maintenance Engineering and Management, PHI
3) S. K. Shrivastava, Industrial Maintenance Management, S. Chand Publications.
4) B. K. N. Rao, Handbook of Condition Monitoring. Elsevier.
5) S. C. Sharma and T. R. Banga, Industrial Engineering and Management, Khanna Publishers.
6) L. Higgins, R. K. Mobley and K. Mobley, Maintenance Engineering Handbook, Mc-Graw Hill Co.

Course code / Category	**MEO401 / Open Elective**				
Course title	**3D Printing and Design**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction to 3D printing.

History and evolution of 3D printing - Early developments and milestones - Impact on various industries - Fundamentals of 3D printing: basic principles - different types of 3D printing technologies (FDM, SLA, SLS, etc.) - Overview of the 3D printing workflow - Components of a 3D printer (Energy source, extruder, build platform, print head, etc.) - Multi-material printing: process, benefits and limitations.

Unit 2 3D printing materials and considerations.

Common 3D printing materials (PLA, ABS, Nylon, Metal Filaments and Resins) - Material properties and applications (strength, flexibility and heat resistance) - Material selection for specific design requirements - Introduction to advanced materials (bioprinting, conductive filaments, smart-materials, etc.) - Safe handling and storage of printing materials.

Unit 3 3D modelling and design for printability.

Introduction to 3D modelling software (CATIA or any open-source software of choice such as Fusion 360, TinkerCAD, Blender) - Understanding 3D printing file formats (STL, OBJ and G-code) - 3D scanning and reverse engineering: reverse engineering techniques - integrating 3D scanning with 3D printing - Design principles: considerations for printability (tolerance, wall thickness, overhangs and support structures) - Design for strength and durability - Nesting and orientation for efficient printing - Model optimization for printing (slicing software settings, infill density and print orientation).

Unit 4 Pre and post-processing for 3D printing.

Introduction to slicing software (open-source software of choice such as Cura, Simplify3D, PrusaSlicer) - Understanding slicer settings (layer height, infill density, print speed and support generation) - Troubleshooting common printing issues - Removing supports and cleaning printed parts - Finishing techniques (sanding, smoothing, painting and machining) - Advanced post-processing: heat treatment, HIP, vapor smoothing, metal plating, etc.

Unit 5 Applications and future of 3D printing.

Application-specific design considerations (e.g., functional parts, wearables and medical implants) - Sustainability in 3D printing: bio-composites, recycled materials, minimizing waste, etc. - Introduction to future trends in 3D printing (bioprinting, large-scale printing, 4D printing, textile printing, construction industry, etc.) - Exploring the potential impact of 3D printing on society and future manufacturing.

Textbooks / References.

1) J. M. Jordan, 3D Printing, 1e, MIT Press.
2) R. Horne and K. K. Hausman, 3D Printing for Dummies, 2e, Wiley.
3) B. Redwood, F. Schöffer and B. Garret, The 3D Printing Handbook: Technologies, Design and Applications, 1e, 3D Hubs.
4) L. W. Kloski and N. Kloski, Getting Started with 3D Printing, 1e, Make Community, LLC.
5) H. N. Pandya, 3D Printing Technology: Fundamentals and Applications, 1e, Studera Press.
6) Abhinav and C. A. Kumar, From Idea to Reality: A Comprehensive Guide to 3D Printing, 1e, Shashwat Publication.
7) Y. Binstock, How to Become a 3D Printing Entrepreneur, 1e, CreateSpace Independent Publishing Platform.

Course code / Category	**MEO402 / Open Elective**				
Course title	**Financial & Accounting Management**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Financial management (FM).

Meaning, scope and role - A brief study of functional areas of financial management - Introduction to various FM tools - Ratio analysis: meaning, basis of comparison and types of ratios.

Unit 2 Working capital management.

Theory of working capital management - Nature of working capital - Concepts and definitions of working capital - Need for working capital - Permanent and temporary working capital - Changes in working capital - Determinants of working capital.

Unit 3 Budgeting.

Budgets: purpose - budgetary control - preparation of budgets - master budget - fixed and flexible budgeting.

Unit 4 Accounting.

Accounting process and principles - Financial, cost and management accounting.

Unit 5 Bookkeeping.

Elements of bookkeeping - Journal, cash and handbook - Book reconciliation statement - Ledger, trial balance, profit and loss accounts - Final accounts of proprietary and partnership concern and balance sheet.

Unit 6 Cost accounting.

Objectives - Elements of cost - Understanding of the different methods of costing.

Textbooks / References.

1) L. N. Chopde and D. H. Choudhari, Bookkeeping and Accountancy, Sheth Publishers Private Limited.
2) L. N. Chopde and D. H. Choudhari, Cost Accounting, Sheth Publishing House.
3) M. Y. Khan and P. K. Jain, Financial Management: Text and Problems, McGraw-Hill Education.
4) P. Chandra, Financial Management Theory & Practice, Tata McGraw Hill.
5) S. A. Siddiqui and A. S. Siddiqui, Managerial Economics and Financial Analysis, New Age Publishers.

Course code / Category	**MEO403 / Open Elective**				
Course title	**Industry 4.0**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEE308**				

Unit 1 Advanced technology and materials.

Advanced electro-optical sensing technology - Active, passive, multi-spectral and hyper spectral imaging - Electronic beam steering - Vacuum technology - Surface and coating technology - Health care technology - Nanotechnology - Nano-mechanics - Nano optoelectronics - Energy storage technology: next generation Li-based batteries - hydrogen storage - solar photovoltaic cells - Flexible electronics - Intellectual property rights: case studies governing / pertaining to materials / technology.

Unit 2 Transforming technologies in bioengineering.

Establishment of smart biotechnology factory - Artificial intelligence in bioprocess technology - Omics - Big data analysis through automation - 3D bio printing for tissue engineering - Simulation tools - RSM and Box models - Cyber physical system based telemedicine, diagnosis and therapeutics through real time biosensors - Bio-nanotechnology - Intellectual property rights (IPR): case studies.

Unit 3 Advancements in sustainable built environment.

Technological developments in Architecture, Engineering and Construction - Building Information Modelling (BIM) using cloud computing technology and Internet of Things (IoT) - Sensors - Additive manufacturing in construction - Concrete 3D printing - Materials used - Lightweight and functionally graded structures - Net zero energy buildings - Bioswales - Biofiltration pond - Ecosan systems - Recent developments in waste water management - Air pollution control - Waste disposal - Integration of energy, water and environmental systems for sustainable development - Emerging technologies: robot highway- vertical farming - case studies.

Unit 4 Smart manufacturing.

Smart factories and interconnection - Smart manufacturing - Automation systems - Additive manufacturing - Smart grids - Micro Electro Mechanical Systems (MEMS) - Stealth technology - Metal finishing - Self-propelled vehicles - E-mobility - Green fuels - Drones - Unmanned aerial vehicles (UAVs) - Aerodynamics - Robotic automation and collaborative robots - Augmented reality and haptics - Engineering cybernetics and artificial intelligence (AI) - Disruptive technologies - Frugal innovations - Emerging technologies: autonomous robots, swam robot, modular robots and space craft - case studies.

Unit 5 Cyber physical systems (CPS).

Introduction - Architecture of CPS - Data science and technology for CPS - Prototypes of CPS - Emerging applications in CPS including social space, crowd sourcing, healthcare and human computer interactions - Industrial AI - Networking systems for CPS applications - Wearable CPS and applications - Domain applications of CPS: agriculture, infrastructure, disaster management, energy and transportation - Case studies.

Textbooks / References.

1) C. J. Bartodziej, The Concept Industry 4.0: An Empirical Analysis of Technologies and Applications in Production Logistics, Springer.
2) T. Devezas, J. Leitão and A. Sarygulov, Industry 4.0: Entrepreneurship and Structural Change in the New Digital Landscape, Springer.

Course code / Category	**MEO404 / Open Elective**				
Course title	**Product Design and Ergonomics**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Characteristics of successful product development - Design and development of products - Duration and cost of product development - Challenges in product development - Development processes and organizations - Product planning - Identify customer needs and organize them into hierarchy - Establish the relative importance of needs and reflect on the results and process - Product specifications: establishing target specifications - setting the final specifications.

Unit 2 Concept generation, selection and testing.

Concept generation: clarify the problem, search externally, search internally, explore systematically and reflect on the results and process - Concept selection: methodology - concept screening - concept scoring - Concept testing: define the purpose of concept test, choose a survey population, choose a survey format, communicate the concept, measure customer response, interpret the result and reflect on the results and process.

Unit 3 Design for manufacturing.

Definition - estimation of manufacturing cost - reducing the cost of components - assembly - supporting production - impact of DFM on other factors - Prototyping: basics - principles of prototyping - technologies and planning for prototypes - Product development economics: elements of economic analysis - base case financial mode - sensitive analysis - project trade-offs - influence of qualitative factors on project success - qualitative analysis.

Unit 4 Introduction to ergonomics.

Ergonomic principles and fundamentals - Man-machine systems - Anthropometry: physiological requirements - engineering anthropometry - Ergonomic design: performance and energy cost of different modes and postures of operation of handles, levers, knobs, gadgets, etc. - Ergonomic design of system, equipment, devices and tools.

Unit 5 Human physical dimension concern.

Human body: structure and function - anthropometrics - Anthropometry: body growth and somatotypes - static and dynamic anthropometry - Stand posture: erect - Anthropometry landmark: sitting postures - squatting and cross-legged postures - Anthropometric measuring techniques - Statistical treatment of data and percentile calculations.

Textbooks / References.

1) K. T. Ulrich and S. D. Eppinger, Product Design and Development, Tata McGraw-Hill.
2) K. Otto and K. Wood, Product Design: Techniques in Reverse Engineering and New Product Development, 1e, Pearson Education.
3) D. G. Ullman, The Mechanical Design Process, McGraw-Hill Inc.

4) A. C. Chitale and R. C. Gupta, Product Design and Manufacturing, 3e, Prentice Hall of India.
5) Tim Jones, New Product Development, Butterworth Heinmann.
6) G. Boothroyd, P. Dewhurst and W. Knight, Product Design for Manufacture and Assembly, CRC Press.

Course code / Category	**MEO405 / Open Elective**				
Course title	**Renewable Energy Engineering**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Scenario of renewable energy (RE) sources.

Needs of renewable energy - Advantages and limitations of RE - Present energy scenario of conventional and RE sources.

Unit 2 Solar energy.

Energy available from sun - Spectral distribution - Solar radiation outside the earth's atmosphere and at the earth's surface - Solar radiation geometry - Instruments for solar radiation measurements - Empirical equations for prediction of availability of solar radiation - Radiation on tilted surface - Solar energy conversion into heat - Types of solar collectors: evacuated and non-evacuated solar air heater - concentrated collectors - thermal analysis of liquid flat plate collector - air heater and cylindrical parabolic collector - Solar energy thermal storage - Heating and cooling of buildings - Solar pumping - Solar cooker, solar still, solar drier, solar refrigeration and air conditioning - Solar pond, heliostat and solar furnace - Photovoltaic system for power generation - Solar cell modules and arrays - Solar cell types, material, applications, advantages and disadvantages.

Unit 3 Wind energy.

Energy available from wind - Basics of lift and drag - Basics of wind energy conversion system - Effect of density, angle of attack and wind speed - Windmill rotors: horizontal and vertical axes rotors - drag, lift, torque and power coefficients - tip speed ratio - solidity of turbine - Wind turbine performance curves - Wind energy potential and site selection - Basics of wind farm.

Unit 4 Bio energy.

Types of biogas plants - Biogas generation - Factors affecting biogas generation - Advantages and disadvantages - Biomass energy - Energy plantation - Gasification: types and applications of gasifiers.

Unit 5 Ocean energy.

Ocean Thermal Energy Conversion (OTEC) principle - Open, closed and hybrid cycle OTEC system - Energy from tides - Estimation of tidal power - Tidal power plants - Single and double basin plants - Site requirements - Advantages and limitations - Wave energy - Wave energy conversion devices - Advantages and disadvantages - Ocean thermal energy - Geothermal energy: introduction - vapor and liquid dominated systems - binary cycle - hot dry rock resources - magma resources - advantages and disadvantages - applications - Magnetohydrodynamic (MHD) power generation: concept and working principle.

Unit 6 Economic analysis.

Initial and annual cost - Basic definitions - Present worth calculations - Repayment of loan in equal annual instalments - Annual savings - Cumulative saving and life cycle cost - Economic analysis of addon solar system - Payback period - Clean development mechanism.

Textbooks / References.

1) S. P. Sukhatme and J. K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, McGraw-Hill Education.
2) J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley, New York.
3) S. N. Singh, Non-conventional Energy Resources, Pearson India.
4) F. Krieth and J. F. Kreider, Principles of Solar Energy, John Wiley, New York.

Course code / Category	**MEO406 / Open Elective**				
Course title	**Soft Computing Techniques**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEE302 / MES203**				

Unit 1 Introduction to soft computing.

Soft computing vs. hard computing: limitations of traditional computing and emergence of soft computing - Components of soft computing: Fuzzy Logic, Artificial Neural Networks and Evolutionary Computation (Genetic Algorithms).

Unit 2 Fuzzy logic.

Fuzzy sets and membership functions - Operations on fuzzy sets: fuzzy intersection, union, complement and other operations - Fuzzy reasoning: fuzzy propositions, implications and rules - Inference mechanisms (e.g., Mamdani, Sugeno) - Fuzzy logic control systems (FLCS): design principles - components (fuzzification, inference engine and defuzzification).

Unit 3 Artificial neural networks (ANNs).

Biological inspiration - Basic structure of ANNs (neurons and layers) - Types of neural networks: feedforward networks (Perceptron and Multilayer Perceptron) - recurrent networks - Learning algorithms in ANNs: supervised learning (backpropagation) and unsupervised learning (Hebbian

learning) - Training and validation of ANNs: training data preparation - performance evaluation metrics (e.g., mean squared error) - Applications of ANNs: function approximation - prediction - optimization.

Unit 4 Evolutionary computation.

Introduction - Bio-inspired optimization techniques - Concept of population and fitness function - Single objective vs. multi-objective, non-dominant solutions - Genetic algorithms (GAs): selection - crossover - mutation operators - genetic algorithm cycle - Applications of GAs: optimization problems in engineering - scheduling - Other evolutionary techniques: brief introduction to methods like Particle Swarm Optimization, ANT colony optimization and Bacterial Foraging Optimization.

Unit 5 Advanced topics and applications.

Hybrid soft computing systems: fuzzy-neural networks and neuro-evolutionary approaches - Introduction to recent advancements in soft computing - Case studies demonstrating the use of soft computing techniques in Mechanical engineering.

Textbooks / References.

1) D. K. Pratihar, Soft Computing: Fundamentals and Applications, 1e, Narosa Publishing House, 2015.
2) S. N. Sivanandam and S. N. Deepa, Principles of Soft Computing, 3e, Wiley India, 2019.
3) E. Volna, Introduction to Soft Computing, 1e, bookboon.com, 2013.
4) J. Paulo Davim, Kaushik Kumar and Supriyo Roy, Soft Computing Techniques for Engineering Optimization, 1e, CRC Press, 2021.
5) K. S. Ray, Soft Computing and Its Applications, Volume I: A Unified Engineering Concept, 1e, Apple Academic Press, 2015.
6) P. K. Chawdhry, R. Roy and R. K. Pant, Soft Computing in Engineering Design and Manufacturing, 1e, Springer-Verlag, 1997.
7) S. Haykin, Neural Networks and Learning Machines, 3e, Pearson Education India, 2016.

Course code / Category	**MEO407 / Open Elective**				
Course title	**Virtual Reality**				
Scheme and credits	L	T	P	C	Year
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**MEE302**				

Unit 1 Introduction to virtual reality (VR).

Introduction to virtual reality and virtual environment - Computer graphics - Real-time computer graphics - Flight simulation - Virtual environment requirement - Benefits of VR - Historical development of VR - Scientific landmark - Introduction to 3D computer Graphics - The virtual world space - Positioning the virtual observer - The perspective projection - Human vision - Stereo perspective projection - 3D clipping - Colour theory - Simple 3D modelling - Illumination models - Reflection models - Shading algorithms - Radiosity - Hidden surface removal - Realism - Stereographic image.

Unit 2 Geometric modelling.

Geometric modelling: introduction - from 2D to 3D - 3D space curves - 3D boundary representation - Geometrical transformations: introduction, frames of reference - modelling transformations - instances - picking - flying - scaling the VE - collision detection - Generic VR system: introduction - virtual environment - computer environment - VR technology - model of interaction - VR systems.

Unit 3 Virtual environment.

Animating the virtual environment: introduction - the dynamics of numbers - linear and nonlinear interpolation - animation of objects - linear and nonlinear translation - shape and object inbetweening - freeform deformation - particle system - Physical simulation: introduction - objects falling in a gravitational field - rotating wheels - elastic collisions - projectiles - simple pendulum - springs - flight dynamics of an aircraft.

Unit 4 VR hardware and software.

Human factors: introduction - the eye - the ear - the somatic senses - VR hardware: introduction - sensor hardware - head-coupled displays - acoustic hardware - Integrated VR systems - VR software: introduction - modelling virtual world - physical simulation - VR toolkits - Introduction to VRML.

Unit 5 VR applications.

Introduction - Engineering, entertainment, science and training applications - The future: virtual environment - modes of interaction

Textbooks / References.

1) John Vince, Virtual Reality Systems, Pearson Education Asia, 2007.
2) R. Anand, Augmented and Virtual Reality, Khanna Publishing House, Delhi.
3) Adams, Visualizations of Virtual Reality, Tata McGraw Hill, 2000.
4) G. C. Burdea and P. Coiffet, Virtual Reality Technology, 2e, Wiley Inter Science, 2006.
5) W. R. Sherman and A. B. Craig, Understanding Virtual Reality: Interface, Application and Design, Morgan Kaufmann, 2008.

SYLLABUS FOR HONOURS COURSES

Course code / Category	**MEH221 / Honours in Mechanical Engineering**				
Course title	**Advanced Engineering Materials**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**MES105**				

Unit 1 Introduction.

Classes of materials and their usage - Historical perspective - Intelligent materials - Structural materials - Functional materials - Primitive functions of intelligent materials - Intelligence inherent in materials - Materials intelligently harmonizing with humanity - Biomimetic - Case studies in materials selection with relevance to aero, auto, marine, machinery and nuclear applications.

Unit 2 Modern materials.

Electrocaloric effect: history of electrocaloric cooling - mechanism of working of electrocaloric cooling - electrocaloric materials - performance of electrocaloric materials - Dual steels - Micro alloyed - High strength low alloy (HSLA) steel - Transformation induced plasticity (TRIP) steel - Maraging steel - Inter-metallics - Ni and Ti Aluminides - Non-metallic materials: polymeric materials and their molecular structures - Production techniques for fibers, foams, adhesives and coatings - Structure, properties and applications of engineering polymers.

Unit 3 Nano-alloys and shape memory alloys.

Nano-alloys: introduction - Chemical synthesis: general concepts - reduction of metallic salts - the organometallic route - thermal decomposition method - other chemical methods for synthesis of nano-alloys - Physical routes for synthesis of nano-alloys - Experimental techniques and examples - Shape memory alloys (SMA): shape memory effect and the metallurgical phenomenon of SMA - types of SMA - One-way and two-way shape memory effect - Temperature assisted shape memory effect - Pseudo-elasticity.

Unit 4 High and low temperature materials.

High temperature materials: high temperature materials and their applications - factors influencing the functional life of components at elevated temperatures - definition of creep curve - stages of creep - metallurgical factors influencing various stages - effect of stress, temperature and strain rate - Low temperature materials: low temperature material properties - heat capacity - thermal contraction - electrical and thermal conductivity - superconductivity - cryogenic material failures.

Unit 5 Nanomaterials and superalloys.

Nanomaterials: definition - types of nanomaterials including carbon nanotubes and nanocomposites - physical and mechanical properties - applications of nanomaterials - Superalloys: Iron base, Nickel base and Cobalt base super alloys - composition control - solid solution strengthening - precipitation hardening by gamma prime - grain boundary strengthening.

Textbooks / References.

1) S. H. Avner, Introduction to Physical Metallurgy, 2e, Tata McGraw Hill Education Pvt. Ltd., 2009.
2) R. E. Reed Hill and R. Abbaschian, Physical Metallurgy Principles, 3e, PWS Publishers USA, 1994.
3) W. E. Smith, Structure and Properties of Engineering Alloys, McGraw Hill, 1993.
4) F. L. Matthews and R. D. Rawlings, Composite Materials: Engineering and Science, CRC Press / Woodhead Publishing Ltd., 1994.
5) K. K. Chawla, Composite Materials, 2e, Springer-Verlag, 2001.

Course code / Category	**MEH222 / Honours in Mechanical Engineering**				
Course title	**Advanced Fluid Mechanics**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**MEC202**				

Unit 1.

Review of basic concepts - Reynold's transport theorem - Fluid kinematics : flow visualization - decomposition of relative motion - velocity gradient.

Unit 2.

Conservation laws: conservation of mass, momentum, and energy - Integral and differential formulations - Navier-Stokes and energy equations - Dimensionless forms and dimensionless numbers - Solution of Navier-Stokes equations.

Unit 3.

Two-dimensional potential flows - Types of flow patterns - Complex potential conformal mapping.

Unit 4.

Momentum integral approach - Turbulent flows - Reynolds equation and closure problems - Free and wall bounded shear flows - Prandtl and von Karman hypothesis - Universal velocity profile near a wall - Flow through pipes - Boundary layer concepts.

Unit 5.

Boundary layer thickness - Prandtl's equations - Blasius solution - Skin friction coefficient.

Textbooks / References.

1) P. K. Kundu and I. M. Cohen. Fluid Mechanics. 4e, Academic Press, 2008.

2) R. L. Panton, Incompressible Flow. 3e, Wiley, 2005.
3) F. M. White, Viscous Fluid Flow, 3e, McGraw-Hill, 2017.
4) D. J. Acheson, Elementary Fluid Dynamics, Oxford University Press, 1990.

Course code / Category	**MEH223 / Honours in Mechanical Engineering**				
Course title	**Advanced Welding Technology**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**MEC205**				

Unit 1 The welding arc.

Definition - Structure and characteristics - Arc blow - Electrical characteristics of an arc - Methods of arc initiation - Methods of arc maintenance - Role of electrode polarity.

Unit 2 Arc welding power sources.

Requirements for an arc welding power source - Volt-ampere characteristics of welding power source - Selection of static volt-ampere characteristics for welding process - Dynamic volt-ampere characteristics - Mathematical problems on static volt-ampere characteristics - Duty cycle - Operating principles of a welding transformer - Rectified DC welding power sources - Solid state inverter - Pulsed arc welding power sources.

Unit 3 Arc Welding consumables.

Coated electrodes - Electrode coating - Welding rods and wires - Welding fluxes - Shielding gases.

Unit 4 Metal transfer.

Forces affecting metal transfer - Classification of modes of metal transfer - Parameters affecting metal transfer - Pulsed GMAW - Synergic GMAW.

Unit 5 Weldability and weldability tests.

Weldability - Weldability of specific materials: weldability of carbon steels, HSLA, cast iron and stainless steels - Weldability assessment - Weldability tests - Fabrication weldability tests - Service weldability tests.

Unit 6 Heat flow in welding.

Heat flow in welding - Temperature distribution and cooling rate - Heat flow equation - Rosenthal solution of heat flow equation.

Unit 7 Basic metallurgy of fusion welds.

Introduction - Weld metal zone - Fusion boundary zone - Heat affected zone - Microstructure in weldments.

Unit 8 Welding stresses and distortion.

Residual stresses - Causes of the development of residual stresses - Methods of relieving welding residual stresses - Distortion in welds.

Unit 9 Weld defects.

Classification of weld defects - Arc welding defects.

Unit 10 Weld joints, weld symbols and weld design.

Types of joints - Welding symbols - Weld design for static loading.

Textbooks / References.

1) R. S. Parmar, Welding Processes and Technology, Khanna Publishers.
2) R. S. Parmar, Welding Engineering and Technology, 3e, Khanna Publishers.
3) O. P. Khanna, A Textbook of Welding Technology, Dhanpat Rai Publications.
4) Stuart W. Gibson, Advanced Welding, Macmillan Press Ltd.
5) Sindo Kou, Welding Metallurgy, 3e, Wiley.

Course code / Category	**MEH311 / Honours in Mechanical Engineering**				
Course title	**Fuels, Combustion and Emission Control**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**5**
Pre-requisites if any	**MEC206**				

Unit 1.

Types of fuels and their properties - Coal characterization - Combustion chemistry - Stoichiometry - Heat of reaction - Calorific value - Adiabatic flame temperature - Equilibrium - Mass transfer.

Unit 2.

Chemical kinetics - Important chemical mechanisms - Simplified conservation equations for reacting flows - Laminar premixed flames - Simplified analysis. Factors influencing flame velocity and thickness flame stabilization - Diffusion flames - Introduction to turbulent flames.

Unit 3.

Coal combustion systems - Liquid fuel atomizers - FBC: types of FBCs - Models for droplet and Carbon particle combustion.

Unit 4.

Emissions - Emission index - Corrected concentrations - Control of emissions for premixed and non-premixed combustion.

Unit 5.

Fuel chemical kinetic simulations with detailed and reduced reaction mechanism - Numerical simulation of simplified combustion problems using CFD software.

Textbooks / References.

1) S. P. Sharma and C. Mohan, Fuels and Combustion, Tata McGraw-Hill, 1987.
2) S. Sarkar, Fuels and Combustion, Orient Longman, 2005.
3) John B. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill Co., 2018.
4) E. F. Obert, Internal Combustion Engine and Air Pollution, International Textbook Publishers, 1983.

Course code / Category	**MEH312 / Honours in Mechanical Engineering**				
Course title	**Analysis of Thermal Power Cycles**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**5**
Pre-requisites if any	**MEC206**				

Unit 1.

Steam power plant cycle - Rankine cycle - Reheat cycle - Regenerative cycle with one and more feed heaters: types of feed heaters - open and closed types - steam traps types.

Unit 2.

Cogeneration - Condensing turbines - Combined heat and power - Combined cycles: Brayton and Rankine cycle combinations - Binary vapor cycle.

Unit 3.

Air standard cycles - Cycles with variable specific heat - Fuel-air cycle - Deviation from actual cycle.

Unit 4.

Brayton cycle - Open cycle gas turbine - Closed cycle gas turbine - Regeneration - Inter cooling and reheating between stages.

Unit 5.

Refrigeration cycles - Vapor compression cycles - Cascade system - Vapor absorption cycles - GAX Cycle.

Textbooks / References.

1) R. Culp, Principles of Energy Conversion, McGraw-Hill, 2000.
2) P. K. Nag. Power Plant Engineering, 2e, Tata McGraw-Hill, 2002.
3) P. K. Nag, Engineering Thermodynamics, 3e, Tata McGraw-Hill, 2005.
4) C. P. Arora, Refrigeration and Air Conditioning, 2e, Tata McGraw-Hill, 2004.

Course code / Category	**MEH313 / Honours in Mechanical Engineering**				
Course title	**Computational Fluid Dynamics**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5**
Pre-requisites if any	**MEC202**				

Unit 1.

Computational fluid dynamics: introduction, advantages, and applications - Principles of conservation: Reynolds transport theorem - conservation of mass - conservation of linear momentum: Navier-Stokes equation - conservation of energy: general scalar transport equation - Approximate solutions of differential equations: error minimization principles - functions with higher order derivatives - essential and natural boundary conditions.

Unit 2.

Discretization methods - Finite element and finite difference methods: well posed boundary value problem - possible types of boundary conditions - conservativeness - boundedness - transportiveness - Finite volume method: illustrative examples - basic concepts and implementation of boundary conditions - Discretization of unsteady state problems: 1D unsteady state diffusion problems - implicit, fully explicit, and Crank-Nicholson scheme.

Unit 3.

Important consequences of discretization of time dependent diffusion type problems: consistency - stability - convergence - grid independent and time independent study - Stability analysis of parabolic and hyperbolic equations - Finite volume discretization of 2D unsteady state diffusion type problems: 2D unsteady state diffusion problems.

Unit 4.

Solution of systems of linear algebraic equations: criteria for unique solution - infinite number of solutions and no solution - Solution techniques for systems of linear algebraic equations: elimination, iteration and gradient search methods with examples - Norm of a vector - Norm of a matrix: some important properties of matrix norm - Error analysis of elimination methods.

Unit 5.

Finite volume discretization of convection-diffusion equations: schemes - the concept of false diffusion - QUICK scheme - Discretization of Navier-Stokes equations - Discretization of the momentum equation - Staggered grid and collocated grid - SIMPLE algorithm - SIMPLER algorithm - What is there in implementing a CFD code?: the basic structure of a CFD code - pre-processor, solver and post-processor - user-defined subroutines.

Textbooks / References.

1) J. E. Tannehill, D. A. Anderson and R. H. Pletcher, Computational Fluid Mechanics and Heat Transfer, 2e, Taylor & Francis, 1997.
2) K. A. Hoffmann and S. T. Chiang, Computational Fluid Dynamics for Engineers, Engineering Education Systems, 2000.
3) J. D. Anderson, Computational Fluid Dynamics - The Basics with Applications, McGraw-Hill, 1995.
4) H. K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics - The Finite Volume Method, Longman Scientific.
5) S. V. Patankar, Numerical Heat Transfer & Fluid Flow, Hemisphere, 1980.
6) A. W. Date, Introduction to Computational Fluid Dynamics, Cambridge University Press, 2005.

Course code / Category	**MEH321 / Honours in Mechanical Engineering**				
Course title	**Advanced Heat Transfer**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**7**
Pre-requisites if any	**MEC304**				

Unit 1 Conduction.

Boundary conditions - Thermal Conductivity - Conduction equation - Fin design: analytical solutions - Multi-dimensional steady state heat conduction - Transient heat conduction - Lumped capacitance method - Semi-infinite media method.

Unit 2 Convection.

Energy and momentum equations - Laminar and turbulent boundary layers - Entry length - Reynolds-Colburn analogy - Heat transfer coefficient for flow over a flat surface, circular and non-circular ducts.

Unit 3 Two-phase flow.

Flow patterns - Void fraction - Critical flow - Dispersed, slug, annular and stratified flow - Homogeneous, drift and separated flow models.

Unit 4 Two-phase heat transfer.

Pool and convective boiling - Critical heat flux - Dropwise and film-wise condensation - Melting and solidification - Heat transfer enhancement methods.

Unit 5 Thrust areas.

Thermoregulation - Laser generated heat transfer - Tissue thermal properties and perfusion - Thermal damage and rate processes in biological tissues - Thermal injury - Mathematical models of bio-heat transfer - Machine learning in heat transfer - Linear regression and Neural networks - Practical considerations and applications.

Textbooks / References.

1) John H. Lienhard IV and John H. Lienhard V, A Heat Transfer Textbook, Phlogiston Press, 2020.
2) Adrian Bejan, Convection Heat Transfer, Wiley, 2013.
3) J. P. Holman, Heat Transfer, Tata McGraw Hill, 2002.
4) Yunus Cengel, Heat and Mass Transfer: Fundamentals and Applications, McGraw Hill, 2020.
5) C. E. Brennen, Fundamentals of Multiphase Flow, Cambridge University Press, 2005.
6) J. G. Collier and J. R. Thome, Convective Boiling and Condensation, 3e, Oxford University Press.
7) F. P. Incropera and D. P. DeWitt, Fundamentals of Heat and Mass Transfer, John Wiley & Sons, 2002.
8) Ashley J. Welch and Martin J. C. Gemert, Optical-Thermal Response of Laser-Irradiated Tissue, Springer Dordrecht, 2011.
9) P. Prakash and G. Srimathveeravalli, Principles and Technologies for Electromagnetic Energy Based Therapies, Academic Press, 2021.

Course code / Category	**MEH322 / Honours in Mechanical Engineering**				
Course title	**Advanced Metal Forming Technology**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**6**
Pre-requisites if any	**MEC205**				

Unit 1 Forming.

Review of stress and strain behavior of materials - Plastic stress-strain relations (isotropic and anisotropic) - Plastic and tangent modulus - Yield criteria - Flow rule - Plastic potential - Strain hardening - Plastic instability - Empirical stress-strain equations - Effect of pressure, strain-rate and temperature - Stress equilibrium and virtual work - Deformation and recrystallization - Cold and hot working - Heat effect during forming.

Unit 2 Plasticity.

Yield criteria - Isotropic and anisotropic hardening - Rules of plastic flow - Levy-Mises and Prandtl-Reuss equations - Isotropic and anisotropic yield theories: von Mises - Tresca - Hill's yield criteria.

Unit 3 Analysis.

Mechanics of deformation in forming processes - Determination of loads, pressures, torques and powers required in metal forming processes - Analysis of stress tensor, eigen values, deviatoric and hydrostatic stress components - Octahedral stresses - Analysis of strain and strain-rates - Spring back - Theory and applications of slab method - Limit analysis: upper and lower bound technique - slip-line field method.

Unit 4 Forming processes.

Drawing and sheet metal work - Stamping - FLD concepts - FLC prediction - Forging - Extrusion - Rolling - Bending - Deep drawing - Wire and tube drawing - High velocity forming.

Unit 5 Other topics.

Factors affecting deformation mechanisms in different metal forming processes.

Textbooks / References.

1) B. Avitzur, Metal Forming: Processes and Analysis, Tata McGraw Hill Publishing Co. Ltd., 1977.
2) J. Chakrabarty, Theory of Plasticity, McGraw-Hill, 1998.
3) W. F. Hosford and R. M. Caddell, Metal Forming Mechanics and Metallurgy, Prentice Hall, 2007.
4) V. Gopinathan, Plasticity Theory and its Application in Metal Forming, Wiley Eastern Limited, 2005.

Course code / Category	**MEH323 / Honours in Mechanical Engineering**				
Course title	**Mechanical Vibrations and Analysis**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**6**
Pre-requisites if any	**-----**				

Unit 1 Free vibration.

Basic concepts and classification of vibration - Ffree vibration of undamped translational motion - Free vibration with viscous damping.

Unit 2 Forced vibration.

Response of damped and undamped system under harmonic force and base excitation - Forced vibration with coulomb and hysteresis damping - Steady state solution of single degree of freedom system - Reciprocating and rotating unbalance - Transmissibility.

Unit 3 Multi-degrees of freedom systems.

Two degrees of freedom: free vibration analysis of an undamped system - coordinate coupling - torsional system - self-excitation and stability analysis - Multi-degree freedom: undamped free vibration of multi-degree of freedom system - Eigenvalue and Eigenvectors - Orthogonality of modes - Continuous systems: whirling of shafts - vibration of string - longitudinal vibration of rods - torsional vibration of shafts - vibration of beams.

Unit 4 Measurement and control.

Vibration testing - Transducers - Vibration pickups - Signal analysis - Vibration isolation with rigid and flexible foundation - Passive and active vibration control - Vibration absorber.

Unit 5 Non-linear vibrations.

Introduction - Development of non-linear equation of motion - Exact, approximate, and analytical solution - Sub-harmonic and super-harmonic oscillation - Random vibration: Fourier Analysis - response of single degree of freedom system to random excitation.

Textbooks / References.

1) William T. Thomson, Theory of Vibrations with Applications, 5e, Pearson Education, 2008.
2) S. S. Rao, Mechanical Vibrations, 6e, Pearson Education, 2018.
3) Leonard Meirovitch, Elements of Vibration Analysis, 2e, McGraw Hill Education, 2014.
4) A. A. Shabana, Theory of Vibration: An Introduction, 3e, Springer, 2018.
5) A. A. Shabana, Theory of Vibration, Volume II: Discrete and Continuous Systems, 1e, Springer-Verlag New York Inc., 1991.

Course code / Category	**MEH411 / Honours in Mechanical Engineering**				
Course title	**Finite Element Methods in Mechanical Engineering**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7**
Pre-requisites if any	**MES201 / MEC304**				

Unit 1 Finite element analysis of one-dimensional problems.

Historical background - Weighted residual methods - Basic concepts of FEM - Variational formulation of boundary value problems - Ritz method - Finite element modelling - Element equations - Linear and higher order shape functions - Bar and beam elements - Applications to heat transfer problems.

Unit 2 Finite element analysis of two-dimensional problems.

Basic boundary value problems in two-dimensions - Linear and higher order triangular and quadrilateral elements - Poisson's and Laplace's equation - Weak formulation - Element matrices and vectors - Application to scalar variable problems - Introduction to theory of elasticity - Plane stress - Plane strain and axisymmetric formulation - Principle of virtual work - Element matrices using energy approach.

Unit 3 Isoparametric formulation.

Natural coordinate systems - Lagrangian interpolation polynomials - Isoparametric elements formulation - Shape functions: one-dimensional, two-dimensional, triangular, and quadrilateral elements - Serendipity elements - Jacobian transformation - Numerical integration - Gauss quadrature: one-, two- and three-point integration.

Unit 4 Eigen value problems.

Dynamic analysis - Equations of motion - Consistent and lumped mass matrices - Free vibration analysis - Natural frequencies of longitudinal, transverse, and torsional vibration - Solution of Eigenvalue problems - Introduction to transient field problems.

Unit 5 Nonlinear analysis.

Introduction to nonlinear problems - Some solution techniques - Computational procedure - Material nonlinearity - Plasticity and Visco-plasticity - Stress stiffening - Contact interfaces - Problems of gaps and contact - Geometric nonlinearity - Modeling considerations - Free and mapped meshing - Mesh quality - Error estimate.

Textbooks / References.

1) K. J. Bathe, Finite Element Procedures in Engineering Analysis, Prentice Hall, 1990.
2) David Hutton, Fundamentals of Finite Element Analysis, Tata McGraw-Hill, 2005.
3) S. S. Rao, The Finite Element Method in Engineering, 6e, Butterworth Heinemann, 2018.
4) J. N. Reddy, Introduction to the Finite Element Method, 4e, Tata McGraw-Hill, 2018.
5) P. Seshu, Textbook of Finite Element Analysis, PHI Learning Pvt. Ltd., New Delhi, 2012.
6) T. R. Chandrupatla and A. D. Belegundu, Introduction to Finite Elements in Engineering, Pearson Education Limited, 2014.

Course code / Category	**MEH412 / Honours in Mechanical Engineering**				
Course title	**Advanced Metal Cutting Technology**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**7**
Pre-requisites if any	**MES105 / MEC308**				

Unit 1.

Introduction - Classification of material removal operation - Geometry of cutting tools - Tool signature - Normal rake system - Importance of tool geometry - Orthogonal cutting and oblique cutting - Components of machining force.

Unit 2.

Mechanism of chip formation - Types of chips and their characteristics - Determination of shear plane angle by different methods - Shear strain-velocity relationship - Rate of strain.

Unit 3.

Forces in orthogonal cutting - Stresses - Merchant's first analysis and second analysis - Lee and Shaffer solution - Stress distribution on rake face in orthogonal cutting - Mechanics of milling process - Chip thickness in milling process.

Unit 4.

Heat generation and cutting tool temperature in metal cutting - Theoretical and practical determination of cutting tool temperature - Cutting fluids: purpose - essential characteristics - selection and methods of application.

Unit 5.

Cutting tool failure - Mechanics of tool wear - Types of tool wear - Tool life - Machinability - Cutting tool materials - Indexable inserts - Chip curling and chip breaking - Form tools.

Unit 6.

Surface finish and surface integrity - Economics of machining: optimum cutting speed for minimum cost and optimum cutting speed for maximum rate of production - Hi-E range.

Textbooks / References.

1) B. L. Juneja, G. S. Sekhon and Nitin Seth, Fundamental of Metal Cutting and Machine Tools.
2) Amitabha Ghosh and Asok Kumar Mallik, Manufacturing Science.
3) Milton C. Shaw, Metal Cutting Principles.
4) Amitabha Bhattacharyya, Metal Cutting Theory and Practice.

Course code / Category	**MEH413 / Honours in Mechanical Engineering**				
Course title	**Design of Heat Transfer Equipment**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**7**
Pre-requisites if any	**MEC304**				

Unit 1.

Classification of heat transfer equipment - Selection of heat exchangers - Application of heat exchangers - Overall heat transfer coefficient - LMTD method for heat exchanger analysis for parallel, counter, multi-pass, and cross flow heat exchangers - e-NTU method for heat exchanger analysis - Fouling - Cleanliness factor - Techniques to control fouling.

Unit 2.

Classification of shell and tube exchangers - Design calculation of shell and tube heat exchangers based on TEMA standards - Tube side flow area calculations - Calculation of shell side heat transfer coefficient - Evaluation for wall temperature - Calculations of tube side and shell side pressure drop - Baffle spacing.

Unit 3.

Design of finned surface heat exchangers - Compact heat exchangers - Plate fin heat exchangers (PFHE): types - construction - fabrication - design - applications.

Unit 4.

Thermal design of heat exchange equipment such as air pre-heaters, economizer, super heater, condensers - Calculation procedure for steam condenser - Selection of compact heat exchangers - Analysis and design of cooling towers.

Unit 5.

Heat pipes: construction - working principle - application - analysis - special heat pipes - Heat exchanger testing: steady state and dynamic methods.

Textbooks / References.

1) V. Ganapathy, Applied Heat Transfer, Pennwell Books, 1982.
2) W. M. Kays and A. L. London, Compact Heat Exchangers, McGraw-Hill, 1998.
3) P. Dunn and D. A. Reay, Heat Pipes, Pergamon, 1994.
4) S. Kakac and H. Liu, Heat Exchangers, CRC Press, 2002.
5) Arthur P. Frass, Heat Exchanger Design, John Wiley & Sons, 1988.
6) G. F. Hewitt, G. S. Shires and T. R. Bott, Process Heat Transfer, CRC Press, 1994.
7) Nicholas Cheremisioff, Cooling Tower, Ann Arbor Science Pub., 1981.
8) D. P. Sekulic, Fundamentals of Heat Exchanger Design, John Wiley, 2003.
9) T. Taborek, G. F. Hewitt and N. Afgan, Heat Exchangers, Theory and Practice, McGraw-Hill Book Co. 1980.

Course code / Category	**MEH421 / Honours in Mechanical Engineering**				
Course title	**Advanced CAD and Computational Geometry**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**8**
Pre-requisites if any	**MEC306**				

Unit 1 NURBS and basic algorithms.

NURBS (Non-Uniform Rational B-Splines): definition and properties of NURBS curves and surfaces - derivatives of NURBS curves and surfaces - Basic algorithms: knot insertion, knot refinement and knot removal algorithms - degree reduction and degree elevation algorithms - Implementations using C++ and OpenGL.

Unit 2 Advanced algorithms, conics, and circles.

Point inversion and projection - Transformations and projections - Reparameterization of NURBS curves and surfaces - Applications of NURBS for representation of conic sections and circles.

Unit 3 Curves and surfaces fitting.

Global interpolation - Local interpolation - Global approximation - Local approximation - Advanced surface construction techniques: skinned surfaces - interpolation of bidirectional curve network - Coons surfaces - Shape modification: control points repositioning - weights modification - constrained surface and curve modification.

Unit 4 Computational geometry.

Introduction and applications - Polygon triangulation and partitioning - Convex hulls - Algorithms for generating convex hulls in 2D and 3D - Voronoi diagrams - Delaunay triangulations - Search and intersection algorithms - Motion planning - Applications of computational geometry in manufacturing and metrology.

Textbooks / References.

1) David F. Rogers, An Introduction to NURBS with Historical Perspective, Morgan Kaufmann Publishers, 2001.
2) Les Piegl and Wayne Tiller, The NURBS Book, Springer-Verlag, 1997.
3) Gerald Farin, Curves and Surfaces for CAGD - A Practical Guide, 5e, Morgan Kaufmann Publishers, 2002.
4) F. P. Preparata and M. I. Shamos, Computational Geometry - An Introduction, Springer-Verlag, 1985.
5) M. J. Laszlo, Computational Geometry and Computer Graphics in C++, Prentice Hall, 1996.
6) Joseph O' Rourke, Computational Geometry in C, 2e, Cambridge University Press

Course code / Category	**MEH422 / Honours in Mechanical Engineering**				
Course title	**Dies, Moulds & Tools Manufacturing**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**8**
Pre-requisites if any	**MES105 / MEC205 / MEC308**				

Unit 1 Stamping die design.

Press tool: theory of sheet metal behaviour - Metal stamping dies: construction, assembly and function - Blanking and piercing operations - Blank calculation and flat layout - Punching force calculation - Springs: their design and calculations - Material and surface finish - Bending and forming operations.

Unit 2 Forging die design.

Basic principles of metal flow - Die material and their alternatives - Parting line and its position - Balancing of parting lines, draft angles, rib, web, bosses, corner fillet and other radii - Flash land, gutter and their design consideration - Die design principle: general steps, fuller design, rolling or edging design, bender design, blocker design, die layout, centre of pressure and dowel position - die register or die lock - Dies for solid upsetting - Grain flow: factors contributing to grain flow - control of grain flow - Metal flow in impression dies - Factors influencing die filling - Forgeability.

Unit 3 Injection moulding.

General mould construction: basic terminology - mould cavities and cores - bolsters - Ejection: ejector grid - ejector plate assembly - ejection techniques - ejection from fixed half - sprue pullers - Feed system - runner and its shape - gates and its types - parting surface and its types - venting - mould cooling - integer type and insert bolster - water connections and seals - splits-sliding and angled lift - design features of side cores and side cavities and their types - internal undercuts - form pin, split cores, side cores and stripping of internal undercuts - Mould for threaded components: internal and external - Multi daylight mould - Underfeed moulds and triple daylight moulds - Runner-less mould: nozzle type - hot runner unit - insulated runner - hot runner plate - Calculation of number of impression.

Unit 4 Jigs and fixtures.

Concepts - Differences and benefits of jigs and fixtures - Jigs: types - sketches with nomenclature - working and applications - Fixtures: types - sketches with nomenclature - working and applications of fixtures - Steps to design jigs and fixture for given simple component - Geometric dimensioning and tolerancing (GD&T): introduction - datum reference plane - Taylor's principle - GD&T symbols and meanings - Material conditions: maximum material condition - least material condition - Regardless of feature size.

Unit 5 Cutting tools and accessories.

Cutting tool materials: types - composition, properties and applications - Carbide inserts: types, ISO designation and applications - Re-sharpening methods - Gear hob - Tool holders for turning and milling - Tool holding and tool mounting systems for conventional milling and drilling machine tools - Locating and clamping devices: concepts - meaning and definitions of location and clamping - use of locating and clamping principles in day-to-day supervision on shop floor - Degree of freedom: concept and importance - Principle of location - Locators: types - sketches with nomenclature - working and applications - Fool proofing and ejecting - Clamping devices: types - sketches with nomenclature - design principles - working and applications.

Textbooks / References.

1) Eugene Ostergard, Advanced Die Design, National Tooling & Machining Association.
2) V. Boljanovic and J. R. Paquin, Die Design Fundamentals, 3e, Industrial Press Inc.
3) D. V. Rosato and D. V. Rosato, Plastic Processing Data Handbook, Van Nostrand Reinhold.
4) P. H. Joshi, Jigs & Fixtures, 11e, Tata McGraw-Hill Pub. Co. Ltd.
5) W. E. Boyes, Jigs, Fixtures & Gauges, SME, Michigan.

Course code / Category	**MEH423 / Honours in Mechanical Engineering**				
Course title	**Advanced Internal Combustion Engines**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**8**
Pre-requisites if any	**MEC402**				

Unit 1.

Combustion process in SI and CI engines - Combustion chambers and abnormal combustion.

Unit 2.

Composition and effect of Fossil and Alternative Fuels in IC Engine.

Unit 3.

IC Engines modelling: zero-dimensional, two-zone and multi-zone modelling.

Unit 4.

Instrumentation to study the combustion process in engines such as particle image velocimetry - Holographic PIV - Spray visualization - Phase Doppler interferometry for spray characterization.

Unit 5.

Pollutant formation in SI and CI engines and Control measures such as DOC, DPF, SCR and LNT.

Textbooks / References.

1) J. B. Heywood, Internal Combustion Engine Fundamentals, McGraw-Hill, 1988.
2) P. W. S. Gill, J. R. Smith and J. Ziurys, Fundamentals of Internal Combustion Engines, Oxford and IBH, New Delhi, 1959.
3) C. F. Taylor, The Internal Combustion Engine in Theory and Practice, MIT Press, Cambridge, 1985.
4) E. F. Obert, Internal Combustion Engines and Air Pollution, Intext Educational Publishers, New York, 1973.
5) R. L. Bechtold, Alternative Fuels Guidebook, Properties, Storage, Dispensing, and Vehicle Facility Modifications, SAE Publications, 1997.
6) D. J. Patterson and N. A. Henein, Emission from Combustion engines and their control, Ann Arbor Science Publishers, 1981.
7) H. Heisler, Advanced Engine Technology, SAE Publications, 1995.
8) J. L. Lumley, Engines: An Introduction, Cambridge University Press, 1999.

SYLLABUS FOR MULTI-DISCIPLINARY MINOR (MECHANICAL ENGINEERING)

Course code / Category	**MEM121 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Engineering Mechanics**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Introduction - Basic concepts of force, moment and couple - Equilibrium of coplanar force systems - Friction.

Unit 2.

Internal forces in members of Trusses and (Method of joints and Method of Sections) and Analysis of Frames (Method of Members).

Unit 3.

Properties of surfaces: centroid and moment of inertia of plane figures - Polar moment of inertia - Product of inertia - Principal axes - Principle of virtual work and applications.

Unit 4.

Kinetics of rectilinear motion and curvilinear motion of a particle - D'Alembert's principle - Linear momentum and impulse - Angular momentum - Work and energy - Impact.

Unit 5.

Rigid body motion: kinematics of rotation equation of motion of a rotating rigid body - Compound pendulum - Energy equations for rotating bodies - Plane motion: kinematics of plane motions - instantaneous centre of rotation - equations of plane motion of a rigid body and energy equations for plane motion - D'Alembert's principle for rotation and plane motion.

Textbooks / References.

1) R. C. Hibbeler, Engineering Mechanics - Statics, 14e, Prentice Hall.
2) R. C. Hibbeler, Engineering Mechanics - Dynamics, 14e, Prentice Hall.
3) F. P. Beer, E. R. Johnston, et al., Vector Mechanics for Engineers: Statics and Dynamics, 12e, McGraw-Hill Co.
4) S. Timoshenko, D. H. Young, J. V. Rao and Sukumar Pati, Engineering Mechanics, McGraw-Hill Co.
5) J. L. Meriam and L. G. Kraige, Engineering Mechanics - Statics, 8e, John Wiley and Sons.
6) J. L. Meriam and L. G. Kraige, Engineering Mechanics - Dynamics, 8e, John Wiley and Sons.
7) Bedford and W. Fowler, Engineering Mechanics - Statics and Dynamics, Pearson Publications.

Course code /	**MEM122 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Engineering Thermodynamics**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**-----**				

Unit 1 Fundamentals of thermodynamics.

Thermodynamic system and control volume - Thermodynamics equilibrium, properties, states, processes and cycles, exact and inexact differentials - Definition and classification of thermodynamic work and heat - Displacement work and illustrations for simple processes - Electrical, magnetic, and shaft work - Zeroth law of thermodynamics - Temperature scales and thermometric property.

Unit 2 First law of thermodynamics.

First law for cyclic and non-cyclic processes - Concept of total energy E - Demonstration that E is a property - Various modes of energy - Internal energy and enthalpy - First law for a closed system undergoing a cycle and change of state - First law of thermodynamics for steady flow process - Steady flow energy equation applied to nozzle, boiler, turbine, compressor, pump, heat exchanger and throttling process.

Unit 3 Second law of thermodynamics.

Second law of thermodynamics: definitions of direct and reverse heat engines - Definitions of thermal efficiency and COP - Kelvin-Plank and Clausius statements - Definition of reversible process - Internal and external irreversibility - Carnot cycle - Corollary of Carnot theorem.

Unit 4 Entropy.

Clausius theorem - Property of entropy - Inequality of Clausius - Entropy change in an irreversible process - Principle of increase of entropy - Entropy change for non-flow and flow processes - Availability and irreversibility and exergy.

Unit 5 Pure substance.

Pure substances - p-V-T-surfaces - T-S and h-s diagrams - Mollier charts - Phase transformations - Triple point at critical state properties during change of phase - Dryness fraction - Clausius-Clapeyron equation.

Textbooks / References.

1) P. K. Nag, Engineering Thermodynamics, Tata McGraw-Hill, 1995.
2) R. E. Sonntag, C. Borgnakke and G. J. Van Wylen, Fundamentals of Thermodynamics, 6e, John Wiley & Sons, 2003.
3) J. B. Jones and R. E. Duggan, Engineering Thermodynamics, Prentice Hall of India, 1996.

4) P. Chattopadhyaya, Engineering Thermodynamics, Oxford University Press, 2010.
5) G. F. C. Rogers and Y. R. Mayhew, Engineering Thermodynamics - Work and Heat Transfer, 4e, Pearson, New Delhi, 2012.

Course code	**MEM123 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Fluid Mechanics and Hydraulic Machines**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Introduction to fluids - Hypothesis of continuum - Shear stress in a moving fluid - Properties of fluids - Pressure and head - Pascal's law - Variation of pressure vertically in a fluid under gravity - Equality of pressure at the same level in a static fluid - General equation for point-to-point variation of pressure due to gravity in a static fluid - Pressure measurements using elastic pressure transducers, force balance pressure gauge and electrical pressure transducers.

Unit 2 Static forces on surface and buoyancy.

Fluid statics - Action of fluid pressure on surface: resultant force and centre of pressure on a plane surface under uniform pressure - Resultant force and centre of pressure on a plane surface immersed in a liquid - Forces on a curved surface due to hydrostatic pressure - Buoyancy - Equilibrium of floating bodies - Stability of a submerged body - Stability of floating bodies - Metacentric height and its determination.

Unit 3 The energy equation and its application.

Momentum and fluid flow - Momentum equation for 2D and 3D flow along a streamline - Momentum correction factor - Euler's equation of motion along a streamline - Bernoulli's theorem - Kinetic energy correction factor - Pitot tube, venturi meter and orifice meter - Theory of small orifices discharging to atmosphere - Theory of large orifices - Rotameter - Elementary theory of notches and weirs - Flow in a curved path.

Unit 4 Dimensional analysis and similarities.

Dimensional analysis using Rayleigh's method, and Buckingham π-theorem - Similarities: geometric similarity, dynamic similarity, and kinematic similarity - Model testing and model laws - Undistorted and distorted models.

Unit 5 Viscous flow.

Reynolds number and Reynolds experiment - Flow of viscous fluid through circular pipe - Hagen Poiseuille formula - Flow of viscous fluid between two parallel fixed plates - Power absorbed in viscous flow through journal, footstep and collar bearing - Movement of piston in dash pot - Turbulent flow: expression for coefficient of friction - Darcy-Weisbach equation - Moody diagram - Resistance of smooth and rough pipes - Velocity distribution in turbulent flow through pipes.

Unit 6 Flow through pipes.

Major energy losses - Minor energy losses - Hydraulic gradient and total energy lines - Pipes in series and parallel - Equivalent pipes - Power transmission through pipe - Flow through nozzle at the end of pipe - Water hammer in pipes - Compressible flow: basic equations for one dimensional compression - pressure wave propagation - sound velocity in fluid - Mach number - stagnation properties.

Unit 7 Hydraulic machines.

Euler equation for turbomachines - Velocity triangles - Centrifugal and axial flow pumps - Hydraulic turbines - Cavitation - Water hammer.

Textbooks / References

1) D. S. Kumar, Fluid Mechanics and Fluid Power Engineering, S. K. Kataria & Sons.
2) R. K. Bansal, Fluid Mechanics and Hydraulic Machines, Laxmi Publications.
3) Frank M. White, Fluid Mechanics, McGraw Hill Publishing Company Ltd.
4) R. W. Fox and A. T. McDonald, Introduction to Fluid Mechanics, 10e, John Wiley & Sons.
5) Y. A. Cengel and John Cimbala, Fluid Mechanics Fundamental and applications, 3e, Tata McGraw-Hill Education.
6) S. K. Som, G. Biswas and S. Chakraborty, Introduction to Fluid Mechanics and Fluid Machines, 3e, Tata McGraw-Hill Education.

Course code	**MEM131 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Kinematics of Machines**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**5 / 6**
Pre-requisites if any	**-----**				

Unit 1 Mechanisms.

Classification of links, pairs, and degree of freedom - Mobility of mechanisms - Kinematic inversions of four bar chain and slider crank - Mechanical advantage - Transmission angle - Description of some common mechanisms - Quick return mechanism - Straight line generators (Peaucellier, Hart, Watt, Roberts straight line motion) - Universal coupling - Motor car steering.

Unit 2 Velocity and acceleration.

Displacement, velocity, and acceleration analysis of simple mechanisms - Graphical velocity analysis using instantaneous centres - Kennedy's theorem - Angular velocity theorem - Velocity and acceleration analysis using loop closure equation - Kinematics analysis of simple mechanisms -

Slider crank mechanism dynamics - Quick return mechanism - Coincident points - Velocity and acceleration image - Coriolis component of acceleration.

Unit 3 Kinematics synthesis of mechanism.

Number synthesis - Kinematics synthesis - Graphical methods of dimensional synthesis for four bar mechanism - Introduction to motion and path generation.

Unit 4 Cam and follower mechanism.

Classification of cams and followers - Terminology and definitions - Displacement diagrams - Uniform velocity, parabolic, simple harmonic, and cycloidal motions - Derivatives of follower motion-specified contour, cams-circular and tangents cams - Pressure angle and undercutting - Sizing of cams, graphical and analytical disc cam profile synthesis for roller and flat face followers.

Unit 5 Gears and gear trains.

Involute and cycloidal gear profiles - Gear parameters - Fundamental law of gearing and conjugate action, spur gear, arc and path of contact - Contact ratio and interference / undercutting - Helical gears - Simple, compound and epicyclic gear train kinematics.

Textbooks / References.

1) S. S. Ratan, Theory of Machines, 1e, McGraw Hill Education India Private Limited, 2017.
2) Ashok G. Ambekar, Mechanism and Machine Theory, 1e, PHI Learning, 2007.
3) Thomas Bevan, Theory of Machines, 3e, Pearson Education India, 2009.
4) W. L. Cleghorn and Nikolai Dechev, Mechanisms of Machines, 2e, Oxford University Press, 2014.
5) A. Ghosh and A. K. Mallick, Theory of Mechanism and Machines, Affiliated East-West Pvt. Ltd, New Delhi.

Course code	**MEM132 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Manufacturing Technology**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5 / 6**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Importance of manufacturing - Selection of materials and manufacturing processes - Planning for manufacturing - Global competitiveness of manufacturing - Fundamentals of materials, their behaviour and manufacturing properties.

Unit 2 Metal casting processes.

Introduction to patterns and foundry process - Types of sands - Sand binders and different additives - Sand testing - Melting furnaces for ferrous and non-ferrous metals such as Cupola, Induction furnace, Arc furnace and Resistance furnace - Introduction to the sand casting process - Pattern design - Green sand moulding - Microstructure in castings - Cooling curves, heat transfer and solidification time - Gating design - Fluidity - Other casting processes: Die casting, squeeze casting, centrifugal casting, investment casting and continuous casting - Casting defects.

Unit 3 Metal forming processes.

Introduction to forming processes - Basic structure of metals and heat treatment - Plastic deformation and yield criteria - Dependence of stress-strain diagram on strain rate and temperature - Idealized stress-strain curves - Flow curve - Hot and cold working of metals - Conventional forming processes: rolling, forging, extrusion and wire drawing - Slab analysis for force estimation - Forming dies and tools - Effect of friction and lubrication - Forming defects - Nonconventional forming processes: electromagnetic, hydraulic and explosive forming - Superplastic deformation.

Unit 4 Sheet metal processes.

Introduction and classification - Shearing processes - Bending processes - Stretch forming - Deep drawing - Spinning - Sheet metal formability - High velocity and high energy rate forming.

Unit 5 Welding processes.

Introduction - Types of joints - Weld specifications - Symbols - Conventional fusion welding processes: gas welding, shielded metal arc welding, gas metal arc welding, submerged arc welding and gas tungsten arc welding - Physics of arc welding - Metal transfer in arc welding - Power sources - Heat flow in welds - Welding thermal cycle - TT curves - Generalized heat flow equation - Other welding processes: solid-state welding and high energy density beam welding processes - Design of weld joints - Weld defects - Weld quality and destructive and non-destructive testing.

Unit 6 Introduction to machine tools.

Classification and specifications of machine tools - Functional principles of machine tools - Conventional machine tools: features and characteristics - Centre lathe: constructional features, specification and operations - Taper turning - Thread cutting - Special attachments - Machining time and power estimation - Capstan and turret lathes - Tool layout - Automatic lathes: semi-automatic, single spindle, Swiss type and automatic screw type - Multi-spindle automats - Reciprocating machine tools: shaper, planer and slotter - Types and operations - Hole making: drilling, reaming, boring and tapping - Milling: types of milling cutter - attachments - Introduction to finishing processes.

Textbooks / References.

1) A. Ghosh and A. K. Mallik, Manufacturing Science, Wiley Eastern, 2010.
2) P. N. Rao, Manufacturing Technology: Foundry, Forming and Welding, Tata McGraw Hill, 2017.

3) Roy A. Lindberg, Processes and Materials of Manufacture, 4e, PHI/Pearson Education.
4) M. P. Groover, Introduction to Manufacturing Processes, Wiley, 2011.
5) S. Kalpakjian and S. R. Schmid, Manufacturing Processes for Engineering Materials, Pearson Education, 6th Edition, 2016.
6) H. A. Youssef, H. A. El-Hofy and M. H. Ahmed, Manufacturing Technology: Materials, Processes and Equipment, CRC Press.
7) HMT, Production Technology, Tata McGraw-Hill, New Delhi.

Course code	**MEM133 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Thermal Engineering**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5 / 6**
Pre-requisites if any	**MEM122**				

Unit 1.

Fuel and Combustion - Introduction to solid, liquid and gaseous fuels - Stoichiometry - Exhaust gas analysis - First law analysis of combustion reactions - Heat calculations using enthalpy tables - Adiabatic flame temperature.

Unit 2.

Vapor power cycles: Rankine cycle with superheat, reheat and regeneration - Energy analysis - Super-critical and ultra-super-critical Rankine cycles - Analysis of steam turbines - Velocity and pressure compounding of steam turbine.

Unit 3.

Gas power cycles - Classification of IC engines - Working of SI and CI engines - Two and four stroke engines - Air standard Otto, Diesel and Dual cycles - Brayton cycle - Effect of reheat, regeneration and intercooling -Combined gas and vapor power cycles.

Unit 4.

Compressible flow - Basics of compressible flow - Stagnation properties - Isentropic flow of a perfect gas through a nozzle - Chocked, subsonic and supersonic flows - Normal shocks - Use of ideal gas tables for isentropic flow and normal shock flow - Flow of steam and refrigerant through nozzle.

Unit 5.

Refrigeration and air conditioning systems - Vapour compression refrigeration cycle - Effect of super heat and sub cooling - Psychrometric processes - Properties of dry and wet air - Use of psychrometric chart - Processes involving heating/cooling and humidification / dehumidification - Dew point - Working principles and concept of RSHF, GSHF and ESHFC.

Module 6.

Reciprocating compressors - Staging of reciprocating compressors - Optimal stage pressure ratio - Effect of intercooling - Minimum work for multistage reciprocating compressors.

Textbooks / References.

1) P. K. Nag, Basic and Applied Thermodynamics, 2e, Tata McGraw-Hill, 2009.
2) P. L. Ballaney, Thermal Engineering, Khanna Publishers, 2005.
3) R. S. Khurmi and J. K. Gupta, Thermal Engineering, S Chand and Co., 2006.
4) M. J. Moran, H. N. Shapiro, D. D. Boettner and M. B. Bailey, Principles of Engineering Thermodynamics, 8e, Wiley, New Delhi, 2015.
5) H. I. H. Saravanamuttoo, G. F. C. Rogers and H. Cohen, Gas Turbine Theory, 5e, Pearson, New Delhi, 2003.
6) C. P. Arora, Refrigeration and Air Conditioning, Tata McGraw Hill, 1994.

Course code / Category	**MEM141 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Dynamics of Machines**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7 / 8**
Pre-requisites if any	**-----**				

Unit 1 Mechanism force analysis.

Piston effort - Crank pin effort - Crank effort - Dynamic force analysis in slider crank mechanism - Inertia force and torque in reciprocating engines - Dynamically equivalent systems - Turning moment diagram - Flywheels.

Unit 2 Friction and brakes.

Friction: types, angle of repose and angle friction - Axial force and friction movement in pivots and collars - Friction between lubricated surfaces - Friction clutches - Brakes: band and block brakes - Internal expanding shoe brakes - Effect of braking - Braking of vehicles - Types of dynamometers.

Unit 3 Governors and gyroscopes.

Governors: types of governors - stability and isochronism - sensitiveness - hunting - Governor effort and power - Effect of friction - Gyroscopes: gyroscopic effect on aeroplanes and naval ships - Stability of an automobile and two-wheelers - Rigid disk fixed at an angle to the rotating shaft.

Unit 4 Balancing.

Static balancing - Dynamic balancing - Balancing of reciprocating masses - Balancing of locomotives - Balancing of 2-stroke and 4-stroke inline engines - Balancing of machines.

Unit 5 Vibrations.

Free and forced vibration of single-degree-of-freedom systems - Vibration isolation - Effect of damping - Resonance - Critical speeds of shafts.

Textbooks / References.

1) S. S. Rattan, Theory of Machines, 1e, McGraw Hill Education India Private Limited, 2017.
2) Ashok G. Ambekar, Mechanism and Machine Theory, 1e, PHI Learning, 2007.
3) A Ghosh, Theory of Mechanisms Machines, 1e, East West, 2008.
4) Thomas Bevan, Theory of Machines, 3e, Pearson Education India, 2009.
5) R. L. Norton, Kinematics and Dynamics of Machinery, 1e, McGraw Hill Education, 2017.

Course code / Category	**MEM142 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Design of Machine Elements**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**7 / 8**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Design considerations and philosophy - Design procedure - Stress concentration - Factor of safety - Review of failure theories for static and dynamic loading (including fatigue failure).

Unit 2 Design of joints.

Design of riveted joints, threaded fasteners, pre-loaded bolts, and welded joints.

Unit 3 Design of shafts and couplings.

Design of flange coupling - Keys - Design of solid and hollow shafts under combined bending torsion and axial load static and fatigue loadings.

Unit 4 Design of bearings and transmission elements.

Analysis and design of sliding and rolling contact bearings - Design of flat belt, V-belt, and chain drives - Design of transmission elements: spur, helical, and bevel gear using beam strength and wear strength.

Unit 5 Design of springs, clutches, and brakes.

Design of helical compression, tension, torsional and leaf springs - Design of a single plate, multiple friction clutches, band brakes and shoe brakes.

Textbooks / References.

1) V. B. Bhandari, Design of Machine Elements, McGraw-Hill International.
2) D. Deutschman, W. J. Michels and C. E. Wilson, Machine Design Theory and Practice, Macmillan, 1992.
3) M. F. Spotts, Design of Machine Elements, Prentice-Hall India, 1994.
4) R. L. Norton, Mechanical Design - An Integrated Approach, Prentice Hall, 1998

Course code / Category	**MEM143 / Multidisciplinary Minor in Mechanical Engineering**				
Course title	**Heat and Mass Transfer**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7 / 8**
Pre-requisites if any	**MEM122**				

Unit 1 Fundamentals.

Modes of heat transfer - Effect of temperature on thermal conductivity of different solids, liquids and gases - Conduction: Fourier's law - one dimensional steady state heat conduction in simple geometries - Plane wall-cylinder and sphere-composite walls - Critical thickness of insulation - Thermal contact resistance - Heat generation in plane wall, cylinder and sphere - Transient conduction - Lumped heat capacity analysis - Biot number.

Unit 2 Convection.

Boundary layer theory - Newton's law of cooling - Conservation equations of mass, momentum and energy for laminar flow over a flat plate and turbulent flow over a flat plate - Flow over cylinders - Internal flows: natural convection - Blasius solution for laminar boundary layer.

Unit 3 Radiation.

Thermal radiation - Laws of radiation - Black and grey bodies - Shape factor - radiation exchange between surfaces - Radiation shields.

Unit 4 Heat exchangers.

Classification - Heat exchanger analysis - LMTD for parallel and counter flow exchangers - Condenser and evaporator - Overall heat transfer coefficient - Fouling factor - Correction factors for multi pass arrangement - Effectiveness and number of transfer unit for parallel and counter flow heat exchangers.

Unit 5.

Heat transfer from extended surfaces: types of fins, heat flow through rectangular fin and infinitely long fin - Fins insulated at the tip and fins losing heat at the tip - Efficiency and effectiveness of fins.

Unit 6.

Boiling and condensation - Pool boiling regimes and correlations - Nusselt's theory - Film-wise and drop-wise condensation - Condensation over surfaces.

Textbooks / References.

1) P. K. Nag, Heat and Mass Transfer, 2e, Tata McGraw-Hill, 2007.
2) T. L. Bergman, A. S. Lavine, F. P. Incropera and D. P. Dewitt, Fundamentals of Heat and Mass Transfer, 7e, John Wiley & Sons, 2011.
3) J. P. Holman, Heat Transfer, 10e, Tata McGraw-Hill, 2010.
4) M. N. Ozisik, Heat Transfer - A Basic Approach, McGraw-Hill, 1985.
5) Y. A. Cengel, Heat Transfer - A Practical Approach, 2e, McGraw-Hill, 2002.
6) R. C. Sachedva, Fundamentals of Heat and Mass Transfer, 4e, New Age International, 2012.

SYLLABUS FOR MULTI-DISCIPLINARY MINOR (MANUFACTURING ENGINEERING)

Course code / Category	**MEM221 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Engineering Mechanics**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**4**
Pre-requisites if any	**-----**				

Unit 1.

Introduction - Basic concepts of force, moment and couple - Equilibrium of coplanar force systems - Friction.

Unit 2.

Internal forces in members of Trusses and (Method of joints and Method of Sections) and Analysis of Frames (Method of Members).

Unit 3.

Properties of surfaces: centroid and moment of inertia of plane figures - Polar moment of inertia - Product of inertia - Principal axes - Principle of virtual work and applications.

Unit 4.

Kinetics of rectilinear motion and curvilinear motion of a particle - D'Alembert's principle - Linear momentum and impulse - Angular momentum - Work and energy - Impact.

Unit 5.

Rigid body motion: kinematics of rotation equation of motion of a rotating rigid body - Compound pendulum - Energy equations for rotating bodies - Plane motion: kinematics of plane motions - instantaneous centre of rotation - equations of plane motion of a rigid body and energy equations for plane motion - D'Alembert's principle for rotation and plane motion.

Textbooks / References.

1) R. C. Hibbeler, Engineering Mechanics - Statics, 14e, Prentice Hall.
2) R. C. Hibbeler, Engineering Mechanics - Dynamics, 14e, Prentice Hall.
3) F. P. Beer, E. R. Johnston, et al., Vector Mechanics for Engineers: Statics and Dynamics, 12e, McGraw-Hill Co.
4) S. Timoshenko, D. H. Young, J. V. Rao and Sukumar Pati, Engineering Mechanics, McGraw-Hill Co.
5) J. L. Meriam and L. G. Kraige, Engineering Mechanics - Statics, 8e, John Wiley and Sons.
6) J. L. Meriam and L. G. Kraige, Engineering Mechanics - Dynamics, 8e, John Wiley and Sons.
7) Bedford and W. Fowler, Engineering Mechanics - Statics and Dynamics, Pearson Publications.

Course code	**MEM222 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Engineering Materials**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**4**
Pre-requisites if any	**-----**				

Unit 1 Crystallography and material characterization.

Crystalline and non-crystalline solids - Bonding in solids - Crystallography: basics, atomic radius, coordination number and atomic packing factor of BCC, FCC and HCP - Miller's indices - Polymorphism and allotropy - Solid solutions and intermetallic compounds - Laws of diffusion - Imperfection in solids: point defect, line defect, planar defect and volume defects - Material characterization: X-ray diffraction (XRD) - Bragg's law of diffraction - Scanning electron microscopy (SEM) - Transmission electron microscopy (TEM).

Unit 2 Phase diagrams, Ferrous and Non-ferrous alloys.

Phase diagrams: solidification of metals - phase rules - construction of phase diagram - binary isomorphous system - cooling curve of pure iron - Fe-Fe_3C equilibrium diagram - Eutectoid and Peritectic reactions - Ferrous alloys: classification of ferrous alloys - influence of alloying elements - Designation systems - Types of steels and cast iron - Typical compositions, properties and applications of ferrous alloys - Non-ferrous alloys: typical compositions, properties and applications of Aluminium, Copper, Titanium and Nickel and their alloys.

Unit 3 Strengthening mechanisms and heat treatment processes.

Strengthening mechanisms: dislocation and plastic deformation - mechanisms of strengthening in metals - Recovery, recrystallization, and grain growth - Dispersion strengthening and precipitation hardening - Heat treatment of steel: TTT diagram and CCT diagram - Heat treatment processes: annealing, normalizing, tempering and quenching - Jominy quench test - Case hardening: carburizing, nitriding, cyaniding, carbonitriding, flame hardening and induction hardening.

Unit 4 Mechanical properties of materials, failures and testing.

Mechanical properties: engineering material and their properties - compressive, shear and torsional deformation - Fracture and failure of materials: various types of fracture - brittle to ductile from low temperature to high temperature - Defects in materials - Deformation mechanisms - Failure mechanisms and influencing factors of ductile and brittle failure - Fatigue failure, creep failure and impact failure - Mechanical testing: universal testing machine - Stress–strain curve for ductile and brittle material - Hardness testing: Rockwell, Brinell's and Vicker's hardness tests - Impact testing: Charpy impact test and Izod impact test.

Unit 5 Polymer structures and composites.

Polymer structures: melting and glass transition temperatures - Polymer types - Forming techniques for plastics - Fabrication of elastomers, fibres and films - Composites: particle-reinforced composites, fibre-reinforced composites and structural composites.

Textbooks / References.

1) S. H. Avner, Introduction to Physical Metallurgy, 2e, Tata McGraw Hill Education Pvt. Ltd., 2009.
2) W. D. Callister Jr. and D. G. Rethwisch, Materials Science and Engineering: An Introduction, 9e, John Wiley & Sons Inc., 2013.
3) J. F. Shackelford and M. K. Muralidhara, Introduction to Materials Science for Engineers, 6e, Pearson Education, 2006.
4) P. R. Khangaonkar, An Introduction to Material Characterization, 1e, Penram International Publishing Pvt. Ltd., 2013.
5) M. F. Ashby, Materials Selection in Mechanical Design, 5e, Butterworth-Heinemann, 2017.
6) O. P. Khanna, A Textbook of Material Science & Metallurgy, 2e, Dhanpat Rai Publications, 2014.
7) K. G. Budinski and M. K. Budinski, Engineering Materials: Properties and Selection, 9e, Pearson, 2009.

Course code / Category	**MEM231 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Computer Aided Design and Manufacture**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5 / 6**
Pre-requisites if any	**-----**				

Unit 1 Introduction to computer aided design (CAD)

Need and scope of CAD - Hardware: CAD workstation, memory types, input devices, display devices, hard-copy devices, hardware integration and networking - Software: graphics standards - Database structures for graphic modelling - Database coordinate systems - Software modules.

Unit 2 Computer graphics.

Transformations: translation, scaling, rotation, reflection and concatenation - Orthographic and perspective projections of geometric models - Scan conversion algorithms: DDA algorithm, Bresenham's line algorithm, Midpoint circle algorithm and ellipse generating algorithm - Visual realism: back face removal, Z-buffer, depth sort and ray tracing algorithms.

Unit 3 Geometric modelling.

Geometric models - Requirements of geometric modelling - Types of models and their limitations and applications - Wireframe models: wireframe entities, curve representation methods, line, circle, ellipse, parabola, hyperbola, Hermite cubic spline curve, Bezier curve, B-spline curve and rational curve - Surface models: surface entities and their representation methods - Plane surface, ruled surface, surface of revolution, tabulated cylinder, Bezier surface, B-spline surface and Coons patch - Solid models: solid entities, regularized set operations, half-space, B-Rep and constructive solid geometry (CSG).

Unit 4 Elements of numerical control (NC).

NC systems: basic components - advantages and disadvantages - NC machine tools - Economics of NC - Some mathematical elements for NC - Computer control in NC - CNC - DNC - Adaptive control - NC system devices such as stepper motors, encoders, etc. - Interpolators: hardware and software interpolation - NC machining: point-to-point and continuous path machining - Part programming: G and M Codes, and APT programming.

Unit 5 CAD/CAM integration.

Role of process planning in CAD/CAM integration - Computer-aided Process Planning (CAPP): development, benefits, model and architecture - CAPP approaches (variant, generative and hybrid process planning systems) - CAPP systems: CAM-I, D-CLASS and CMPP - criteria for selecting a CAPP system - CAD/CAM data exchange: shape-based format - product-based format - standard for exchange of product model data - drawing exchange format - dimensional measurement interface specification - Initial Graphics Exchange Specification (IGES) standard - STL files.

Textbooks / References.

1) P. N. Rao, CAD/CAM: Principles and Applications, 3e, McGraw Hill Education, 2017.
2) M. P. Groover and E. W. Zimmers, Jr., CAD/CAM: Computer-Aided Design and Manufacturing, PTR Prentice Hall, New Jersey, 1984.
3) I. Zeid and R. Sivasubramanian, CAD/CAM: Theory and Practice, 2e, McGraw Hill Education, 2009.
4) I. Zeid, Mastering CAD/CAM, Special Indian Edition, Tata McGraw Hill Co., 2007.
5) Donald D. Hearn and M. Pauline Baker, Computer Graphics, C Version, 2e, Pearson Education India, 2002.
6) P. Radhakrishnan, S. Subramanyan and V. Raju, CAD/CAM/CIM, 3e, New Age International (P) Ltd., 2008.

Course code	**MEM232 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Manufacturing Technology I**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**0**	**5 / 6**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Importance of manufacturing - Selection of materials and manufacturing processes - Planning for manufacturing - Global competitiveness of manufacturing - Fundamentals of materials, their behaviour and manufacturing properties.

Unit 2 Metal casting processes.

Introduction to patterns and foundry process - Types of sands - Sand binders and different additives - Sand testing - Melting furnaces for ferrous and non-ferrous metals such as Cupola, Induction furnace, Arc furnace and Resistance furnace - Introduction to the sand casting process - Pattern design - Green sand moulding - Microstructure in castings - Cooling curves, heat transfer and solidification time - Gating design - Fluidity - Other casting processes: Die casting, squeeze casting, centrifugal casting, investment casting and continuous casting - Casting defects.

Unit 3 Metal forming processes.

Introduction to forming processes - Basic structure of metals and heat treatment - Plastic deformation and yield criteria - Dependence of stress-strain diagram on strain rate and temperature - Idealized stress-strain curves - Flow curve - Hot and cold working of metals - Conventional forming processes: rolling, forging, extrusion and wire drawing - Slab analysis for force estimation - Forming dies and tools - Effect of friction and lubrication - Forming defects - Nonconventional forming processes: electromagnetic, hydraulic and explosive forming - Superplastic deformation.

Unit 4 Sheet metal processes.

Introduction and classification - Shearing processes - Bending processes - Stretch forming - Deep drawing - Spinning - Sheet metal formability - High velocity and high energy rate forming.

Unit 5 Welding processes.

Introduction - Types of joints - Weld specifications - Symbols - Conventional fusion welding processes: gas welding, shielded metal arc welding, gas metal arc welding, submerged arc welding and gas tungsten arc welding - Physics of arc welding - Metal transfer in arc welding - Power sources - Heat flow in welds - Welding thermal cycle - TT curves - Generalized heat flow equation - Other welding processes: solid-state welding and high energy density beam welding processes - Design of weld joints - Weld defects - Weld quality and destructive and non-destructive testing.

Unit 6 Polymer fabrication methods.

Injection moulding - Compression moulding - Transfer moulding - Thermoforming - Composite fabrication methods, viz., compression moulding, vacuum moulding, prepreg fabrication and filament winding - Powder metallurgy and its applications.

Textbooks / References.

1) A. Ghosh and A. K. Mallik, Manufacturing Science, Wiley Eastern, 2010.
2) P. N. Rao, Manufacturing Technology: Foundry, Forming and Welding, Tata McGraw Hill, 2017.
3) M. P. Groover, Introduction to Manufacturing Processes, Wiley, 2011.
4) S. Kalpakjian and S. R. Schmid, Manufacturing Processes for Engineering Materials, Pearson Education, 6th Edition, 2016.
5) H. A. Youssef, H. A. El-Hofy and M. H. Ahmed, Manufacturing Technology: Materials, Processes and Equipment, CRC Press.

Course code / Category	**MEM233 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Manufacturing Technology II**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**5 / 6**
Pre-requisites if any	**MEM231**				

Unit 1 Introduction to metal cutting and machine tools.

Orthogonal and oblique metal cutting - Forces in machining - Merchant's analysis of metal cutting process - Types of chips and mechanism of chip formation - Thermal aspects: sources of heat generation - effects of temperature - cutting temperature determination using analytical / experimental methods - methods of controlling cutting temperature - Single-point and multi-point cutting tools: tool geometry - significance of various angles of single point turning tools - ASA system - Orthogonal Rake System (ORS) - Normal Rake System (NRS) - Conversions between ASA and ORS - Cutting tool materials: desirable properties of tool materials - Indexable inserts and coated tools - Cutting fluids: functions, characteristics, types and their selection - Tool wear, tool life, surface finish and machinability.

Unit 2 Machine tools.

Classification and specifications of machine tools - Functional principles of machine tools - Conventional machine tools: features and characteristics - Machine tool power drives.

Unit 3 Turning machines.

Centre lathe: constructional features, specification and operations - Taper turning - Thread cutting - Special attachments - Machining time and power estimation - Capstan and turret lathes - Tool layout - Automatic lathes: semi-automatic, single spindle, Swiss type and automatic screw type - Multi-spindle automats.

Unit 4 Reciprocating, milling and gear cutting machines.

Reciprocating machine tools: shaper, planer and slotter - Types and operations - Hole making: drilling, reaming, boring and tapping - Milling: types of milling cutter - attachments - machining time calculations - Gear cutting, forming and generation - Gear milling, gear hobbing and gear shaping.

Unit 5 Abrasive processes and broaching.

Grinding wheel: specifications and selection - Types of grinding: cylindrical grinding, surface grinding, centreless grinding and internal grinding - Micro finishing methods - Typical applications - Concepts of surface integrity - Broaching machines - Broach construction - Push, pull, surface and continuous broaching machines.

Unit 6 Advanced machining techniques.

Overview of non-conventional machining processes - Working principles of common non-conventional machining processes - Micromachining - Wafer machining.

Textbooks / References.

1) A. Ghosh and A. K. Mallik, Manufacturing Science, Wiley Eastern.
2) Roy A. Lindberg, Processes and Materials of Manufacture, 4e, PHI/Pearson Education.
3) P. N. Rao, Manufacturing Technology: Metal Cutting and Machine Tools, Tata McGraw-Hill, New Delhi.
4) Richerd R. Kibbe, John E. Neely, Roland O. Merges and Warren J. White, Machine Tool Practices, Prentice Hall of India.
5) HMT, Production Technology, Tata McGraw-Hill, New Delhi.
6) S. K. Hajra Choudhury and A. K. Hajra Choudhury, Elements of Workshop Technology, Vol. II, Media Promoters and Publishers.
7) Geofrey Boothroyd, Fundamentals of Metal Machining and Machine Tools, McGraw-Hill Publishing Co.
8) P. C. Pandey and H. S. Shan, Modern Machining Processes, Tata McGraw-Hill Publishing Co.
9) B. L. Juneja and G. S. Sekhon, Fundamentals of Metal Cutting and Machine Tools, New Age International Publishers.

Course code / Category	**MEM241 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Engineering Metrology**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7 / 8**
Pre-requisites if any	**-----**				

Unit 1 Introduction.

Principles of dimensional and form measurements - Basic standards of length and angle - Industrial standards - Errors in measurement - Limits, fits and tolerances: basics of limits, fits and tolerances - terminologies used - maximum and least material conditions - disposition of tolerances and deviations - Limit gauging: types of gauges - Taylor's principle - design of gauges.

Unit 2 Linear and angular measurements.

Linear measurements: principle of alignment - design and operational considerations of linear measuring instruments - description, merits and demerits of some mechanical, pneumatic, electrical, electronic and optical comparators - Angular measurements and circular division: angle gauges - sine bar - measurement of taper gauges and bores - precision level - autocollimator - angle Dekkor - alignment telescope - circular division.

Unit 3 Geometric dimensioning and tolerancing.

Introduction to geometric dimensioning and tolerancing - Measurement and evaluation of form tolerances.

Unit 4 Metrology of gears and screw threads.

Metrology of gears: measurement of gear tooth thickness using constant chord and base tangent methods - testing of involute form - gear pitch measurements - Metrology of screw threads: measurement of major and minor diameters and thread forms - pitch errors in screw threads - measurement of simple effective diameter using wire methods - best size wire - thread gauges.

Unit 5 Surface roughness measurements and machine tools metrology.

Surface roughness measurements: basics - various 2D parameters - surface measuring instruments - analysis and evaluation of roughness parameters - Machine tools metrology: alignment and squareness tests.

Unit 6 Interferometry and computers in metrology.

Interferometry: types of light sources and interferometers - optical flats - some typical interferometers with their application to flatness testing, calibration of height standards, etc. - Computers in metrology: applications of computers to metrological calculations and dedicated measuring instruments - coordinate measuring machines.

Textbooks / References.

1) ASTME, Handbook of Industrial Metrology, Prentice-Hall Inc., Englewood Cliffs.
2) J. A. Bosch, Coordinate Measuring Machines and Systems, Marcel Dekker, Inc.
3) J. F. W. Galyer, and C. R. Shotbolt, Metrology for Engineers, Cassell Publishers, London.
4) I. C. Gupta, A Textbook of Engineering Metrology, Dhanpat Rai Publications, New Delhi.
5) K. J. Hume, Engineering Metrology, Kalyani Publishers, Ludhiana.
6) J. D. Meadows, Geometric Dimensioning and Tolerancing, Marcel Dekker, Inc., New York.
7) D. J. Whitehouse, Surfaces and their Measurement, Hermes Penton Science, London.

Course code / Category	**MEM242 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Dies, Moulds & Tools Engineering**				
Scheme and credits	L	T	P	C	Semester
	3	**0**	**0**	**3**	**7 / 8**
Pre-requisites if any	**MES105 / MEC205 / MEC308**				

Unit 1 Stamping die design.

Press tool: theory of sheet metal behaviour - Metal stamping dies: construction, assembly and function - Blanking and piercing operations - Blank calculation and flat layout - Punching force calculation - Springs: their design and calculations - Material and surface finish - Bending and forming operations.

Unit 2 Forging die design.

Basic principles of metal flow - Die material and their alternatives - Parting line and its position - Balancing of parting lines, draft angles, rib, web, bosses, corner fillet and other radii - Flash land, gutter and their design consideration - Die design principle: general steps, fuller design, rolling or edging design, bender design, blocker design, die layout, centre of pressure and dowel position - die register or die lock - Dies for solid upsetting - Grain flow: factors contributing to grain flow - control of grain flow - Metal flow in impression dies - Factors influencing die filling - Forgeability.

Unit 3 Injection moulding.

General mould construction: basic terminology - mould cavities and cores - bolsters - Ejection: ejector grid - ejector plate assembly - ejection techniques - ejection from fixed half - sprue pullers - Feed system - runner and its shape - gates and its types - parting surface and its types - venting - mould cooling - integer type and insert bolster - water connections and seals - splits-sliding and angled lift - design features of side cores and side cavities and their types - internal undercuts - form pin, split cores, side cores and stripping of internal undercuts - Mould for threaded components: internal and external - Multi daylight mould - Underfeed moulds and triple daylight moulds - Runner-less mould: nozzle type - hot runner unit - insulated runner - hot runner plate - Calculation of number of impression.

Unit 4 Jigs and fixtures.

Concepts - Differences and benefits of jigs and fixtures - Jigs: types - sketches with nomenclature - working and applications - Fixtures: types - sketches with nomenclature - working and applications of fixtures - Steps to design jigs and fixture for given simple component - Geometric dimensioning and tolerancing (GD&T): introduction - datum reference plane - Taylor's principle - GD&T symbols and meanings - Material conditions: maximum material condition - least material condition - Regardless of feature size.

Unit 5 Cutting tools and accessories.

Cutting tool materials: types - composition, properties and applications - Carbide inserts: types, ISO designation and applications - Re-sharpening methods - Gear hob - Tool holders for turning and milling - Tool holding and tool mounting systems for conventional milling and drilling machine tools - Locating and clamping devices: concepts - meaning and definitions of location and clamping - use of locating and clamping principles in day-to-day supervision on shop floor - Degree of freedom: concept and importance - Principle of location - Locators: types - sketches with nomenclature - working and applications - Fool proofing and ejecting - Clamping devices: types - sketches with nomenclature - design principles - working and applications.

Textbooks / References.

1) Eugene Ostergard, Advanced Die Design, National Tooling & Machining Association.
2) V. Boljanovic and J. R. Paquin, Die Design Fundamentals, 3e, Industrial Press Inc.
3) D. V. Rosato and D. V. Rosato, Plastic Processing Data Handbook, Van Nostrand Reinhold.
4) P. H. Joshi, Jigs & Fixtures, 11e, Tata McGraw-Hill Pub. Co. Ltd.
5) W. E. Boyes, Jigs, Fixtures & Gauges, SME, Michigan.

Course code / Category	**MEM243 / Multi-disciplinary Minor in Manufacturing Engineering**				
Course title	**Precision Manufacturing**				
Scheme and credits	L	T	P	C	Semester
	3	**1**	**0**	**4**	**7 / 8**
Pre-requisites if any	**-----**				

Unit 1 Concepts of accuracy.

Accuracy of machine tools - Spindle and displacement accuracies - Accuracies of NC systems - Numerical interpolation errors - Displacement measurement system and velocity lags.

Unit 2 Geometric Dimensioning and Tolerancing (GD&T).

Tolerance zone conversions - Surface, features and features of size, datum features - Datums - Oddly configured and curved surfaces as datum features - Equalizing datums - Datum feature of size representation - Form and orientation controls.

Unit 3 Processing systems.

Processing systems for nanometre accuracies - Mechanism of metal processing - Nano physical processing of atomic bit units - Nano chemical and electrochemical atomic bit processing.

Unit 4 Measuring systems.

In-process measurement of position of processing unit - Post-process and on-machine measurement of dimensional features - Surface mechanical and optical measuring systems - Nano positioning systems - Guide systems for moving elements - Servo control systems for tool positioning - Computer aided digital and ultra-precision position control.

Unit 5 Applications and future trends.

Applications and future trends in nano technology - Nano-grating systems - Nanolithography, photolithography and electron beam lithography - Machining of soft metals: diamond turning - mirror grinding of ceramics - nano-mechanical parts and micro-machines.

Textbooks / References.

1) P. S. Gill, Geometric Dimensioning and Tolerancing, S. K. Kataria & Sons, New Delhi.
2) J. D. Meadows, Geometric Dimensioning and Tolerancing, Marcel Dekker, Inc., New York.
3) R. L. Murty, Precision Engineering in Manufacturing, New Age International (P) Limited, New Delhi.
4) Norio Taniguchi, Nanotechnology, Oxford University Press, New Delhi.
5) Relevant Indian and International Standards.