ACADEMIC REGULATIONS (R22PG)

COURSE STRUCTURE AND DETAILED SYLLABUS

For

M.Tech.- Regular Two Year Post Graduate Degree Programe

(For the batches admitted from 2022-23)

MASTER OF TECHNOLOGY
IN
RENEWABLE ENERGY

KANDULA SRINIVASA REDDY MEMORIAL COLLEGE OF ENGINEERING

(UGC-Autonomous)

Kadapa 516005, A.P

(Approved by AICTE, Affiliated to JNTUA, Ananthapuramu, Accredited by NAAC)

(An ISO 14001:2004 & 9001: 2015 Certified Institution)

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ABOUT THE COLLEGE

The college owes its existence to the keen interest of Late Kandula Obul Reddy to develop technical education in Rayalaseema region of Andhra Pradesh. With a view to translating his noble ideal of imparting technical education into reality, a Technical Training Institute at Vempalli, Kadapa District was started in 1979 under the aegis of Sri Kandula Obul Reddy charities. It is in the year 1980 that K.S.R.M. College of Engineering was established to perpetuate the memory of Late Sri. Srinivasa Reddy, youngest son of Late Sri Obul Reddy. Sri Srinivasa Reddy, a brilliantstudent of III year Mechanical Engineering at Delhi College of Engineering, New Delhi, met with his untimely death in a scooter accident on 18th Oct, 1979. The college was formally inaugurated on 14 November 1980 by Sri T. Anjaiah, the Chief Minister of Andhra Pradesh and it started functioning from the academic year 1980-81.

The college had its modest beginnings in 1980 with an intake of 160 students with core branches "Civil, Electrical & Electronics, Electronics & Communications and Mechanical Engineering. Keeping in view the latest trends, priorities and relevance in Engineering and Technology, the Board of Management decided to start Computer Science and Engineering in 1990 commemorating the decennial year of the college. With the conserted efforts of the Management and the Successive Principals, the departments have been strengthened year after year and the intake has steadily been increased to 1080 by the year 2014. Furthering its sphere of activity, the college started post graduate programme in CAD/CAM (ME), Geo-technical Engineering (CE) in the year 2004, Power Systems (EEE) & Computer Science and Engineering (CSE) during 2010-11 and Digital Electronics and Communication Systems (ECE) in 2011-12 respectively. The branches have constantly been strengthened by increasing the intake from time to time. This reflects one aspect of the progress and development of the college.

The College campus is located 7 K.M. away from Kadapa town on Kadapa to Pulivendula Highway in a calm and salubrious area of 35 acres. The College is set in a serene environment with lush greenery and fresh air. Four multi-storeyed RCC structures measuring 26,700 sqm provide accommodation for the departments. The College has dedicated electric power feeder and 250 KVA substation. Other capital resources include transport vehicles and four hostels. Excellent Bus facilities exist from Kadapa to Hyderabad, Vijayawada, Nellore, Tirupati, Kurnool, Bangalore, Chittoor and Chennai.

VISION

To evolve as center of repute for providing quality academic programs amalgamated with creative learning and research excellence to produce graduates with leadership qualities, ethical and human values to serve the nation.

MISSION

M1: To provide high quality education with enriched curriculum blended with impactful teaching learning practices.

M2: To promote research, entrepreneurship and innovation through industry collaborations.

M3: To produce highly competent professional leaders for contributing to Socio-economic development of region and the nation.

ABOUT THE DEPARTMENT

The department was established in the year 1980. For the past 43 years, the department of Mechanical engineering takes its pride in educating and serving the mechanical engineering community and its stake

holders creating leaders in mechanical engineering and allied engineering fields. It has a strong back up of 25 faculty members comprising of 03 professors, 05 Associate professors and 17Assistant professors. Ever since the department has been established 39 batches have passed out with 90% students getting graduated. The department has undergone several improvements over the past five years like modernization of Faculty rooms, class rooms and labs, procuring latest CNC Milling, Robot and computer software's for the CAD/CAM lab, 100 MBPS dedicated internet connection for the department, technical training and know-how for non-teaching staff on CNC Lathe, CNC Milling machine etc.. The department has started a Mechanical Engineering Association whose main function is to conduct several programs that are required for the overall development of the student community. The programs generally conducted are Essay writing, Elocution, Debate, JAM and Dumb-C, Bull's Eye, Collage, Technical Quiz, Seminars and Pot-Pori. The Association activities also include invited guest lectures from eminent industrialists, professors from NIIT's and IIT's.

Industrial Connection: The department has to its credit corporate training programs, industrial consultancy, and funded projects from government bodies. These connections served to benefit students in the form of good placements, well-equipped laboratories and industrial exposure. The participation of industries in curriculum designing has helped the department to keep pace with fast-changing industrial needs. DST Sanctioned 1 crore & 10 lakhs rupees for I.C Engine project, and two minor projects. Our alumnus is one of the important stakeholders of the institution and we wish to expand the database of our alumni spread all over the globe.

VISION

To evolve as a department of high repute in Mechanical Engineering and allied fields through effective teaching, learning process and research activities, operating with a sense of professional and social responsibility.

MISSION

M1: To produce Mechanical Engineers with sound knowledge through quality teaching-learning process and well-designed curriculum.

M2: To induce critical thinking attitude and inculcate the use of modern tools through inter-disciplinary research and develop entrepreneurial skills through industry-institute interaction.

M3: To provide opportunities/platforms for students to nurture leadership abilities and ethical values.

PROGRAM EDUCATIONAL OBJECTIVES

PEO1: To apply engineering principles to develop products, processes or knowledge to solve mechanical and associated engineering problems for successful career in mechanical engineering and allied fields.

PEO2: To pursue higher education, research and development and engage in the process of life-long learning.

PEO3: To demonstrate leadership qualities, professional ethics, and communication skills and adapt current technologies to meet the societal requirements.

PROGRAM OUTCOMES

PO1 - Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2 - Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3 - Design/Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4 - 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.

PO5 - Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6 - 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 the professional engineering practice.

PO7 - 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.

PO8 - Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

PO9 - Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10 - Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11 - 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.

PO12 - 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.

PROGRAM SPECIFIC OUTCOMES

PSO1: To apply their knowledge in the domain of engineering mechanics, thermal and fluid sciences to solve engineering problems utilizing advanced technology.

PSO2: To successfully apply the principles of design, analysis and implementation of mechanical systems/processes which have been learned as a part of the curriculum.

PSO3: To Develop and implement new ideas on product design and development with the help of modern CAD/CAM tools, while ensuring best manufacturing practices.

K.S.R.M College of Engineering (Autonomous), KADAPA - 516005, AP
Regulations for PG Programs in Engineering (R22 PG)
(Effective from 2022-23)

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1.0 Nomenclature

1.1 *Academic Year*: Academic Term of, approximately, one-year duration that usually starts in June/July and ends in April/May next

1.2 *Semester*: Either of two Academic Terms that make up an Academic Year

1.3 *Major*: A specific field of study

1.4 *Minor*: An area outside of, or complementary to, a Major

1.5 *Subject*: An area of knowledge that is studied as part of a Course

1.6 *Core*: A subject that is mandatory for a Major course of study

1.7 *Elective*: A subject that is selected for study to suit one's individual needs

1.8 *Audit Subject*: A subject that is studied to meet certain requirements but has no credits assigned to it

1.9 *Humanities subjects*: Subjects that describe and interpret human achievements, problems and historical changes at individual and societal levels covering the disciplines of literature, history, and philosophy

1.10 *Social Sciences subjects*: Subjects that describe the mental and behavioural activities of individuals, groups, organizations, institutions, and nations covering the disciplines of anthropology, economics, linguistics, political science, and psychology

1.11 *Exam*: A test to measure one's progress, knowledge, or ability in a subject

1.12 *Credit*: A numerical weight given to a subject

1.13 *Grade*: A numerical or alphabetic designation measuring the level of achievement in an exam

1.14 *Attendance*: Physical presence of oneself in a classroom/laboratory for purpose of a scheduled academic instruction

1.15 *Course*: A series of subjects that constitute a Major field of study

1.16 *Branch*: Same as Course

1.17 *Program*: Same as Course

1.18 *Specialization*: Same as branch

1.19 *Degree*: An academic title conferred to honour distinguished achievement

2.0 Short Title and Application

2.1 These rules and regulations may be called as R22PG and come into force from Academic Year 2022-23 and exist until superseded by new regulations

2.2 These rules and regulations are applicable to all post graduate courses in engineering and technology leading to Master's Degree in Technology (M. Tech)

2.3 The Specializations offered, at present, are:

2.3.1 Geotechnical Engineering, Code - 12

2.3.2 Power Systems, Code - 07

2.3.3 Renewable Energy, Code - 99

2.3.4 Embedded Systems and VLSI, Code - 84

2.3.5 Artificial Intelligence and Data Science, Code - 98

2.4 The Institute may offer new Specializations in future to which these rules and regulations will be applicable.

3.0 Suspension and Amendment of Rules

3.1 Academic Council has the authority to suspend a rule temporarily.

3.2 Academic Council has the authority to amend a rule.

3.3 For affirmative action on any suspension or amendment of a rule, an affirmative vote of three-fifths of the members present and voting shall be required in Academic Council.

4.0 Requirements for Admission

4.1 At present, admissions into first semester of various Specializations are governed by Government and the Affiliating University. The eligibility criteria and procedure for admission are prescribed by Government and Affiliating University.

4.2 A student is not allowed change of Specialization after admission.

4.3 A student must fulfil medical standards required for admission.

4.4 The selected students are admitted into first semester after payment of the prescribed fees.

5.0 Structure of the M. Tech course

5.1 *Duration*: The duration of M. Tech degree course is four semesters

5.2 *Working Days*: Calendar for any semester shall be announced at least four weeks before its commencement. Minimum number of working days is 90 per semester.

5.3 *Curriculum*: Each Specialization shall have core, elective and audit subjects. The curriculum for each Specialization shall be approved by its corresponding Board of Studies and then by the Academic Council.

5.4 *Credits*: All subjects that are assessed for marks have credits assigned to them. The credits assigned to subjects shall be given in curriculum. The total number of credits for entire course is 70 for all Specializations. The distribution of total credits semester-wise is given in Table 1.

Table 1 Semester-wise Total Credits:

Semester	Total Credits
First Semester	18
Second Semester	18
Third Semester	18
Fourth Semester	16
Total for entire course	**70**

5.5 The curriculum and syllabus is given in Annexure-1 and Annexure-2 respectively

5.6 Responsibility and Advising: It is the responsibility of the student to understand and know the regulations and requirements to earn the degree. Each student admitted in to the degree programs is assigned to a Faculty Advisor who assists the student in designing an effective program of study. Students should consult

their Faculty Advisors for selection of electives and for general advice on academic program.

5.7 All subjects/courses offered for the M.Tech. degree programme are broadly classified as follows:

S.No.	Broad Course Classification	Course Category	Description
1.	Core Courses	Foundational & Professional Core Courses (PC)	Includes subjects related to the parent discipline/department/branch of Engineering
2.	Elective Courses	Professional Elective Courses (PE)	Includes elective subjects related to the parent discipline/department/ branch of Engineering
		Open ElectiveCourses (OE)	Elective subjects which include inter - disciplinary subjects or subjects in an area outside the parent discipline which are of importance in the context of special skill development
3.	Research	Research Methodology & IPR	To understand importance and process of creation of patents through research
		Technical Seminar	Ensures preparedness of students to undertake major projects/Dissertation, based on core contents related to specialization
		Co-curricular Activities	Attending conferences, scientific presentations and other scholarly activities
		Dissertation	M.Tech. Project or Major Project
4.	Audit Courses	Mandatory noncredit courses	Covering subjects of developing desired attitude among the learners is on the line of initiatives such as Unnat Bharat Abhiyan, Yoga, Value educationetc.

6.0 Registration and Enrolment

6.1 Prior to opening of each semester, every student shall register for all the credit-bearing and audit subjects listed in curriculum of the semester. Excepting first semester, the registration for a semester shall be done during a specified week after end examinations of previous semester. In first semester, the registration shall be done within six working days from date of opening. Recommendation of Faculty Advisor is needed for registration.

6.2 Late registration will be permitted with a fine, decided from time to time, up to six working days from the last date specified for registration.

6.3 A student will be eligible for registration for a semester if she or he i) is promoted to that semester, ii) has cleared all fees to the Institute, library and hostel of previous semester, and iii) is not disqualified for registration by a disciplinary action of the Institute.

6.4 A student will be enrolled and allowed to attend the classes on successful registration and payment of necessary fees to Institution, library, and hostel.

6.5 Registration and enrolment will be controlled by the Office of the Controller of Examinations.

7.0 Assessment Procedure – Internal Tests and End Examinations

7.1 Performance of students in all subjects is assessed continuously through internal assessment tests and an End examination.

7.2 Allocation of internal assessment and End examination marks.

7.2.1 For theory subjects, the allocation is 40 marks for internal assessment and 60 marks for End examination totalling 100 marks.

7.2.2 For laboratory/project work subjects, the allocation is 50 marks for internal assessment and 50 marks for End examination totalling 100 marks.

7.2.3 For mini-project/mini-project with seminar total 100 marks are allocated for internal assessment. There shall be no end examination for this mini-project.

7.2.4 For all audit subjects the allocation is 40 marks for internal assessment and no allocation for End examination.

7.3 Internal Assessment Examinations

7.3.1 Internal assessment means performance evaluation of students by faculty members who teach the subjects.

7.3.2 For theory subjects, including audit subjects, the internal assessment shall be done by midterm tests. For each subject, two midterm tests will be conducted for 40 marks each and the internal assessment mark is the better of two marks. If any student abstains for any midterm test, she or he will be awarded zero marks for that midterm test. There shall be no choice of questions in midterm tests.

7.3.3 For laboratory/practical subjects, the internal assessment will be based on regular laboratory work over full semester. The assessment will be done by the faculty concerned. The students shall be informed sufficiently early of the procedure to be followed for internal assessment.

7.3.4 There shall be a **Technical Seminar** during II semester for internal evaluation of 100 marks. A student under the supervision of a faculty member shall collect the literature on a topic and critically review the literature and submit it to the department in a report form and shall make an oral presentation before the Project Review Committee consisting of Head of the Department, two other senior faculty members and faculty guide of the concerned student. The student has to secure a minimum of 50% of marks, to be declared successful. If he fails to obtain the minimum marks, he has to reappear for the same as and when supplementary examinations areconducted. The Technical seminar shall be conducted anytime during the semester as per the convenience of the Project Review Committee and students. There shall be no external examination for Technical Seminar.

7.3.5 There shall be Mandatory **Audit courses** in I & II semesters for zero credits. There is no external examination for audit courses. However,

attendance shall be considered while calculating aggregate attendance and student shall be declared to have passed the mandatory course/audit course only when he/she secures 50% or more in the internal examinations. In case, the student fails, a re- examination shall be conducted for failed candidates for 40 marks.

7.3.6 For subjects like project-work and industrial training, the internal assessment will be done by a concerned Department Committee consisting of two senior faculty members and faculty guide of concerned student. The assessment procedure will be informed sufficiently early to the students.

7.4 End examinations

7.4.1 End examinations shall be conducted after completion of coursework in each semester.

7.4.2 The question papers for theory subjects shall be set by faculty members outside of the Institute. The external faculty members for question paper setting will be selected by the Principal.

7.4.3 Evaluation of answer scripts shall be done by faculty members from outside of the Institute selected by the Principal.

7.4.4 For laboratory subjects, end examination shall be conducted by a committee consisting of two internal examiners. One examiner shall be recommended by Head of Department of concerned Major, and the other examiner shall be appointed by the Principal.

7.4.5 For project work viva-voce, End examination shall be conducted by a committee consisting of one internal examiner, one external examiner, and the concerned guide of the student. Internal examiner shall be appointed by Head of Department of concerned Major, and the external examiner shall be appointed by the Principal.

7.4.6 If a student abstains from End examination of any subject, for any reason, she or he shall be awarded zero marks in that subject.

7.4.7 There is no end examination for audit subjects.

8.0 Method of Assigning Letter Grades and Grade Points

8.1 For all credit-bearing subjects, performance of a student in a subject is indicated by a letter grade that corresponds to absolute marks earned in that subject. Each letter grade is assigned a numeric Grade Point that is used to compute Grade Point Average on a scale of 0 to 10.

8.2 Performance of a student in both internal assessment and End examination will be considered for awarding grades for credit bearing subjects. Total marks earned in a subject is the sum of marks obtained in internal and End examinations in that subject.

8.3 Pass grade A+ to D+ is assigned to a subject based on total marks earned in that subject provided that a student earns at least i) 35% of marks in End examination marks and ii) 50% of marks in internal and End examination marks put together; otherwise fail grade F will be assigned to that subject.

8.4 Grade I will be assigned to a subject if a disciplinary action is pending and is not resolved before publication of results. Office of Controller of Examinations shall resolve the pending disciplinary action within six working days from the date of publication of results and change the grade to any of A+ to D+ or F.

8.5 Grade X will be assigned to a subject if a student abstains for End examination of that subject.

8.6 The absolute marks and corresponding letter grade and grade points are given in Table2

Table 2: Letter Grades and Grade Points

Absolute Marks	Letter Grade	Grade Points	Remark
90-100	S (Out Standing)	10.0	Pass
80-89	A (Excellent)	9.0	Pass
70-79	B (Very Good)	8.0	Pass
60-69	C (Good)	7.0	Pass
50-59	D (Pass)	6.0	Pass
<50	F (Fail)	0.0	Fail
Absent	AB (Absent)	0.0	Fail
---	I	0.0	Result Withheld

8.7 *SGPA*: Semester Grade Point Average indicates the performance of a student in all credit-bearing subjects of a semester. SGPA is calculated as the weighted average of Grade Points of all subjects of the semester with corresponding credits of subjects as weights. Audit subjects are not considered for SGPA calculation.

8.8 *CGPA*: Cumulative Grade Point Average indicates the performance of a student in all terms up to and including the current semester under consideration. CGPA is calculated as the weighted average of SGPAs with total credits in each semester as the weights.

8.9 *Grade Card*: All students shall be issued Grade Cards after the publication of results of a semester. Grade Card is a statement of performance of a student in a semester. It contains information about each registered subject: type of subject, allocated credits, and letter grade earned. SGPA and CGPA will also be indicated.

8.10 CGPA to Percentage Conversion:

$$\text{Percentage} = (\text{CGPA} - 0.5) * 10$$

9.0 Credit Transfer Policy

As per University Grants Commission (Credit Framework for Online Learning Courses through SWAYAM) Regulation, 2016, the University shall allow up to a maximum of 40% of the total courses being offered in a particular Programme in a semester through the Online Learning courses through SWAYAM.

9.1 The University shall offer credit mobility for MOOCs and give the equivalent credit weightage to the students for the credits earned through online learning courses through SWAYAM platform.

9.2 The online learning courses available on the SWAYAM platform will be considered for credit transfer. SWAYAM course credits are as specified in the platform.

9.3 Student registration for the MOOCs shall be only through the institution, it is mandatory for the student to share necessary information with the institution.

9.4 The institution shall select the courses to be permitted for credit transfer through SWAYAM. However, while selecting courses in the online platform institution would essentially avoid the courses offered through the curriculum in the offline mode.

9.5 The institution shall notify at the beginning of semester the list of the online learning courses eligible for credit transfer in the forthcoming Semester.

9.6 The institution shall also ensure that the student has to complete the course and produce the course completion certificate as per the academic schedule given for the regular courses in that semester

9.7 The institution shall designate a faculty member as a Mentor for each course to guide the students from registration till completion of the credit course.

9.8 The college shall ensure no overlap of SWAYAM MOOC exams with that of the college end examination schedule. In case of delay in SWAYAM results, the university will re-issue the marks sheet for such students.

9.9 Student pursuing courses under MOOCs shall acquire the required credits only after successful completion of the course and submitting a certificate issued by the competent authority along with the percentage of marks and grades.

Note: Students shall also be permitted to register for MOOCs offered through online platforms other than SWAYAM NPTEL.

10.0 Re-registration for Improvement of Internal Evaluation Marks

A candidate shall be given one chance to re-register for each subject provided the internal marks secured by a candidate are less than 50% and has failed in the end examination

10.1 The candidate should have completed the course work and obtained examinations results for **I, II and III** semesters.

10.2 The candidate shall be given one chance for each Theory subject and for a maximum of **three** Theory subjects for Improvement of Internal evaluation marks.

10.3 The candidate has to re-register for the chosen subjects and fulfill the academic requirements.

10.4 For reregistration the candidates have to apply to the college by paying the requisite fees, before the start of the semester in which re-registration is required

10.5 In the event of availing the Improvement of Internal evaluation marks, the internal evaluation marks as well as the End Examinations marks secured in the previous attempt(s) for the reregistered subjects stand cancelled.

11.0 Credits for Co-Curricular Activities

A Student shall earn 02 credits under the head of co-curricular activities, viz., attending Conference, Scientific Presentations and Other Scholarly Activities. Following are the guidelines for awarding Credits for Co-Curricular Activities:

Name of the Activity	Maximum Credits / Activity
Participation in National Level Seminar / Conference / Workshop / Training programs (related to the specialization of the student)	1
Participation in International Level Seminar / Conference / workshop/Training programs held outside India (related to the specialization of the student)	2
Academic Award/Research Award from State Level / National Agencies	1
Academic Award/Research Award from International Agencies	2
Research / Review Publication in National Journals (Indexed in Scopus/Web of Science)	1
Research / Review Publication in International Journals with Editorial board outside India (Indexed in Scopus / Web of Science)	2
Vocational Course / Certificate Course (Minimum 36 hours)	2

Note:

i) Credit shall be awarded only for the first author. Certificate of attendance and participation in a Conference/Seminar is to be submitted for awarding credit.

ii) Certificate of attendance and participation in workshops and training programs (Internal or External) is to be submitted for awarding credit. The total duration should be at least one week.

iii) Participation in any activity shall be permitted only once for acquiring required credits under co-curricular activities.

12.0 Requirements for Completing Subjects

12.1 A student shall complete all credit-bearing and audit subjects successfully to be eligible for award of degree

12.2 *Credit-bearing subjects*: A student is considered to have completed a credit-bearing subject successfully and earned credits if she or he obtains a pass grade from A+ to D+ in that subject. If a student receives fail grade F or X in any subject, she or he must register for supplementary End examination for that subject as and when opportunity arises and improve grade to pass grade

12.3 *Audit subjects*: A student is considered to have successfully completed an audit subject if she or he earns at least 40% of marks in internal assessment marks.
Supplementary exam for audit subjects: If a student fails in audit subject, she or he shall register for supplementary examination in that subject as and when the opportunity arises and pass that subject.

The supplementary exam will be conducted for 40 marks covering the entire syllabus and student is deemed to have passed in the subject if she or he earns 16 marks (40% marks) in the supplementary exam, disregard of her or his performance in internal tests.

13.0 Requirements for taking End Examinations

13.1 A student is eligible to take regular End Examinations of current semester if she or he full fills the attendance requirement.

13.2 A student shall be promoted from current semester to succeeding semester on satisfying the attendance requirement.

13.3 A student shall complete all credit-bearing and audit subjects successfully before taking End examination for project viva-voce.

13.4 Attendance Requirement

13.4.1 Attendance of students shall be recorded for credit-bearing and audit subjects as per the workload indicated in curriculum.

13.4.2 Total class-periods conducted shall be reckoned from beginning to end of a semester as published in academic calendar.

13.4.3 Aggregate Percentage of Attendance is calculated using total number of class-periods attended as numerator and total number of class-periods conducted for the concerned subject as the denominator.

13.4.5 A minimum aggregate attendance of 75% is required for promotion to succeeding semester.

13.4.6 A student can appeal to the Principal for condoning deficiency in aggregate attendance if she or he gets 65% or more aggregate attendance presenting a valid reason for deficiency. Such a student will be granted promotion if the Principal pardons the deficiency. Principal has the right to reject the appeal if it is not satisfied with the performance of the student or the reason cited for deficiency of the attendance.

13.4.7 A student earning less than 75% aggregate attendance will be denied promotion. A student who is not promoted on basis of attendance shall be removed from the rolls and shall register for the same semester when opportunity arises. The current semester record of the student is cancelled automatically.

14.0 Revaluation of End Examination Scripts

14.1 Revaluation of End Examination scripts is allowed for theory subjects only by paying requisite fee.

14.2 A Procedure for Revaluation: The script will be revaluated by an examiner appointed by the Principal. The maximum of revaluation and regular end examination marks will be awarded for that subject.

14.3 A student can apply for revaluation in a subject only once.

15.0 Supplementary End Examinations

15.1 Students are eligible to take Supplementary examinations in subjects with fail grade F or X only.

15.2 Supplementary examinations for even semester subjects will be conducted with regular examinations of odd semester subjects and vice versa.

15.3 A student will be allowed to improve grade in any theory subject provided she or he has completed coursework of all semesters but before award of provisional/final degree.

16.0 Requirements for Award of M. Tech degree

16.1 Time Limit for completion of requirements for award of degree is four calendar years from the date of admission. A student who could not complete all the requirements in this time limit shall forego admission and will be removed from the rolls of the Institute.

16.2 A student shall be eligible for award of degree provided she or he has:

16.2.1 Registered and successfully completed all required credit-bearing and audit subjects with a total of 68 credits.

16.2.2 Secured a CGPA of 5.5 or more.

16.2.3 Cleared all dues to the Institute, library and hostel.

16.2.4 No disciplinary action is pending against her or him.

16.2.5 Satisfied any other stipulation of the affiliating University.

16.3 Award of Class: Each student will be given class in degree based on CGPA as given in Table 3.

Table 3 Class of Degree

ass of Degree	nge of CGPA
cond Class	5.5 but <6.5
st Class	6.5 but <7.5
st Class with Distinction	7.5

16.4 Consolidated Grade Card and Degree will have issued under the seal of affiliating University

17.0 Transitory Regulations

17.1 A student who initially joins the Institute in a previous Regulation and has to re-join in any semester of the present Regulations, due to any reason, shall be bound by the rules of the current Regulations. Board of Studies of the concerned Major will specify, extra or otherwise, academic coursework to be undertaken by such students who re-join the current Regulations

Rules for Disciplinary Action for Malpractice / Improper Conduct inExaminations

S. No	Nature of Malpractice/Improper conduct	Punishment
1.	Possesses or keeps accessible, any paper, note book, programmable calculators, Cell phones, pager, palm computers or any other form of material concerned with or related to the subject of the examination (theory or practical) in examination hall in which he is appearing but has not made use of (material shall include any marks on the body of the student which can be used as an aid in the subject of the examination)	Expulsion from the examination hall and cancellation of the performance only in that subject.
2.	Uses objectionable, abusive or offensive language in the answer paper or in letters to the examiners or writes to the examiner requesting him to award pass marks.	Cancellation of the performance in that subject.
3.	Copying detected on the basis of internal evidence, such as, during valuation or during special scrutiny.	Cancellation of the performance in that subject.
4.	Gives / receives assistance or guidance from any other student orally or by communicatingbody language.	Expulsion of both from the examination hall and cancellation of the performance only in that subject.
5.	Has copied in the examination hall from any paper, book, programmable calculators, palm computers or any other form of material relevant to the subject of the examination (theory or practical) in which the student is appearing.	If copied material is related to the concerned subject and if that material is related to question paper then expulsion from the examination hall and cancellation of the performance in that subject and all other subjects including practical examinations and project workof that semester/year, otherwise expulsion from that subject only.
6.	Enters in a drunken state to the examination hall.	Expulsion from the examination hall and cancellation of performance in all subjects of the semester/year including practical examinations and projectwork.
7.	Smuggles in the Answer book or takes out or arranges to send out the question paper during the examination or answer book during or after the examination	Expulsion from the examination hall and cancellation of performance in all subjects of the semester / year including practical examinations and projectwork.
8.	Any outsider or impersonator found in and oroutside the examination hall.	Handing him over to the police and registering a case against him.

COURSE STRUCTURE

Curriculum
RENEWABLE ENERGY

I SEMESTER

S. No.	Course Codes	Course Name	Category	Hours per Week			IM	EM	CR
				L	T	P			
1	2299101	Advanced Thermodynamics and Fluid Mechanics	PC	3	0	0	40	60	3
2	2299102	Introduction to Renewable Energy systems	PC	3	0	0	40	60	3
3	**Program Elective Course - I**		PE	3	0	0	40	60	3
	2299103	Hydrogen and Fuel Cell Technologies							
	2299104	Wind Energy Technology							
	2299105	Process Modeling and Simulation in Renewable Energy Systems-I							
4	**Program Elective Course - II**		PE	3	0	0	40	60	3
	2299106	Energy Storage Technology							
	2299107	Energy Conservation by Waste Heat Recovery-I							
	2299108	Developing Energy Efficiency and Renewable Energy Projects-I							
5	2299109	Fuels lab	PC	0	0	4	50	50	2
6	2299110	Solar lab	PC	0	0	4	50	50	2
7	2299111	Research Methodology & IPR	MC	2	0	0	40	60	2
8	**Audit Course - I**		AC	2	0	0			
	2270A06	Disaster Management							
	2270A05	Constitution of India							
	2270A07	Stress Management by Yoga							
				16	**0**	**8**			**18**

II SEMESTER

S. No.	Course Codes	Course Name	Category	Hours per week			IM	EM	CR
				L	T	P			
1	2299201	Energy Audit and Management	PC	3	0	0	40	60	3
2	2299202	Computational Fluid Dynamics	PC	3	0	0	40	60	3
3	**Program Elective Course - III**		PE	3	0	0	40	60	3
	2299203	Energy Storage Technology							
	2299204	Energy Conservation by Waste Heat Recovery-II							
	2299205	Developing Energy Efficiency and Renewable Energy Projects-II							
4	**Program Elective Course - IV**		PE	3	0	0	40	60	3
	2299206	Hydrogen and Fuel Cell Technologies							
	2299207	Solar Energy Technology							
	2299208	Process Modeling and Simulation in Renewable Energy Systems-II							
5	2299209	Wind energy lab	PC	0	0	4	50	50	2
6	2299210	Control systems and simulation lab	PC	0	0	4	50	50	2
7	2299211	Technical Seminar	MC	0	0	4	100		2
8	**Audit Course - II**		AC	2	0	4	40	--	0
	2270A08	Sanskrit for Technical Knowledge							
	2270A09	Pedagogy Studies							
	2270A10	English for Research Paper Writing							
									18

III SEMESTER

S. No.	Course Codes	Course Name	Category	Hours per week			IM	EM	CR
				L	T	P			
1	**Program Elective Course - V**		PE	3	0	0	40	60	3
	2299301	Economics and Financing of Renewable Energy Systems							
	2299302	Environmental Engineering and Pollution Control							
	2299303	Fuels and Combustion Technology							
2	**Open Elective**		OE	3	0	0	40	60	3
	2299304	Electric Vehicle Technology							
	2299305	Operations Research							
	2299306	Composite Materials							
3	2299307	Dissertation Phase – 1	PR	0	0	20	100	0	10
4	2299308	Co-Curricular Activities	PR	0	0	0			2
				6	0	20			18

IV SEMESTER

S. No.	Course Codes	Course Name	Category	Hours per week			IM	EM	CR
				L	T	P			
1	2299401	Dissertation Phase - 2	PR	0	0	32	50	50	16
				0	**0**	**32**			**16**

M.TECH.-
I- SEMESTER SYLLABUS

Course Title	ADVANCED THERMODYNAMICS AND FLUID MECHANICS				M. Tech. RE I Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
		L	T	P	C	Continuous Internal Assessment	End Exams	Total
2299101	PCC	3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- To develop the ability to use the thermodynamics concepts for various applications like availabilityanalysis and thermodynamic relations.
- To analyses the real gas behavior and chemical thermodynamics.
- To achieve an understanding of the basic concepts of Statistical and Irreversible thermodynamics.
- To understand the laws of fluid flow for ideal and viscous fluids.
- To represent the real solid shapes by suitable flow patterns and to analyze the same for aerodynamicsperformances.
- To understand the changes in properties in compressible flow and shock expansion.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	After the completion of the syllabus students able to understanding the application of thermodynamics in real gas behavior, availability analysis, statistical and irreversible thermodynamics.
CO 2	After the completion of the syllabus students able to familiarized about the ideal and viscous fluid flow, boundary layer concepts and changes in properties in compressible flow and shock expansion.
CO 3	Undertake the three dimensional continuity equation - differential and integral forms – equations of motion momentum andenergy and their engineering applications etc.
CO 4	Identify suitable Laminar and turbulent flow.

UNIT-I

Availability Analysis and Thermodynamic Property Relations: Reversible work - availability - irreversibility and second – law efficiency for a closed system and steady – state control volume. Availability analysis of simple cycles. Thermodynamic potentials. Maxwell relations. Generalized relations for changes in entropy - internal energy and enthalpy - generalized relations for Cp and CV. Clausius Clayperon equation, Joule–Thomson coefficient. Bridgeman tables for thermodynamic relations.

UNIT-II

Chemical Thermodynamics and Equilibrium

Thermochemistry - First law analysis of reacting systems - Adiabatic flame temperature - entropy change of reacting systems - Second law analysis of reacting systems - Criterion for reaction equilibrium. Equilibrium constant for gaseous mixtures - evaluation of equilibrium composition.

UNIT-III

Basic Equations of Fluid Flow and Potential Flow Theory

Three dimensional continuity equation - differential and integral forms – equations of motion momentum andenergy and their engineering applications. Rotational and irrorational flows - circulation – vorticity - stream and potential functions for standard flows and combined flows – representation of solid bodies by flow patterns. Pressure distribution over stationery and rotating cylinders in a uniform flow

UNIT-IV

Viscous Flow Theory

Laminar and turbulent flow - laminar flow between parallel plates - Poiseuille's equation for flow through circular pipes. Turbulent flow - Darcy Weisbach equation for flow through circular pipe - friction factor - smooth and rough pipes - Moody diagram – losses during flow through pipes.

UNIT-V

Compressible Fluid Flow

One dimensional compressible fluid flow – flow through variable area passage – nozzles and diffusers – fundamentals of supersonics – normal and oblique shock waves and calculation of flow and fluid properties over solid bodies (like flat plate, wedge, diamond) using gas tables.

Text and Reference Books:

1. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Cons, 1988.
2. Munson B.R., Young D.F. and Okiisi, T.H., Fundamentals of Fluid Mechanics, John Wiley and Sons Inc.,New York, 1990.
3. Boundary Layer Theory, H Schlichting, Ninth Edition, Springer
4. Viscous Fluid Flow, F M White, Third EditionTata McGraw Hill
5. Anderson J.D., Fundamentals of Aerodynamics, McGraw Hill, Boston, 2001.Thermodynamics – An Engineering Approach, Cengel, Tata McGraw Hill

Course Title	INTRODUCTION TO RENEWABLE ENERGY SYSTEMS				M. Tech. RE I Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299102	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To provide knowledge of solar energy concept and applications.
- To impart knowledge of geothermal, ocean and tidal energy and their applications.
- To understand the design of wind mills and applications.
- To understand the turbines and generators for small scale hydroelectric generation.
- To understand the important parts of a biogas plant, design and principle of bio-diesel.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To explain the basic principles of various renewable energy conversion processes anddevices used therein.
CO 2	To identify various parameters that influences the performance of renewable energy devices/processes.
CO 3	To undertake the field projects in the area of solar thermal, solar PV, wind, biomass, ocean energy, geothermal etc.
CO 4	To identify suitable renewable source and technology for a given requirement to develop the integrated renewable energy technology for decentralized power sector.

UNIT-I

Need of sources of renewable energy: Introduction to different sources of renewable energy, e.g., Solar Energy, Wind Energy, Bio-mass, Geothermal Energy, Ocean energy, Solar Energy and Applications.
Basic concepts of radiations: Solar radiation, Direct and Indirect radiation, Radiation measuring instrument, applications etc.

UNIT-II

Solar Energy: Basics of solar thermal applications both low and high temperature ranges such as water heating, air heating, steam generation, desalination of water, crop drying and power generation, Principle of photovoltaic including introduction to various components of a photovoltaic systems for standalone/hybrid/grid connected systems
Wind Energy: Wind Resource assessment including instrumentation used in resource assessment, basic theory of wind, wind power generators both for decentralized applications and grid connected systems, performance characteristics, Augmentation of wind power, Betz criteria

UNIT-III

Bioenergy: Types and availability of biomass resources, various methods of biomass utilization for energy generation: gasification, briquette, palatization, syngas, Anaerobic/Aerobic digestion, ethanol and biodiesel production, types of Bio-gas digesters, Combustion characteristics of bio- gas and its different utilizations.

Geothermal Energy: availability and methods of utilization of geothermal resource for thermal applications and electricity generation

UNIT-IV

Hydro Energy: Basic principle of hydroelectric power generation, classification of hydropower projects (pico, micro, mini, small hydro sand large hydro projects), types of hydro turbine, various components of hydropower projects.

Ocean Energy: Principles utilization, thermodynamic cycles, tidal and wave energy, potential and conversion technique, Principle of ocean thermal energy conversion system.

UNIT-V

Fuel Cells and Hydrogen Energy: Introduction, principle of fuel cells, thermodynamic analysis of fuel cells, types of fuel cells, fuel cell batteries, applications of fuel cells. Hydrogen as a renewable energy source, sources of hydrogen, fuel for vehicles, hydrogen production- direct electrolysis of water, thermal decomposition of water, biological and biochemical methods of hydrogen production.

Texts and Reference Books:

1. Duffie, J. A., & Beckman, W. A. (2013). Solar engineering of thermal processes, fourthedition, Wiley.
2. Tiwari, G. N., & Ghosal, M. K. (2007). Fundamentals of renewable energy sources. AlphaScience International Limited.
3. Mukherjee, D., & Chakrabarti, S. (2004). Fundamentals of renewable energy systems. NewAge International.
4. Sukhatme, S. P. (2005). Solar Energy Principles of Thermal Collection and storage. TataMcGraw Hill Publishing Company Ltd. New Delhi.
5. Kothari, D. P., Singal, K. C., & Ranjan, R. (2011). Renewable energy sources and emerging technologies. PHI Learning Pvt. Ltd.

Course Title	HYDROGEN AND FUEL CELL TECHNOLOGIES (Program Elective Course-I)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299103	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To improve the skills in publishing technical papers in conference proceedings and journals.
- To produce factual results of their applied research idea in the Energy Engineering, from phase

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To explain the basic principles Hydrogen – Basics And Production Techniques.
CO 2	To identify Hydrogen Storage and Applications.
CO 3	To undertake comparison on battery vs. fuel cell.
CO 4	To identify relative merits and demerits.
CO 5	To develop Future trends in fuel cells.

UNIT-I

Hydrogen – Basics And Production Techniques: Hydrogen – physical and chemical properties, salient characteristics. Production of hydrogen – steam reforming – water electrolysis– gasification and woody biomass conversion – biological hydrogen production – photo dissociation – direct thermal or catalytic splitting of water.

UNIT-II

Hydrogen Storage and Applications: Hydrogen storage options – compressed gas – liquid hydrogen – Hydride – chemical Storage – comparisons. Safety and management of hydrogen, Applications of Hydrogen.

UNIT-III

Fuel Cells: History – principle - working - thermodynamics and kinetics of fuel cell process performance evaluation of fuel cell – comparison on battery vs fuel cell.

UNIT-IV

Fuel Cell – Types: Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – relative merits and demerits.

UNIT-V

Application of Fuel Cell and Economics: Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells.

Texts and Reference Books:

1. Barclay F.J., Fuel Cells, Engines and Hydrogen, Wiley, 2009.
2. Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications,Elsevier, UK 2005.
3. Hart A.B. and G.J.Womack, Fuel Cells: Theory and Application, Prentice Hall, New YorkLtd.,London 1989.
4. Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA 2002.
5. Kordesch K. and G.Simader, Fuel Cell and Their Applications, Wiley-Vch, Germany 1996.
6. Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation, Oklahoma, 2005.
7. Viswanathan B. and Aulice Scibioh.M, Fuel Cells – Principles and Applications.

Course Title	WIND ENERGY TECHNOLOGIES (Program Elective Course-I)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299104	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To understand the fundamentals of wind energy and its conversion system
- To learn gear coupled generator wind turbine components
- To learn modern wind turbine control & monitoring

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Know the energy conversion techniques in wind energy
CO 2	Learn about wind turbine components and their constructions
CO 3	Understand the modern wind turbine control & monitoring
CO 4	Understand the Direct Rotor Coupled Generator (Multipole) [Variable Speed Variable Freq

UNIT-I

Wind Energy Fundamentals & Wind Measurements: Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics, Power Content, Class of wind turbines, Atmospheric Boundary Layers, Turbulence. Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence Analysis

UNIT-II

Aerodynamics Theory & Wind Turbine Types: Airfoil terminology, Blade element theory, Blade design, Rotor performance and dynamics, Balancing technique (Rotor & Blade), Types of loads; Sources of loads Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control, Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator.

UNIT-III

Gear Coupled Generator Wind Turbine Components And Their Construction: Electronics Sensors/Encoder/Resolvers, Wind Measurement : Anemometer & Wind Vane, Grid Synchronization System, Soft Starter, Switchgear[ACB/VCB], Transformer, Cables and assembly, Compensation Panel, Programmable Logic Control, UPS, Yaw & Pitch System : AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery/Super Capacitor Charger & Batteries/ Super Capacitor for Pitch System, Transient Suppressor/Lightning Arrestors, Oscillation & Vibration sensing.

UNIT-IV

Direct Rotor Coupled Generator (Multipole) [Variable Speed Variable Freq.]: Excited Rotor Synch, Generator/PMG Generator, Control Rectifier, Capacitor Banks, Step Up/Boost Converter (DC-DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Safety Chain Circuits

UNIT-V

Modern Wind Turbine Control & Monitoring System: Details of Pitch System & Control Algorithms, Protections used & Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA & Databases: Remote Monitoring and Generation Reports, Operation & Maintenance for Product Life Cycle, Balancing technique (Rotor & Blade), FACTS control & LVRT & New trends for new Grid Codes

Texts and Reference Books:

1. C-Wet : Wind Energy Resources Survey in India VI
2. Duffie A. and Beckmann W. A., "Solar Engineering of Thermal Processes, John Wiley,1991.
3. Freris L.L., "Wind Energy Conversion Systems", Prentice Hall, 1990.
4. Godfrey Boyle, "Renewable Energy, Power for a Sustainable Future", Oxford UniversityPress,1996.
5. John D Sorensen and Jens N Sorensen, "Wind Energy Systems", Woodhead Publishing Ltd,2011.
6. Kaldellis J.K., "Stand – alone and Hybrid Wind Energy Systems", CRC Press, 2010.
7. Mario Garcia –Sanz, Constantine H. Houpis, "Wind Energy Systems",CRC Press 2012.
8. Spera D.A., "Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering",ASME Press, 1994.
9. Twidell J.W. and Weir A., "Renewable Energy Sources", EFN Spon Ltd., 1983.

Course Title	PROCESS MODELING & SIMULATION IN RENEWABLEENERGY SYSTEMS-I (Program Elective Course-I)				M. Tech. RE I Sem			
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299105	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- This course is intended to impart basic skill of model development and optimization in the field of energy. The learners will be familiarized to variety of energy related field problems associated mostly with economy and environment. The main Objectives are to enable learners to develop basic skill of development of energy system model and to enable learners to use system modeling as tool for optimization vis-à-vis decision making on energy related field problems.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand modeling, its types and principles.
CO 2	The learner will understand how to develop a model, and how to apply varies strategies for differentparametric model.
CO 3	To optimize the energy systems and to understand the working principles econometric modeling.
CO 4	To Understand the Solution strategies for Lumped parameter models

UNIT-I

Introduction to modeling: types and classification, uses, limitations, advantages of modeling; Review of computational tools/techniques used for mathematical modeling including solutions for non-linear equations, system of simultaneous equations, Conservation principles, thermodynamic principles.

UNIT-II

Introduction to Development Based on first principles: Steady state and dynamic, Lumped and distributed parameter models, Block diagrams and computer simulation. Modeling of Process elements consisting of Mechanical (translational and rotational), Electrical, Electro- mechanical, Fluid flow, Thermal and Chemical reaction system elements.

Development of Models: Grey box models, Empirical model building, Statistical model calibration and validation. Population balance models, examples of energy system modeling, static and dynamic modeling; Modeling errors, accuracy and methods of model validation

UNIT-III

Solution strategies for Lumped parameter models: Solution methods for initial value and boundary value problems, Euler's method, R-K method, Shooting method, Finite difference methods. Finite element and Finite volume methods. Solving the problems using MATLAB / SCILAB.

UNIT-IV

Optimization: Problem formulation with practical examples from energy system, constrained optimization and unconstrained problems: necessary and sufficiency conditions. Uses of Linear Programming technique for solution of problems related to Energy systems/ case studies. Constrained Optimization, Lagrange multipliers, constrained variations, Kuhn-Tuckerconditions, Case studies of optimization in Energy systems problems, Dealing with uncertainty- probabilistic techniques.

UNIT-V

Energy systems simulation Optimization: Objectives/constraints, problem formulation.Unconstrained problems, Necessary & Sufficiency conditions.

Econometric modeling: Input Output models considering energy budgeting, Sensitivity analysis, importance of parametric analysis and tools for sensitivity analysis

Texts and Reference Books:

1. Rao S. S. (2004). Engineering Optimization: Theory and Practice, Third Edition, New AgeInternational
2. Kennedy P. (2008). A Guide to Econometrics, Sixth Edition, Wiley-Blackwell
3. Meier P. (1984). Energy Systems Analysis for Developing Countries, Springer Verlag
4. Ravindran A. Ragsdell K. M. and Reklaitis G. V. (2006). Engineering Optimization:methods and applications, Second Edition, Wiley
5. Neufville R. De. (1990). Applied Systems Analysis: Engineering Planning and TechnologyManagement, McGraw Hill
6. Hangos, K., & Cameron, I. (2001). Process modelling and model analysis. Academic Press
7. James, J. C. (1989). Process modeling, simulation and control for chemical engineers.McGraw-Hill.
8. Close, C. M., & Frederick, D. K. (2002). Modeling and analysis of dynamic systems. JohnWiley & Sons.

Course Title	ENERGY STORAGE TECHNOLOGY (Program Elective Course-II)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299106	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- This course covers all types of currently-available energy storage systems, which are, or can be, used in the electricity, heat and transport sectors. The various technologies discussed may be categorized as mechanical/kinetic, thermodynamic, electrical, chemical, electrochemical or thermal processes.

Course Outcomes: On successful completion of this course, the students will be able to	
CO 1	To understand the theory and applications of different energy storage devices.
CO 2	Learners will identify the optimal (appropriateness, cost and sustainability) solutions to any potential energy storage application.
CO 3	To Understand the Battery – fundamentals and technologies, characteristics and performance comparison.
CO 4	To Understand the Application of Energy Storage.

UNIT-I

Energy availability: Demand and storage, Need for energy storage, Different types of energy storage; Mechanical, Chemical, Electrical, Electrochemical, Biological, Magnetic, Electromagnetic, Thermal; Comparison of energy storage technologies.

UNIT-II

Thermal energy storage: principles and applications, Sensible and Latent heat, Phase change materials; Energy and exergy analysis of thermal energy storage, solar energy and thermal energy storage, case studies.

Mechanical Energy storage: Flywheel and compressed air storage; Pumped hydro storage; Hydrogen energy storage, Capacitor and super capacitor, Electrochemical Double Layer Capacitor: Principles, performance and applications

UNIT-III

Electrochemical energy storage: Battery – fundamentals and technologies, characteristics and performance comparison: Lead-acid, Nickel-Metal hydride, Lithium Ion; Battery system model, emerging trends in batteries.

Hydrogen as energy carrier and storage: Hydrogen resources and production; Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells

UNIT-IV

Fuel cell types: AFC, PEMFC, MCFC, SOFC, Microbial Fuel cell, Fuel cell performance, characterization and modeling; Fuel cell system design and technology, applications for power and transportation.

UNIT-V

Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage: Greenhouse heating; Drying and heating for process industries.

Texts and Reference Books:

1. Dincer I., and Rosen M. A. (2011); Thermal Energy Storage: Systems and Applications,Wiley
2. Huggins R. A. (2015). Energy Storage: Fundamentals, Materials and Applications.Springer
3. O'Hayre R., Cha S., Colella W., and Prinz F. B. (2009). Fuel Cell Fundamentals, SecondEdition, Wiley
4. Narayan R. and Viswanathan B. (1998). Chemical and Electrochemical Energy System,Universities Press
5. Rahn C. D. and Wang C. (2013). Battery Systems Engineering, First Edition, Wiley
6. Moseley P. T., and Garche J. (2014). Electrochemical Energy Storage for RenewableSources and Grid Balancing, Elsevier Science.
7. Miller F. P., Vandome A. F., and John M. B. (2010). Compressed Air Energy Storage,VDM Publishing.

Course Title	ENERGY CONSERVATION BY WASTE HEAT RECOVERY-I (Program Elective Course-II)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299107	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- The industrial sector accounts for about 40 percent of the total energy consumed in India and are responsible for around one fourth of the total greenhouse gas emissions. This share is more than half of the total GHG emissions, if energy industries are considered together. It is estimated that somewhere between 30 to 50% of industrial energy input is lost as waste heat in the form of exhaust gases, cooling water, and heat lost from equipment surfaces and heated products. As the industrial sector continues efforts to improve its energy efficiency, recovering waste heat losses provides an attractive opportunity for an emission free and less costly energy resource.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand the on basic principles and available technologies forwaste heat recovery.
CO 2	To analyze industrial waste heat recovery systems
CO 3	To understand Waste heat boilers.
CO 4	To determine the Waste Heat Recovery calculations.

UNIT-I

Introduction: heat losses, its quality and quantity, potential for energy conservation. Waste heat sources: steam, compressed air, refrigeration, flue gases, furnace/air stream exhaust, high grade heat, low grade heat.

Optimal utilization of fossil fuels: Total energy approach; Coupled cycles and combined plants; Cogeneration systems.

UNIT-II

Exergy analysis: Utilization of industrial waste heat; Properties of exhaust gas; Gas-to- gas, gas-to- liquid heat recovery systems; Recuperators and regenerators; Shell and tube heat exchangers; Spiral tube and plate heat exchangers.

UNIT-III

Waste heat boilers: various types and design aspects. Heat pipes: theory and applications in waste heat recovery.

UNIT-IV

Prime movers: sources and uses of waste heat; Fluidized bed heat recovery systems; Utilization of waste heat in refrigeration, heating, ventilation and air conditioning systems; Thermoelectric system to recover waste heat; Heat pump for energy recovery; Heat recovery from incineration plants.

UNIT-V

Waste Heat Recovery calculations: Quantifying available heat (kWh), Pinch analysis, typical energy costs/construction costs, pay back analysis, thermo-economic viability.

Need for energy storage: Thermal, electrical, magnetic and chemical storage systems.

Texts and Reference Books:

1. Hewitt, G. F., Shires, G. L., and Bott, T. R. (1993). Process Heat Transfer, CRC Press,Florida.
2. Flynn, A. M., Akashige, T., & Theodore, L. (2019). Kern's Process Heat Transfer. JohnWiley & Sons.
3. Goswami, D. Y., and Kreith, F. (2007). Energy Conversion, CRC Press.
4. Serth, R. W., & Lestina, T. (2014). Process heat transfer: Principles, applications and rulesof thumb. Academic press.
5. Beith, R. (Ed.). (2011). Small and micro combined heat and power (CHP) systems: advanced design, performance, materials and applications. Elsevier.
6. Khanna, S., & Mohan, K. (Eds.). (1996). Wealth from waste. Tata Energy ResearchInstitute.
7. Eriksen, V. L. (Ed.). (2017). Heat Recovery Steam Generator Technology. WoodheadPublishing.

Course Title	DEVELOPING ENERGY EFFICIENCY AND RENEWABLEENERGY PROJECTS-I (Program Elective Course-II)				M. Tech. RE I Sem (R22)			
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299108	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- To introduce all relevant steps as well as the issues and challenges involved in developing projects on energy efficiency and renewable energy utilization. The course also aims at discussion on policy, regulatory and other support measures that can promote such projects.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand the fundamentals of various types of fuel cell system, its components and characterization.
CO 2	To understand comprehensive background in fuel cell base systems and hydrogen technologies.
CO 3	To understand hydrogen generation techniques and hydrogen economy.
CO 4	To understand the Relevance of developing energy efficiency: Renewable energy projects, Key projectdevelopment concepts.

UNIT-I

Project motivation: Key drivers-pre development, gauging market characteristics that provide motivation for the project and assessment of market readiness, Project development framework, Essential elements, project development environment including existing policy environment- relevant codes (such as ECBC),

UNIT-II

Pre-investment phase: assessing potential sites, identifying partners, Assessment of commercially available energy technologies for improving energy efficiency and harnessing renewable energy, preparation of business plan (that includes feasibility study, engineering design, Financial closure, permitting activities and related documentation and agreements), consensus with project stakeholders

UNIT-III

Implementation phase: Procurement, land acquisition, site preparation, construction, installation, commissioning of the project, operation of the facility, Actual implementation of the business plan, Monitoring and evaluation of the business and the project performance, Issues in implementation of energy efficiency and renewable energy projects, Essential areas for strong project development in renewable energy - site, resource, permits, technology, team and capital, Size and diversity ofpotential project sponsors and also of projects in the field of renewable energy and energy efficiency, **Risks Factor:** Risk in energy efficiency and renewable energy projects and appropriate de- risking/ mitigation measures and approaches, dispute resolution,

UNIT-IV

Role of policies: Policy and support measures in promoting energy efficiency and renewable energy, Developing community driven projects, Developing projects for improving energy access, socially inclusive projects,

Issue and Challenges: Issues in using public lands for developing renewable energy projects, Various considerations in selecting local versus imported technologies, Challenges in implementing energy efficiency in public sector within government financial and other regulations, Environmental impact and sustainability assessment of energy efficiency and renewable energy projects and projects while addressing environmental issues, Utility scale versus local projects,

UNIT-V

Examples and Case Studies: developing PV/wind power projects, projects for enhanced LED use in domestic, commercial, institutional and industrial sectors, environmental management projects.

Texts and Reference Books:

1. Lokey, E. (2012). Renewable energy project development under the clean development mechanism: a guide for Latin America. Routledge.
2. Springer, R. (2013). Framework for Project Development in the Renewable Energy Sector (No. NREL/TP-7A40-57963). National Renewable Energy Lab.(NREL), Golden, CO (United States).
3. Ontario Sustainable Energy Association. (2010). Guide to developing a community renewable energy project in North America. Montreal, Canada
4. PVPS, I. (2003). 16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries. International Energy Agency IEA-PVPS.T9-07
5. Trieb, F. (2006). Concentrating solar power now. DLR, Berlin, Germany.
6. Guide, L. S. R. E. (2003) Developing Renewable Energy Projects Larger Than 10 MWs atFederal Facilities. Report DOE/GO-102013-3915, US Department of Energy
7. Thomsen, K. (2014). Offshore wind: a comprehensive guide to successful offshore windfarm installation. Academic Press.
8. Winebrake, J. J. (Ed.). (2004). Alternate energy: Assessment and implementation referencebook. The Fairmont Press, Inc..
9. Chuck, C. (Ed.). (2016). Biofuels for aviation: feedstocks, technology and implementation.Academic Press.

Course Title	FUELS LAB				M. Tech. RE I Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299109	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		0	0	4	2	50	50	100
					End Exam Duration: 3Hrs		

S. No.	NAME OF THE EXPERIMENTS
1	Determination Of Flash Point And Fire Point Of Liquid Fuels/Lubricants Using Ables Apparatus.
2	Determination Of Flash Point And Fire Point Of Liquid Fuels/Lubricants Using Pesky Martens Test.
3	Carbon Residue Test: Liquid Fuels.
4	Determination Of Viscosity Of Liquid Lubricants And Fuels Using Saybolt Viscometer.
5	Determination Of Viscosity Of Liquid Lubricants And Fuels Using red wood viscometer-I & II.
6	Determination Of Viscosity Of Liquid Lubricants And Fuels Using engler viscometer.
7	Determination of calorific value of gaseous fuels using Junkers gas calorimeter.
8	Determination of calorific value of solid/liquid fuels using bomb calorimeter.
9	ASTM distillation test apparatus.
10	Cloud and pour point apparatus.

Course Title	SOLAR LAB				M. Tech. RE I Sem (R22)		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299110	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		0	0	4	2	50	50	100
					End Exam Duration: 3Hrs		

List of Experiments

1. Determination of parameters of Flat Plate Collector – Forced Mode
2. Determination of parameters of Flat Plate Collector – Thermo siphon Mode
3. Determination of parameters of Flat Plate Collector for different mass flow rate
4. Determination of parameters of Flat Plate Collector for different radiation
5. Determination of parameters of Flat Plate Collector – Forced mode of flow at different wind speeds
6. Determination of parameters of Flat Plate Collector for Different Tilt Angle
7. Determination of parameters of Parabolic Trough Collector
8. Determination of parameters of Parabolic Trough Collector for different mass flow rate
9. Measurement of VOC and ISC of a Solar PV Panel
10. Determination of I-V& P-V Characteristics of a Solar PV Panel
11. Determination of I-V& P-V Characteristics of Series and Parallel combination of PV Modules
12. Determination of Characteristics of PV Module With a variation of the Tilt angle
13. Effect of Shading on Solar PV Module Output Power
14. Power Flow calculation of Stand-Alone PV System of DC Load with Battery
15. Charging and Discharging Characteristics of Battery

Course Title	RESEARCH METHODOLOGY & IPR				M. Tech. RE I Sem			
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299111	MC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	2	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- To familiarize with modeling, referencing, literature survey, etc
- To design experiments and to analyze results of the experiments
- To prepare technical reports and research papers
- To prepare material for technical presentation and do oral presentation
- To understand the purpose and terms of IPR
- To orient to ethics in research and publication

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Understand research problem formulation.
CO 2	Analyze research related information.
CO 3	Follow research ethics.
CO 4	Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
CO 5	Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.

UNIT-I

Meaning of Research, Types ofResearch,ResearchProcess,Problemdefinition,ObjectivesofResearch, Research Questions, Research design, Approaches to Research, Quantitative vs. QualitativeApproach,UnderstandingTheory,BuildingandValidatingTheoreticalModels,Exploratoryvs.Co nfirmatoryResearch,ExperimentalvsTheoreticalResearch,Importanceofreasoninginresearch.

UNIT-II

ProblemFormulation,UnderstandingModeling&Simulation,ConductingLiteratureReview,Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures ,Indexing and abstracting services, Citation indexes.

UNIT-III

ExperimentalResearch:Causeeffectrelationship,DevelopmentofHypothesis,MeasurementSystems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis :Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results.

UNIT-IV

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents.

UNIT-V

Intellectual property rights (IPR)- patents- copyrights- Trademarks –Industrial design geographical indication. Ethics of Research- Scientific Misconduct-Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

Texts and Reference Books:

1. Borden, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach",
2. 8thEdition, McGraw-Hill, 2011
3. C. R. Kothari, "Research Methodology – Methods and Techniques", 2nd Edition, New Age
4. International Publishers
5. Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rdEdition,
6. Elsevier Inc.
7. Michael P. Marder," Research Methods for Science", Cambridge University Press, 2011
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
9. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New TechnologicalAge". Aspen Law & Business; 6th Edition July 2012.

Course Title	DISASTER MANAGEMENT (Audit Course-I)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2270A06	Audit	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	0	40	--	40
Mid Exam Duration: 2Hrs								

Course Objectives:

- Learn to demonstrate a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Critically evaluate disaster risk reduction and humanitarian response policy and practice frommultiple perspectives.
- Develop an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Critically understand the strengths and weaknesses of disaster management approaches, planning and programming in different countries, particularly their home country or the countries they workin.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Understand Difference between Hazard and Disaster; Natural and Manmade Disasters.
CO 2	Analyze Repercussions of Disasters and Hazards.
CO 3	Follow Study of Seismic Zones.
CO 4	Understand that Disaster Preparedness and Management.
CO 5	Understanding Risk Assessment.

UNIT-I

Introduction: Disaster: Definition, Factors and Significance; Difference between Hazard and Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

Repercussions of Disasters and Hazards: Economic Damage, Loss of Human and Animal Life, Destruction of Ecosystem.

Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil SlicksAnd Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

UNIT-II

Disaster Prone Areas in India: Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides and Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference to Tsunami; Post- Disaster Diseases and Epidemics

UNIT-III

Disaster Preparedness and Management

Preparedness: Monitoring Of Phenomena Triggering A Disaster Or Hazard; Evaluation Of Risk: Application Of Remote Sensing, Data From Meteorological And Other Agencies, Media Reports: Governmental And Community Preparedness..

UNIT-IV

Risk Assessment: Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques Of Risk Assessment, Global Co-Operation In Risk Assessment And Warning, People's Participation In Risk Assessment. Strategies for Survival.

UNIT-V

Disaster Mitigation

Meaning, Concept and Strategies of Disaster Mitigation, Emerging Trends in Mitigation.
Structural Mitigation and Non-Structural Mitigation, Programs OfDisaster Mitigation in India.

Texts and Reference Books:

1. R. Nishith, Singh AK, "Disaster Management in India: Perspectives, issues andstrategies "'New Royal book Company.

2. Sahni, Pardeep et. al. (Eds.)," Disaster Mitigation Experiences and Reflections", Prentice Hall OfIndia, NewDelhi.

3. Goel S. L. Disaster Administration And Management Text and Case Studies" Deep &Deep Publication Pvt. Ltd., New Delhi.

Course Title	CONSTITUTION OF INDIA (Audit Course-I)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2270A05	Audit	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	0	40	--	40
Mid Exam Duration: 2Hrs								

Course Objectives:

- Understand the premises informing the twin themes of liberty and freedom from a civil rightsperspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals" constitution a roleand entitlement to civil and economic rights as well as the emergence of nation hood in the early years of Indian nationalism.
- ToaddresstheroleofsocialisminIndiaafterthecommencementoftheBolshevik
- Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
CO 2	Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
CO 3	Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
CO 4	Discuss the passage of the Hindu Code Bill of 1956.

UNIT-I

History of Making of the Indian Constitution: History Drafting Committee, (Composition & Working)

UNIT-II

Philosophy of the Indian Constitution:

Preamble Salient Features

UNIT-III

Contours of Constitutional Rights & Duties:

- Fundamental Rights
- Right to Equality
- Right to Freedom
- Right against Exploitation
- Right to Freedom of Religion
- Cultural and Educational Rights
- Right to Constitutional Remedies
- Directive Principles of State Policy
- Fundamental Duties

Organs of Governance:

- Parliament
- Composition
- Qualifications and Disqualifications
- Powers and Functions
- President
- Governor
- Council of Ministers
- Judiciary, Appointment and Transfer of Judges, Qualifications Powers and Functions

UNIT-IV

Local Administration:

- District's Administration head: Role and Importance,
- Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation.
- Pachayati raj: Introduction, PRI: Zila Pachayat.
- Elected officials and their roles, CEO ZilaPachayat: Position and role.
- Block level: Organizational Hierarchy (Different departments),
- Village level: Role of Elected and Appointed officials, Importance of grass root democracy

UNIT-V

Election Commission:

- Election Commission: Role and Functioning.
- Chief Election Commissioner and Election Commissioners.
- State Election Commission: Role and Functioning. Institute and Bodies for the welfare ofSC/ST/OBC and women

Text & Reference Books:

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
3. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis,2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

Course Title	STRESS MANAGEMENT BY YOGA (Audit Course-I)				M. Tech. RE I Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2270A07	Audit	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	0	40	--	40
Mid Exam Duration: 2Hrs								

Course Objectives:

- To achieve overall health of body and mind.
- To overcome.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Develop healthy mind in a healthy body thus improving social health alsoImprove efficiency.

UNIT	Content	Hours
1	Definitions of Eight parts of yoga. (Ashtanga)	8
2	Yam andNiyam. Do`s and Don‟t‟s inlife. Ahinsa, satya, astheya, bramhacharya andaparigraha Shaucha, santosh, tapa, swadhyay,ishwarpranidhan	8
3	Asan and Pranayam i) Various yoga poses and their benefits for mind & body. ii) Regularization of breathing techniques and its effects- Types of pranayama.	8

Suggested Readings:

1. ‘Yogic Asanas for Group Tarining-Part-I” : Janardan Swami YogabhyasiMandal,Nagpur.
2. “Rajayoga or conquering the Internal Nature” by SwamiVivekananda.
3. Advaitashrama(Publication Department),Kolkata.

M.TECH.-
II- SEMESTER SYLLABUS

Course Title	ENERGY AUDIT AND MANAGEMENT				M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299201	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- The course discusses about the energy scenario, energy conservation and its importance, energy strategy for the future, energy conservation act-2001 and its features, Kyoto protocol and global warming. The students would learn about the concepts of energy management & audit.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Students will be able to understand the current energy scenario along with energy management and strategies.
CO 2	Students will be able to take action on energy conservation techniques.
CO 3	Students will acquire the knowledge of financial management.
CO 4	Students will be able to analyze the data for energy monitoring and targeting.

UNIT-I

Energy Scenario: Commercial and Non-Commercial Energy, Primary Energy Resources, Commercial Energy Production, Energy Needs of Growing Economy, Long Term Energy Scenario, Energy Pricing, Energy Sector Reforms, Energy and Environment: Air Pollution, Climate Change, Energy Security, Energy Conservation and its Importance, Energy Strategy for the Future, Energy Conservation Act-2001 and its Features, Kyoto Protocol, Global warming.

UNIT-II

Energy Conservation: Introduction, Energy and heat balances, Methods for preparing process flow chart, material and energy balance in different processes, Sankey diagram, Energy conservation in boilers, Energy conservation in steam systems, Heat exchanger networking, concept of pinch, lighting systems energy efficiency study, Energy conservation opportunities; conservation in buildings, opportunities in compressed air systems, Refrigeration plants etc.

Principles And Objectives of Energy Management: Introduction, Energy Planning, Energy Staffing, Energy Organization, Energy Requirement, Energy Costing, Energy Budgeting, Energy Monitoring, Energy Consciousness Energy Conversions, Energy Efficient Equipment, Energy Management Professionals, Environment Pollution due to Energy Use, Evaluation of alternative Energy Sources.

UNIT-III

Energy Management & Audit: Definition, Types of energy audit, Energy management (audit) approach-understanding energy costs, Ventilation Audit, Measuring and Detection Instruments for Energy Survey, Scope of Energy audit, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments.

UNIT-IV

Energy Action Planning: Key elements, Force field analysis, Energy policy purpose, perspective, Contents, Formulation, Ratification, Design of Energy Management Programmes, Saving Energy and Implementation of Energy Conservation, location of energy management, Top management support, Managerial function, Roles and responsibilities of energy manager, Accountability. Motivating-motivation of employees: Information system designing barriers, Strategies; Marketing and communicating-training and planning.

Financial Management: Investment-need, Appraisal and criteria, Financial analysis techniques, Simple payback period, Return on investment, Net present value, Internal rate of return, Cash flows, Risk and sensitivity analysis; Financing options, Energy performance contracts and role ofESCOs.

UNIT-V

Project Management: Definition and scope of project, Technical design, Financing, Contracting, Implementation and performance monitoring. Implementation plan for top management, Planning Budget, Procurement Procedures, Construction, Measurement & Verification.

Energy Monitoring and Targeting: Defining monitoring & targeting, Elements of monitoring & targeting, Data and information-analysis, Techniques, energy consumption, Production, Cumulative sum of differences (CUSUM).

Texts and Reference Books:

1. Capehart, B. L., Turner, W. C., & Kennedy, W. J. (2006). Guide to energy management.The Fairmont Press, Inc. Atlanta, GA
2. Kumar, Anil, Om Prakash, Prashant Singh Chauhan, and Samsher Gautam. Energy Management: Conservation and Audits. CRC Press, 2020.
3. Thumann, A., & Mehta, D. P. (2001). Handbook of energy engineering. CRC Press.
4. Loftness, Robert L. "Energy Handbook." 2d ed. New York: Van Nostrand Reinhold Co.,1984.
5. Turner, W. C., & Doty, S. (2013). Energy management handbook (Vol. 2). Lulu Press, Inc.
6. Kenney, W. F. Energy conservation in the process industries. Academic Press, 2012.
7. Kreith, F., & Goswami, D. Y. (Eds.). (2007). Energy management and conservationhandbook. CRC Press.
8. Rao, P. S., & Rao, P. R. P. (2000). Environment Management and Audit. Deep and DeepPublications.

Course Title	COMPUTATIONAL FLUID DYNAMICS				M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299202	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- Student will be able to apply the concept of computational fluid dynamics in the Energy systemsto predict the actual performance.

Course Outcomes: On successful completion of this course, the students will be able to	
CO 1	To understand the method of modeling the flow and heat transfer phenomenon.
CO 2	To develop finite difference and finite volume discretized forms of the CFD equations.
CO 3	To understand the various numerical schemes to solve convection and diffusion equations.
CO 4	To Understand the Algebraic Models – One equation model, K – ϵ Models, Standard and High and Low Reynolds number mode.

UNIT-I

Introduction: Numerical simulation – Advantages, Methods of classification of PDE's, Elliptic, parabolic and hyperbolic equations, Initial and boundary conditions, Discretization Methods, Finite Difference Expressions from Taylor's series, Uniform and non-uniform Grids - Numerical Errors, Grid Independence Test.

UNIT-II

Conservation Equation: Mass, Momentum and Energy Equation three dimensions, Eulerian and Lagrangian Approach, Equation of State, Navier's Strokes equation, Differential and Integral form of general transport equations.

UNIT-III

Conduction Heat Transfer: Steady one-dimensional conduction, Two and three dimensional steady state problems, Transient one-dimensional problem, Two-dimensional Transient Problems
- Finite difference and Finite Volume approach.

UNIT-IV

Incompressible Fluid Flow: Stream Function – Vortices methods, Finite volume methods for Convection and diffusion problem – Central difference scheme, Upwind scheme, Hybrid scheme – Assessment of each scheme - Solution algorithm for pressure – velocity – coupling in steady flows - SIMPLE Procedure of Patankar and Spalding, SIMPLER and PISO Algorithm.

UNIT-V

Turbulence Models: Algebraic Models – One equation model, K – ϵ Models, Standard and High and Low Reynolds number models, Prediction of fluid flow and heat transfer using standard codes.

Texts and Reference Books:

1. Anderson D.A., Tannehill J.I. and Pletcher R.H., "Computational fluid Mechanics and HeatTransfer, "Hemisphere Publishing Corporation, New York, USA,1984.
2. Bose T.X., "Numerical Fluid Dynamics" ,Narosa Publishing House, 1997.
3. Fletcher C.A.J. "Computational Techniques for fluid Dynamics 2" Specific Techniques for Different Flow Categories, Springer – Verlag, 1987.
4. Fletcher C.A.J., "Computational Techniques for Fluid Dynamics 1" Fundamental and General Techniques, Springer – Verlag, 1987.
5. Ghoshdasdidar P.S.,"Computer Simulation of flow and heat transfer" Tata McGraw-Hill Publishing Company Ltd., 1998.
6. Muralidhar K, and Sundararajan T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 1995.
7. Subas V.Patankar ,"Numerical heat transfer fluid flow", Hemisphere Publishing Corporation,1980.
8. Taylor C and Hughes J.B., "Finite Element Programming of the Navier-Stokes Equation",PineridgePress Limited, U.K., 1981.

Course Title	ENERGY STORAGE TECHNOLOGY (Program Elective Course – III)				M. Tech. RE II Sem			
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299203	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- This course covers all types of currently-available energy storage systems, which are, or can be, used in the electricity, heat and transport sectors. The various technologies discussed may be categorized as mechanical/kinetic, thermodynamic, electrical, chemical, electrochemical or thermal processes.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand the theory and applications of different energy storage devices.
CO 2	Learners will identify the optimal (appropriateness, cost and sustainability) solutions to any potential energy storage application.
CO 3	To understand the Mechanical Energy storage.
CO 4	To understand the Hydrogen resources and production; Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells.

UNIT-I

Energy availability: Demand and storage, Need for energy storage, Different types of energy storage; Mechanical, Chemical, Electrical, Electrochemical, Biological, Magnetic, Electromagnetic, Thermal; Comparison of energy storage technologies.

UNIT-II

Thermal energy storage: principles and applications, Sensible and Latent heat, Phase change materials; Energy and exergy analysis of thermal energy storage, solar energy and thermal energy storage, case studies.

UNIT-III

Mechanical Energy storage: Flywheel and compressed air storage; Pumped hydro storage; Hydrogen energy storage, Capacitor and super capacitor, Electrochemical Double Layer Capacitor: Principles, performance and applications.

UNIT-IV

Electrochemical energy storage: Battery – fundamentals and technologies, characteristics and performance comparison: Lead-acid, Nickel-Metal hydride, Lithium Ion; Battery system model,emerging trends in batteries.

Hydrogen as energy carrier and storage: Hydrogen resources and production; Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells.

UNIT-V

Fuel cell types: AFC, PEMFC, MCFC, SOFC, Microbial Fuel cell, Fuel cell performance, characterization and modeling; Fuel cell system design and technology, applications for power and transportation. Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage: Greenhouse heating; Drying and heating for process industries.

Texts and Reference Books:

1. Dincer I., and Rosen M. A. (2011); Thermal Energy Storage: Systems and Applications, Wiley
2. Huggins R. A. (2015). Energy Storage: Fundamentals, Materials and Applications.Springer
3. O'Hayre R., Cha S., Colella W., and Prinz F. B. (2009). Fuel Cell Fundamentals, Second Edition, Wiley
4. Narayan R. and Viswanathan B. (1998). Chemical and Electrochemical Energy System, Universities Press
5. Rahn C. D. and Wang C. (2013). Battery Systems Engineering, First Edition, Wiley
6. Moseley P. T., and Garche J. (2014). Electrochemical Energy Storage for Renewable Sources and Grid Balancing, Elsevier Science.
7. Miller F. P., Vandome A. F., and John M. B. (2010). Compressed Air Energy Storage, VDM Publishing.

Course Title	ENERGY CONSERVATION BY WASTE HEAT RECOVERY-II (Program Elective Course – III)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299204	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- The industrial sector accounts for about 40 percent of the total energy consumed in India and are responsible for around one fourth of the total greenhouse gas emissions. This share is more than half of the total GHG emissions, if energy industries are considered together. It is estimated that somewhere between 30 to 50% of industrial energy input is lost as waste heat in the form of exhaust gases, cooling water, and heat lost from equipment surfaces and heated products. As the industrial sector continues efforts to improve its energy efficiency, recovering waste heat losses provides an attractive opportunity for an emission free and less costly energy resource.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand the on basic principles and available technologies for waste heat recovery-II.
CO 2	To understand industrial waste heat recovery systems.
CO 3	To understand Waste Heat Recovery calculations.
CO 4	To understand the Need for energy storage.

UNIT-I

- **Introduction to Waste Heat Recovery**:Overview of waste heat recovery systems (WHRS),Types and sources of waste heat in industrial processes,Thermodynamics of waste heat recovery (First and Second Laws of Thermodynamics),Heat exchangers and heat recovery systems: types and design considerations
  Waste Heat Generation:Common industrial processes that generate waste heat (e.g., metallurgy, cement, glass, chemical processing),Temperature ranges and characteristics of waste heat,Heat loss through exhaust gases, cooling water, and other systems
  Technologies for Waste Heat Recovery:Recuperators, regenerators, and heat exchangers,Rankine Cycle and Organic Rankine Cycle (ORC),Thermoelectric generators (TEGs),Absorption heat pumps and thermochemical cycles

UNIT-II

Organic Rankine Cycle (ORC) for Waste Heat Recovery: Principles of ORC technology and its advantages over traditional Rankine cycles,Design and operational parameters for ORC systems,Integration of ORC with industrial processes for low- and medium-temperature waste heat,Case studies on ORC applications in various industries (e.g., power plants, cement, and chemical industries)
Thermoelectric Generators (TEGs): Working principle of thermoelectric devices,Materials and efficiency improvements for thermoelectric waste heat recovery,Applications in low-grade waste heat recovery,Hybrid systems combining TEGs with other energy recovery technologies

- **Heat Pumps and Absorption Refrigeration**:Principles of heat pump systems and their role in waste heat recovery,Absorption vs. compression refrigeration cycles,Use of waste heat for heating, cooling, and industrial process applications,Applications in HVAC systems, district heating, and industrial drying

- **Advanced Heat Exchanger Design and Performance**:Compact heat exchangers, plate heat exchangers, and finned tube heat exchangers,Design optimization for maximum heat recovery,Challenges in scaling up heat exchanger systems for large industrial processes

UNIT-III

- **Integration with Industrial Processes**:Process heat integration strategies: Pinch analysis and exergy analysis,Case study: Integrating WHRS with a cement plant, steel plant, or chemical refinery,Heat cascade systems for optimal energy recovery,Matching waste heat supply with demand (thermal energy storage, district heating)
- **Energy Conversion and Utilization**:Conversion of waste heat into electricity, mechanical energy, or useful heat,Thermodynamic cycles for power generation (Rankine, ORC),Cogeneration systems (Combined Heat and Power – CHP),Hybrid systems combining waste heat with renewable energy sources (e.g., solar, geothermal)
- **System Optimization and Performance Monitoring**:Key performance indicators (KPIs) for evaluating WHRS efficiency,Optimization techniques for WHRS design and operation,Monitoring and control systems for waste heat recovery units (e.g., SCADA),Strategies for maximizing heat recovery in multi-stream processes

UNIT-IV

Economic and Environmental Considerations

- **Cost-Benefit Analysis of Waste Heat Recovery**:Capital and operational costs of waste heat recovery systems,Return on investment (ROI), payback period, and lifecycle cost analysis,Financial incentives and subsidies for energy efficiency projects,Funding models for industrial energy efficiency projects (e.g., ESCOs, green financing)
- **Environmental and Sustainability Impacts**:Reducing carbon footprint through waste heat recovery,Energy savings and greenhouse gas (GHG) reduction potential,Waste heat recovery and sustainable industrial development,Role of waste heat recovery in circular economy and zero-emission technologies
- **Regulatory and Policy Framework**:Energy efficiency regulations and standards (e.g., ISO 50001),Government incentives for industrial waste heat recovery projects,Environmental regulations related to waste heat emissions and process heat recovery

UNIT-V

Future Trends and Innovations in Waste Heat Recovery

Next-Generation Materials and Technologies:Advancements in thermoelectric materials (e.g., nanomaterials, metal alloys),Emerging heat storage technologies for waste heat,Integration of nanotechnology with waste heat recovery (e.g., enhanced heat transfer fluids)

Digitalization and Industry 4.0:Smart waste heat recovery systems using sensors and IoT,Artificial Intelligence (AI) and Machine Learning (ML) for system optimization,Real-time performance monitoring and predictive maintenance

Global Market Trends:The role of waste heat recovery in global energy transitions,Trends in the adoption of WHRS in emerging economies,International case studies and best practices in waste heat recovery adoption

Texts and Reference Books:

1. Hewitt, G. F., Shires, G. L., and Bott, T. R. (1993). Process Heat Transfer, CRC Press, Florida.
2. Flynn, A. M., Akashige, T., & Theodore, L. (2019). Kern's Process Heat Transfer. John Wiley & Sons.
3. Goswami, D. Y., and Kreith, F. (2007). Energy Conversion, CRC Press.
4. Serth, R. W., & Lestina, T. (2014). Process heat transfer: Principles, applications and rulesof thumb. Academic press.
5. Beith, R. (Ed.). (2011). Small and micro combined heat and power (CHP) systems:advanced design, performance, materials and applications. Elsevier.
6. Khanna, S., & Mohan, K. (Eds.). (1996). Wealth from waste. Tata Energy Research Institute.
7. Eriksen, V. L. (Ed.). (2017). Heat Recovery Steam Generator Technology. Woodhead Publishing.
8. **"Waste Heat Recovery: Technology and Opportunities in the Industrial Sector"** by Naim G. Caglayan
9. **"Organic Rankine Cycle (ORC) Power Systems: Technologies and Applications"** by Enrico Sciubba and Sergio Silvestri
10. **"Thermoelectrics Handbook: Macro to Nano"** by D.M. Rowe
11. **"Heat Recovery Systems and Applications"** by M. Bianchi, M. Bellini, and F. Zoccoli
12. **"Energy Efficiency and Management in Industry"** by J.P. Meyer and R. C. Sweeting

Course Title	DEVELOPING ENERGY EFFICIENCY AND RENEWABLEENERGY PROJECTS-II (Program Elective Course – III)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299205	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To introduce all relevant steps as well as the issues and challenges involved in developing projects on energy efficiency and renewable energy utilization. The course also aims at discussion on policy, regulatory and other support measures that can promote such projects.

Course Outcomes: On successful completion of this course, the students will be able to	
CO 1	To understand the fundamentals Relevance of developing energy efficiency.
CO 2	To understand Procurement, land acquisition, site preparation, construction, installation, commissioning of the project.
CO 3	To understand Risk in energy efficiency and renewable energy projects and appropriate de-risking/mitigation measures and approaches, dispute resolution.
CO 4	To understand Examples and Case Studies.

UNIT-I

- **Energy Project Lifecycle Management**:Phases of energy project development (Feasibility, Design, Implementation, Operation),Stakeholder management and communication,Risk management strategies for energy projects,Project planning and scheduling tools (Gantt charts, PERT diagrams)
- **Detailed Feasibility Analysis**:Site assessment for renewable energy projects (solar, wind, biomass, hydro),Environmental, social, and regulatory considerations,Geospatial data analysis for site selection,Economic and financial viability assessment,Feasibility study tools and techniques
- **Sustainability Assessment and Circular Economy**:Environmental impact assessments (EIA),Life Cycle Assessment (LCA) for renewable energy systems,Circular economy concepts in energy projects,Sustainability standards and certification (LEED, BREEAM, ISO 14001)

UNIT-II

Project Financing and Investment

- **Financial Models for Renewable Energy Projects**:

  Financial structuring for energy projects (Debt vs Equity, Project Finance),Introduction to discounted cash flow (DCF) analysis,Financing mechanisms (Green Bonds, PPA financing, Power Purchase Agreements),Grants, subsidies, and government incentives for renewable energy projects,International financing opportunities and climate financing (e.g., Green Climate Fund)

- **Risk Analysis and Management**:Identifying and mitigating financial, technical, and regulatory risks,Sensitivity analysis and scenario planning,Contract structures and risk-sharing between parties (Developers, Investors, Government)
- **Energy Performance Contracting (EPC)**:Performance-based contracts in energy efficiency projects,Measurement and verification (M&V) standards for energy savings,Payback periods, Return on Investment (ROI), and internal rate of return (IRR)

UNIT-III

Designing and Implementing Renewable Energy Systems

- **Design and Sizing of Renewable Energy Systems**:Solar PV system design (including energy production estimation and system sizing),Wind turbine selection and farm layout optimization,Biomass, biogas, and small hydro system design considerations,Hybrid renewable energy systems (e.g., wind-solar-battery integration),Net-zero energy buildings and microgrid design.
- **Grid Integration and Smart Grid Considerations**:Energy storage systems (batteries, pumped hydro) for stabilizing renewable generation,Grid connectivity and interconnection standards,Demand-side management (DSM) and smart grid technologies,Power flow analysis for renewable energy integration.
- **Project Implementation and Procurement**:Selecting contractors and vendors,Procurement process for renewable energy projects,Quality assurance and quality control in project construction,Time management and delivery milestones for renewable energy projects

UNIT-IV

Monitoring, Optimization, and Operation

- **Project Commissioning and Operational Optimization**:Commissioning procedures for renewable energy systems,Optimization of system performance (e.g., tracking solar arrays, wind turbine efficiency),O&M (Operation and Maintenance) practices for long-term performance
- **Data Analytics and Performance Monitoring**:IoT (Internet of Things) for real-time monitoring and data collection,SCADA (Supervisory Control and Data Acquisition) systems in renewable energy projects,Key performance indicators (KPIs) for system health and energy output,Predictive maintenance strategies and tools
- **Energy Management Systems (EMS)**:Energy data analytics for improving efficiency,Energy savings monitoring and reporting,Energy management in industrial, commercial, and residential sectors,Optimizing energy consumption and reducing waste

UNIT-V

- **Renewable Energy Policy and Regulations**:National and international renewable energy policies,Feed-in Tariffs (FiTs), Power Purchase Agreements (PPAs), and Renewable Energy Certificates (RECs),Environmental regulations affecting renewable energy projects (e.g., emissions standards, EIA requirements),Energy security, grid reliability, and market design
- **Energy Efficiency Policies**:Energy efficiency regulations in building codes and standards,Energy efficiency performance labeling and certification programs,Standards for industrial, residential, and commercial energy efficiency,International agreements and frameworks (Paris Agreement, SDGs)
- **Incentives and Taxation**:Government subsidies, tax credits, and incentives for renewable energy investments,Carbon pricing and emissions trading systems (ETS),Green certifications and eco-labeling

Module 6: Case Studies and Real-World Applications

- **Case Study: Large-Scale Solar PV Projects**:Project development from feasibility to commissioning,Risk management in large solar projects,Lessons learned from solar power plants in different regions
- **Case Study: Wind Energy Projects**:Wind farm development and operational optimization,Socio-economic and environmental challenges in wind energy deployment.

  Successful wind projects and key takeaways

- **Hybrid Renewable Energy Systems**:Hybrid systems for rural electrification and off-grid applications,Case study on integrating wind, solar, and battery storage for a remote area,Hybrid systems in urban microgrids
- **Energy Efficiency in Industrial and Commercial Sectors**:Energy audits and efficiency improvement in manufacturing facilities,Industrial energy management systems and energy-saving technologies,Energy efficiency retrofitting of commercial buildings,Case studies from energy service companies (ESCOs)

Texts and Reference Books:

1. Lokey, E. (2012). Renewable energy project development under the clean development

mechanism:a guide for Latin America. Routledge.
2. Springer, R. (2013). Framework for Project Development in the Renewable Energy Sector (No. NREL/TP-7A40-57963). National Renewable Energy Lab.(NREL), Golden, CO (United States).
3. Ontario Sustainable Energy Association. (2010). Guide to developing a community renewable energy project in North America. Montreal, Canada
4. PVPS, I. (2003). 16 Case Studies on the Deployment of Photovoltaic Technologies in DevelopingCountries. International Energy Agency IEA-PVPS.T9-07
5. Trieb, F. (2006). Concentrating solar power now. DLR, Berlin, Germany.
6. Guide, L. S. R. E. (2003) Developing Renewable Energy Projects Larger Than 10 MWs atFederalFacilities. Report DOE/GO-102013-3915, US Department of Energy
7. Thomsen, K. (2014). Offshore wind: a comprehensive guide to successful offshore windfarm installation. Academic Press.
8. Winebrake, J. J. (Ed.). (2004). Alternate energy: Assessment and implementation referencebook. TheFairmont Press, Inc..
9. Chuck, C. (Ed.). (2016). Biofuels for aviation: feedstocks, technology and implementation.AcademicPress.
10. **"Renewable Energy Project Development under the Clean Development Mechanism"** by Mohammad Shamsuddin
11. **"Energy Efficiency: Towards the End of Demand Growth"** by Fereidoon P. Sioshansi
12. **"Renewable Energy Finance: Powering the Future"** by Charles W. Donovan
13. **"The Energy Efficiency Guide for Industry in Asia"** by Asian Development Bank
14. **"Handbook of Energy Efficiency and Renewable Energy"** by D.Y. Lee and N.H. O. Reddy

Course Title	HYDROGEN AND FUEL CELL TECHNOLOGIES (Program Elective Course – IV)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299206	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- The students' would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated project outcome of the aimed work.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To improve the skills in publishing technical papers in conference proceedings and journals.
CO 2	To produces factual results of their applied research idea in the Energy Engineering, from phase.
CO 3	To understand the Hydrogen Storage and Applications.
CO 4	To understand the Fuel cell usage for domestic power systems, large scale power generation.

UNIT-I

Hydrogen – Basics And Production Techniques: Hydrogen – physical and chemical properties, salient characteristics. Production of hydrogen – steam reforming – water electrolysis – gasification and woody biomass conversion – biological hydrogen production – photo dissociation – direct thermal or catalytic splitting of water.

UNIT-II

Hydrogen Storage and Applications: Hydrogen storage options – compressed gas – liquid hydrogen – Hydride – chemical Storage – comparisons. Safety and management of hydrogen, Applications of Hydrogen.

UNIT-III

Fuel Cells: History – principle - working - thermodynamics and kinetics of fuel cell process performance evaluation of fuel cell – comparison on battery vs fuel cell.

UNIT-IV

Fuel Cell – Types: Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – relative merits and demerits

UNIT-V

Application of Fuel Cell and Economics: Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell.Future trends in fuel cells.

Texts and Reference Books:

1. Barclay F.J., Fuel Cells, Engines and Hydrogen, Wiley, 2009.
2. Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications, Elsevier, UK2005.
3. Hart A.B. and G.J.Womack, Fuel Cells: Theory and Application, Prentice Hall, New York Ltd., London1989.
4. Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA 2002.
5. Kordesch K. and G.Simader, Fuel Cell and Their Applications, Wiley-Vch, Germany 1996.
6. Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation,Oklahoma, 2005.
7. Viswanathan B. and Aulice Scibioh.M, Fuel Cells – Principles and Applications, Universities Press, 2006.

Course Title	SOLAR ENERGY TECHNOLOGY (Program Elective Course – IV)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299207	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To learn and study the radiation principles with respective solar energy estimation
- To understand PV technology principles and techniques of various solar cells / materials for energy conversion
- To learn economic and environmental merits of solar energy for variety applications.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Suggest and design solar thermal based applications.
CO 2	Designing of solar photovoltaic based power systems for both domestic and industrial applications.
CO 3	Apply the concept of utilization of solar energy for the said application in an economical way.
CO 4	To understand the Solar Thermal Technologies.

UNIT-I

Solar Radiation and Collectors: Solar angles – Sun path diagrams – Radiation - extra-terrestrial characteristics - measurement and estimation on horizontal and tilted surfaces - flat plate collector thermal analysis - testing methods-evacuated tubular collectors - concentrator collectors – classification - design and performance parameters - tracking systems - compound parabolic concentrators - parabolic trough concentrators - concentrators with point focus - Heliostats – performance of the collectors.

UNIT-II

Solar Thermal Technologies: Principle of working, types, design and operation of - Solar heating and cooling systems - Thermal Energy storage systems – Solar Desalination – Solar cooker : domestic, community –Solar pond – Solar drying.

UNIT-III

Solar PV Fundamentals: Semiconductor – properties - energy levels - basic equations of semiconductor devices physics. Solar cells - p-n junction: homo and hetro junctions - metal-semiconductor interface - dark and illumination characteristics - figure of merits of solar cell - efficiency limits - variation of efficiency with band-gap and temperature - efficiency measurements - high efficiency cells – Solar thermo-photovoltaic.

UNIT-IV

Spv System Design and Applications: Solar cell array system analysis and performance prediction-Shadow analysis: reliability - solar cell array design concepts - PV system design - design process and optimization - detailed array design - storage autonomy - voltage regulation - maximum tracking - centralized and decentralized SPV systems - standalone - hybrid and grid connected system - System installation - operation and maintenances - field experience - PV market analysis and economics of SPV systems.

UNIT-V

Solar Passive Architecture: Thermal comfort - bioclimatic classification – passive heating concepts: direct heat gain - indirect heat gain - isolated gain and sunspaces - passive cooling concepts: evaporative cooling - Radiative cooling - application of wind, water and earth for cooling; shading - paints and cavity walls for cooling - roof radiation traps - earth air-tunnel. – energy efficient landscape design - thermal comfort.

Texts and Reference Books:

1. Goswami D.Y., Kreider, J. F. and Francis., "Principles of Solar Engineering', Taylor and Francis, 2000.
2. Chetan Singh Solanki, "Solar Photovoltatics – Fundamental Technologies and Applications", PHI Learning Private limited, 2011.
3. Sukhatme S.P.,. Nayak.J.P, 'Solar Energy – Principle of Thermal Storage and collection", Tata McGraw Hill, 2008.
4. Solar Energy International, "Photovoltaic – Design and Installation Manual" – New Society Publishers, 2006.
5. Roger Messenger and Jerry Vnetre, "Photovoltaic Systems Engineering", CRC Press, 2010.

Course Title	PROCESS MODELING AND SIMULATION IN RENEWABLEENERGY SYSTEMS-II (Program Elective Course – IV)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299208	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- This course is intended to impart basic skill of model development and optimization in the field of energy. The learners will be familiarized to variety of energy related field problems associated mostly with economy and environment. The main Objectives are to enable learners to develop basic skill of development of energy system model and to enable learners to use system modeling as tool for optimization vis-à-vis decision making on energy related field problems.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand modeling, its types and principles.
CO 2	The learner will understand how to develop a model, and how to apply varies strategies for differentparametric model.
CO 3	To optimize the energy systems and to understand the working principles econometric modeling.
CO 4	To Understand the Solution strategies for Lumped parameter models.

UNIT-I

- **Introduction to Modeling in Renewable Energy**:Importance of accurate system modeling,Overview of mathematical and computational tools for modeling renewable systems,Real-world applications and challenges in modeling renewable energy systems
- **Modeling of Solar Energy Systems**:Solar photovoltaic (PV) system components and operation,Modeling of PV arrays, inverters, and batteries,Performance modeling of PV systems under varying environmental conditions,Maximum power point tracking (MPPT) algorithms
- **Modeling of Wind Energy Systems**:Wind turbine modeling: aerodynamic, mechanical, and electrical aspects,Power generation models for wind turbines,Turbine control systems and optimization,Wind farm modeling, including wake effects and resource variability

UNIT-II

Module 2: Energy Storage Systems and Hybrid Systems

- **Introduction to Energy Storage**:Role of energy storage in renewable energy integration Types of energy storage systems: Batteries (Li-ion, Lead-acid), Supercapacitors, Flywheels, etc.Modeling of energy storage systems,
- **Hybrid Renewable Energy Systems**:Integration of multiple renewable energy sources (solar, wind, hydro, etc.),Hybrid system modeling for off-grid and grid-connected applications,Energy management and optimization strategies for hybrid systems

UNIT-III

Smart Grids and Renewable Energy Integration

- **Smart Grid Overview**:Basics of smart grid technologies and their importance in renewable energy integration,Smart grid components: Communication infrastructure, sensors, controllers,Role of smart grids in improving the efficiency and reliability of power systems
- **Grid Integration of Renewable Energy**:Grid stability and power quality issues with renewable energy integration,Power flow models for renewable-based power generation,Voltage and frequency regulation in grid-connected renewable systems,Power electronics and inverters in renewable energy grid integration,Dynamic modeling of power grids with renewable energy sources
- **Demand Response and Smart Metering**:Integration of demand-side management in renewable energy grids,Simulation of demand response strategies and their impacts on grid stability,Role of smart metering in energy consumption modeling.

UNIT-IV Simulation Techniques and Tools

- **Simulation Software for Renewable Energy Systems**:MATLAB/Simulink for renewable energy modeling,HOMER for hybrid system optimization,DIgSILENT PowerFactory for power system modeling,TRNSYS for thermal energy systems,OpenDSS and PSCAD for power system simulations
- **Numerical Methods for Energy System Modeling**:Time-domain simulations and dynamic modeling,Steady-state analysis and fault simulation,Sensitivity analysis and optimization techniques,Monte Carlo simulations for uncertainty analysis in renewable energy systems

UNIT-V

Case Studies and Applications

- **Solar Power Systems**:Performance analysis of solar PV systems in different geographical locations,Hybrid PV-diesel-battery systems
- **Wind Power Systems**:Offshore and onshore wind farm modeling and optimization,Case study: Modeling a wind farm for optimal energy production
- **Hybrid Systems and Microgrids**:Simulation of hybrid energy systems (wind-solar-battery),Design and optimization of a microgrid with renewable energy integration,Case study: Simulation of a rural community's energy demand using renewable sources
- **Energy Storage and Grid Interaction**:Simulation of energy storage integration for smoothing out intermittent renewable power,Case study on battery storage in large-scale wind or solar farms,Grid services provided by energy storage systems (voltage support, frequency regulation)

Texts and Reference Books:

1. Rao S. S. (2004). Engineering Optimization: Theory and Practice, Third Edition, New Age International
2. Kennedy P. (2008). A Guide to Econometrics, Sixth Edition, Wiley-Blackwell
3. Meier P. (1984). Energy Systems Analysis for Developing Countries, Springer Verlag
4. Ravindran A. Ragsdell K. M. and Reklaitis G. V. (2006). Engineering Optimization: methods and applications, Second Edition, Wiley
5. Neufville R. De. (1990). Applied Systems Analysis: Engineering Planning and Technology Management, McGraw Hill
6. Hangos, K., & Cameron, I. (2001). Process modelling and model analysis. Academic Press
7. James, J. C. (1989). Process modeling, simulation and control for chemical engineers. McGraw-Hill.
8. Close, C. M., & Frederick, D. K. (2002). Modeling and analysis of dynamic systems. JohnWiley & Sons.

- **"Renewable Energy Systems: Design and Analysis with Induction Generators"** by B.K. Hodge
- **"Wind Energy Handbook"** by Tony Burton, David Sharpe, Nick Jenkins, and Ervin Bossanyi
- **"Solar Engineering of Thermal Processes"** by John A. Duffie and William A. Beckman
- **"Renewable Energy Systems: A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions"** by Henrik Lund
- **"Energy Storage Systems: Operation and Control"** by Jun Yan, Bin Xu, and Zhaoyu Wang

Course Title	WIND ENERGY LAB				M. Tech. RE II Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299209	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		0	0	4	2	50	50	100
					End Exam Duration: 3Hrs		

List of Experiments:

1. Determination of Average Wind Energy Density by using a Anemometer
2. Aerodynamic Pressure Distribution Study of a Wind Turbine Blade in a Wind Tunnel under Constant Velocity
3. Aerodynamic Force Study of a Wind Turbine Blade in a Wind Tunnel with varying Velocity
4. Aerodynamic Force Study of a Wind Turbine Blade with varying pitch
5. Velocity profiling of a Wind Turbine Blade and Calculation of Drag Coefficient
6. Study of Wind Generator Electrical Output Characteristics for Different Types of Airfoil Assemblies
7. Determination of Power Production in a Wind Turbine as a Function of Wind Speed
8. To study the Variation of Coefficient of Power with respect to Wind Speed for a Wind Turbine

Course Title	CONTROL SYSTEMS AND SIMULATION LAB				M. Tech. RE II Sem (R22)		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299210	PCC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		0	0	4	2	50	50	100
					End Exam Duration: 3Hrs		

List of Experiments:

1. Characteristics of Synchros
2. Transfer Function of DC Machine
3. Characteristics of Magnetic Amplifiers
4. Time Response of Second Order System
5. Effect of P, PI and PID controller of a Second Order System
6. Lead and Lag Compensated Design in Frequency Domain using MATLAB
7. Linear System Analysis (Time Domain using MATLAB)
8. Linear System Analysis (Root Locus and Bode Plot of Linear Time Invariant Systems using MATLAB
9. State Space Model for Classical Transfer Function using MATLAB

Course Title	TECHNICAL SEMINAR				M. Tech. RE II Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299211	MC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		0	0	4	2	100	--	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		
Course Objectives: •							
Course Outcomes: On successful completion of this course, the students will be able to							
CO 1	Students will learn to survey the relevant literature such as books, national/international refereed journals and contact Faculty for the selected topic of seminar.						
CO 2	Students will be able to use different experimental techniques.						
CO 3	Students will learn to write technical reports.						
CO 4	Students will develop skills to present and defend their Report in front of audience.						

Syllabus Contents: Students can take up small topic in the field of Renewable Energy as seminar Topic. It can be related to solution to an engineering problem, verification and analysis of experimental data available, conducting experiments on various subjects, material characterization, studying a software tool for the solution of an engineering problem etc. The Seminar Topic Must present in presence of Concerned Faculty and co students.

Course Title	SANSKRIT FOR TECHNICAL KNOWLEDGE (Audit Course – II)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2270A03	Audit	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	0	40	--	40
Mid Exam Duration: 2Hrs								

Course Objectives:

- To get a working knowledge in illustrious Sanskrit, the scientific language in theworld
- Learning of Sanskrit to improve brain functioning
- Learning of Sanskrit to develop the logic in mathematics, science &othersubjects enhancing the memory power
- The engineering scholars equipped with Sanskrit will be able toexplore the huge knowledge from ancient literature.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Understanding basic Sanskrit language.
CO 2	Ancient Sanskrit literature about science & technology can be understood.
CO 3	Being a logical language will help to develop logic in students.

- Alphabets in Sanskrit,
- Past/Present/Future Tense,
- Simple Sentences
- Order
- Introduction of roots
- Technical information about Sanskrit Literature
- Technical concepts of Engineering-Electrical, Mechanical,Architecture, Mathematics

b. Course Reference Materials

1. Abhyaspustakam" – Dr.Vishwas, Samskrita- Bharti Publication, New Delhi

2. Teach Yourself Sanskrit" PrathamaDeeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New DelhiPublication.

3. India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., NewDelhi

Course Title	PEDAGOGY STUDIES (Audit Course – II)					M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2270A06	Audit	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	0	40	--	40
Mid Exam Duration: 2Hrs								

Course Objectives:

- Review existing evidence on their view topic to inform programed design and policymaking undertaken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	What pedagogical practices are being used by teachers in formal and informal classroomsin developing countries?.
CO 2	What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
CO 3	How can teacher education (curriculum and practicum) and the school curriculumand guidance materials best support effective pedagogy?

Introduction and Methodology:

- Aims and rationale, Policy background, Conceptual framework andterminology
- Theories of learning, Curriculum, Teacher education.
- Conceptual frame work, Research questions**.**
- Overview of methodology and Searching.
- Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries. Curriculum, Teacher education.
- Evidence on the effectiveness of pedagogical practices
- Methodology for the in depth stage: quality assessment of included studies.
- How can teacher education (curriculum and practicum)and the school curriculum andguidance materials best support effective pedagogy?
- Theory of change.
- Strength and nature of the body of evidence for effective pedagogicalpractices.
- Pedagogic theory and pedagogical approaches.
- Teachers‟ attitudes and beliefs and Pedagogic strategies.
- Professionaldevelopment:alignmentwithclassroompracticesandfollow- up support
- Peer support
- Support from the head teacher and the community.
- Curriculum and assessment
- Barriers to learning: limited resources and large class sizes

Research gaps and future directions

- Research design
- Contexts
- Pedagogy
- Teacher education
- Curriculum and assessment
- Dissemination and research impact.

Text and Reference Books:

1. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare,31 (2):245-261.
2. Agrawal M (2004) Curricular reform in schools: The importance of evaluation,Journalof Curriculum Studies, 36 (3):361-379.
3. Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teachereducation research project (MUSTER) country report 1. London:DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33 (3):272–282.
5. Alexander RJ (2001) Culture and pedagogy: International comparisons inprimaryeducation. Oxford and Boston:Blackwell.
6. Chavan M (2003) Read India: A mass scale, rapid, „learning to read" campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

Course Title	ENGLISH FOR RESEARCH PAPER WRITING (Audit Course – II)				M. Tech. RE II Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2270A01	Audit	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		2	0	0	0	40	--	40
Mid Exam Duration: 2Hrs							

Course Objectives:

- Review existing evidence on their view topic to inform programed design and policymaking undertaken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	Understand that how to improve your writing skills and level of readability.
CO 2	Learn about what to write in each section.
CO 3	Understand the skills needed when writing a Title Ensure the good quality of paper at very first- timesubmission.
CO 4	To understand the kills are needed when writing the Methods, skills needed when writing the Results, skills are needed whenwriting the Discussion.

UNIT-I

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences,Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness.

UNIT-II

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper,Abstracts. Introduction.

UNIT-III

Review of the Literature, Methods, Results, Discussion, Conclusions, the Final Check.

UNIT-IV

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills areneeded when writing an Introduction, skills needed when writing a Review of the Literature.

UNIT-V

kills are needed when writing the Methods, skills needed when writing the Results, skills are needed whenwriting the Discussion, and skills are needed when writing the Conclusions.Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission.

Text Books:

1. Gold bort R (2006) Writing for Science, Yale University Press (availableon Google Books)
2. Day R (2006) How to Write and Publish a Scientific Paper,Cambridge University Press
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM.
4. Adrian Wall work , English for Writing Research Papers, Springer NewYork Dordrecht Heidelberg London, 2011.

M.TECH.-
III- SEMESTER SYLLABUS

Course Title	ECONOMICS AND FINANCING OF RENEWABLE ENERGYSYSTEMS (Program Elective Course - V)				M. Tech. RE III Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299301	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- Economics of energy and its financing is a broad scientific area which includes topics related to economic aspects of supply and use of energy in society in general and the nation as a whole for its growth and development needs. Hence, it is very important for the students to understand the basics of economic principles that govern the supply and demand of energy in the context of modern civilization. This course aims at bridging the technological aspects of energy resources to that of its economic principles.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To impart knowledge on fundamentals of economic principles and their applications in the broad field of supply and demand of energy.
CO 2	To make students inquisitive about the problems of energy economics and arousing theirinterest on practical problem solving skills.
CO 3	To Understand the Application of econometrics.
CO 4	To Understand the Fiscal, financial and other incentives for promotion of renewable energy systems and their effect on financial and economic viability, electricity tariff types.

UNIT-I

Energy economics: Basic concepts, energy data, energy cost, energy balance. Relevance of economic and financial viability evaluation of renewable energy technologies, Basics of engineering economics.

UNIT-II

Energy accounting framework: Economic theory of demand, production and cost market structure; National energy map of India, Energy subsidy – National and international perspectives..

UNIT-III

Concepts of economic attributes: Calculation of unit cost of power generation from different sources with examples, different models and methods, Social cost – benefit analysis of renewable energy technologies. Financial feasibility evaluation of renewable energy technologies, Technology dissemination models, Volume and learning effects on costs of renewable energy systems, Dynamics of fuel substitution by renewable energy systems and quantification of benefits

UNIT-IV

Application of econometrics: input and output optimization; energy planning and forecasting - different methods, Economic approach to environmental protection and management.

UNIT-V

Financial incentives: Fiscal, financial and other incentives for promotion of renewable energy systems and their effect on financial and economic viability, electricity tariff types. Financing of renewable energy systems, Carbon finance potential of renewable energy technologies and impact of other incentives. Software for financial evaluation of renewable energy systems. Casestudies on financial and economic feasibility evaluation of renewable energy projects.

Texts and Reference Books:

1. Campbell, H. F., & Brown, R. P. (2003). Benefit-cost analysis: financial and economic appraisal using spreadsheets. Cambridge University Press.
2. Kandpal, T. C., & Garg, H. P. (2003). Financial evaluation of renewable energy technologies. MacMillam India Limited.
3. Park, C. S. (2002). Contemporary engineering economics (Vol. 4). Upper Saddle River, NJ: Prentice Hall.
4. Kroemer, K. H., Kroemer, H. B., & Kroemer-Elbert, K. E. (2001). Ergonomics: how to design for ease and efficiency. Pearson College Division.
5. Dorsman, A. B., Ediger, V. Ş., & Karan, M. B. (Eds.). (2018). Energy Economy, Financeand Geostrategy. Springer.
6. Banks, F. E. (2012). Energy economics: a modern introduction. Springer Science & Business Media.
7. Thuesen G. J. and Fabrycky W. J. (2001); Engineering Economy, Ninth Edition, PrenticeHall India

Course Title	ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL (Program Elective Course - V)				M. Tech. RE III Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks	
2299302	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To impart knowledge on the atmosphere and its present condition, global warming and eco-legislations.
- To detail on the sources of air, water and noise pollution and possible solutions for mitigating heirdegradation.
- To elaborate on the technologies available for generating energy from waste.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand Global atmospheric change – greenhouse effect.
CO 2	To understand Air Pollution**:** Pollutants - sources and effect – air pollution meteorology – atmospheric dispersion – indoor air quality - control methods and equipment.
CO 3	To understand the Other Types of Pollution from Industries.
CO 4	To understands Radiation pollution: types, sources, effects, control of radiation pollution.

UNIT-I

Introduction: Global atmospheric change – greenhouse effect – Ozone depletion - natural cycles - massand energy transfer – material balance – environmental chemistry and biology – impacts – environmental. Legislations.

UNIT-II

Air Pollution: Pollutants - sources and effect – air pollution meteorology – atmospheric dispersion – indoor airquality - control methods and equipments - issues in air pollution control – air sampling and measurement.

UNIT-III

Water Pollution: Water resources - water pollutants - characteristics – quality - water treatment systems – waste water treatment - treatment, utilization and disposal of sludge - monitoring compliance withstandards.

UNIT-IV

Waste Management: Sources and Classification – Solid waste – Hazardous waste - Characteristics – Collection and Transportation - Disposal – Processing and Energy Recovery – Waste minimization.

UNIT-V

Other Types of Pollution From Industries: Noise pollution and its impact - oil pollution - pesticides - instrumentation for pollution control - water pollution from tanneries and other industries and their control – environment impact assessment for various projects – case studies. Radiation pollution: types, sources, effects, control of radiation pollution.

Texts and Reference Books:

1. Arcadio P Sincero and G.A. Sincero, Environmental Engineering – A Design Apporach, Prentice Hall of India Pvt. Ltd, New Delhi, 2002.
2. Bishop P., Pollution Prevention: Fundamentals and Practice, McGraw-Hill International Edition,McGraw-Hill book Co, Singapore, 2000.
3. G. Masters, Introduction to Environmental Engineering and Science Prentice Hall of India Pvt.Ltd,New Delhi, 2003.
4. Gilbert M. Masters, Introduction to Environmental Engineering and Science, 2nd Edition, Prentice Hall, 1998.
5. H.Ludwig, W. Evans, Manual of Environmental Technology in Developing Countries, International Book Company, Absecon Highlands N.J. (1991).
6. H.S. Peavy, D.R. Rowe and G. Tchobanoglous, Environmental Engineering McGraw- Hill BookCompany, NewYork, (1985).
7. Rao C.S., Environmental Pollution Control Engineering, 2nd Edition, New Age International Publishers, 2006.

Course Title	FUELS AND COMBUSTION TECHNOLOGY (Program Elective Course - V)				M. Tech. RE III Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299303	PEC	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- To impart knowledge on fossil fuel and their combustion characteristics.
- To make students inquisitive about the problems of combustion.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand the fuel combustion process.
CO 2	Apply fundamental aspects of combustion related problem and an understanding on the combustion appliances.
CO 3	To understand the Natural gas and its derivatives: Classification of gaseous fuels.
CO 4	To understand the Emissions from fuel combustion systems.

UNIT-I

Basics of fuels: Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points; liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition and gaseous fuels.

UNIT-II

Coal as a source of energy: Coal reserves – World and India, Coal liquefaction process, various types of coal and their properties, Origin of coal, composition of coal, analysis and properties of coal, Action of heat on coal, caking and coking properties of coal; Processing of coal: Coal preparations, briquetting, carbonization, gasification and liquefaction of coal, Coal derived chemicals.

UNIT-III

Petroleum as a source of energy: Origin, composition, classification of petroleum, grading of petroleum; Processing of petroleum: Distillation of crude petroleum, petroleum products, purification of petroleum products – thermal processes, catalytic processes, specifications and characteristics of petroleum products.

UNIT-IV

Natural gas and its derivatives: Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition and density.

UNIT-V

Principles of combustion: Chemistry and Stoichiometric calculation, thermodynamic analysis and concept of adiabatic flame temperature; Combustion appliances for solid, liquid and gaseous fuels: working, design principles and performance analysis.

Emissions from fuel combustion systems: Pollutants and their generation, allowed emissions,strategies for emission reduction, Euro and BIS norms for emission, recent protocols.

Texts and Reference Books:

1. Raghavan, V. (2016). Combustion technology: essentials of flames and burners. JohnWiley & Sons.
2. Sharma, S. P., & Mohan, C. (1984). Fuels and combustion. Tata McGraw Hill
3. Sarkar, S. (1974). Fuels and combustion. Universities Press. Orient Longman
4. Sharma, B. K. (1998). Fuels and Petroleum Processing. Krishna Prakashan Media.
5. Hsu, C. S., & Robinson, P. R. (Eds.). (2017). Springer handbook of petroleum technology. Springer.
6. Zheng, C., & Liu, Z. (Eds.). (2017). Oxy-fuel Combustion: Fundamentals, Theory andPractice. Academic Press.
7. Maurya, R. K., Maurya, R. K., & Luby. (2018). Characteristics and control of lowtemperature combustion engines. Springer.

Course Title	ELECTRIC VEHICLE TECHNOLOGY (Open Elective)				M. Tech. RE III Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299304	OE	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- The objective of this course is to provide an advanced level understanding on electric vehicles and batteries that are used in such vehicles. The course will impart knowledge on the fundamental electrochemistry of battery systems, design of electric vehicle, business model, policy, impact etc.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To get the knowledge of electric vehicles and batteries systems.
CO 2	To get the knowledge of design of electric vehicle, business model, policy, impact etc.
CO 3	To understand the Fundamental of Rechargeable batteries.
CO 4	To u understand the EVs in infrastructure system.

UNIT-I

Review of Conventional Vehicle: Introduction to Hybrid Electric Vehicles: Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving, Energy consumption Concept of Hybrid Electric Drive Trains

UNIT-II

Architecture of Hybrid Electric: Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Electric Propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor.

UNIT-III

Sizing the drive system: Design of Hybrid Electric Vehicle and Plug-in Electric Vehicle, Energy Management Strategies, Automotive networking and communication, EV and EV charging standards, V2G, G2V, V2B, V2H.

UNIT-IV

Energy Storage Requirements:- Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices.

Fundamental of Rechargeable batteries: Electrochemistry, Lithium batteries, Nickel metal hydride battery, Lead-acid battery, High temperature batteries for back-up applications, Flow batteries for load leveling and large scale grid application, Battery applications for stationary and secondary use, Battery chargers and battery testing procedures, Battery management, Regulations and safety aspects of high voltage batteries, Super capacitors.

UNIT-V

Business: E-mobility business, electrification challenges, Business- E-mobility business, electrification challenges, Connected Mobility and Autonomous Mobility- case study E-mobility Indian Roadmap Perspective.

Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.Simulations and case studies in above mentioned areas.

Texts and Reference Books:

1. Emadi, A. (Ed.). (2014). Advanced electric drive vehicles. CRC Press.
2. Larminie, J., & Lowry, J. (2012). Electric vehicle technology explained. JohnWiley &Sons.
3. Fenton, J., & Hodkinson, R. (2001). Lightweight electric/hybrid vehicle design. Elsevier.
4. Dincer, I., Hamut, H. S., & Javani, N. (2016). Thermal management of electricvehiclebattery systems. John Wiley & Sons.
5. Williamson, S. S. (2013). Energy management strategies for electric and plug-inhybridelectric vehicles. New York, NY: Springer.
6. Pistoia, G., & Liaw, B. (Eds.). (2018). Behaviour of Lithium-Ion Batteries in ElectricVehicles: Battery Health, Performance, Safety, and Cost. Springer.
7. Reddy, T. B. (2011). Linden's handbook of batteries (Vol. 4). New York: Mcgraw-hill.
8. Larminie, J., & Lowry, J. (2012). Electric vehicle technology explained. JohnWiley &Sons.

Course Title	OPERATIONS RESEARCH (Open Elective)				M. Tech. RE III Sem		
Course Code	Category	Hours/Week		Credits	Maximum Marks		
2299305	OE	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs		

Course Objectives:

- The objective of this course is to enable the student to understand and analyse managerial and engineeringproblems to equip him to use the resources such as capitals, materials, productions, controlling, directing, staffing, and machines more effectively.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understands the Introduction to Operations Research (OR.)
CO 2	To understand the Transportation and Assignment Problems.
CO 3	To understand the Game theory: Optimal solution of two person zero sum games
CO 4	To understand the Replacement and Maintenance Analysis: Introduction – Types of Maintenance.

UNIT - I

Introduction to OR

Introduction to Operations Research (OR): OR definition - Classification of Models, modeling –Methods of solving OR Models, limitations and applications of OR models Linear Programming(LP): Problem Formulation, Graphical Method, Simplex Method, Big-M Method, Two–Phase Simplex Method, - Degeneracy, Optimal Solutions; Concept of dual theorem

UNIT - II

Transportation and Assignment Problems

Transportation and Assignment Problems: Transportation Problem – Formulation; Different Methods of Obtaining Initial Basic Feasible Solution –North West Corner Rule, Least Cost Method, Vogel's Approximation Method; Optimality Method – Modified Distribution (MODI) Method; Special Cases – Unbalanced Transportation Problem, Degenerate Problem. Assignment Problem – Formulation, Hungarian Method for Solving Assignment Problems, Traveling Salesman problem.

UNIT – III

Game theory & Job Sequencing:

Game theory: Optimal solution of two person zero sum games, the max min and min max principle. Games without saddle points, mixed strategies.Reduction by principles of dominance, arithmetic, algebraic method and graphical method.

Job Sequencing: Introduction to Job shop Scheduling and flow shop scheduling, Solution of Job Sequencing Problem, Processing of n Jobs through two machines, Processing of n Jobs through m machines, graphical method.

UNIT - IV

Queuing Theory & Inventory Control

Queuing Theory: Introduction – Terminology, Arrival Pattern, Service Channel, Population, Departure Pattern, Queue Discipline, Single Channel Models with Poisson Arrivals, Exponential Service Times with infinite and finite queue length; Multichannel Models with Poisson Arrivals, Exponential Service Times with infinite queue length.

Inventory Control: Introduction, Deterministic models – EOQ model with and without shortages, Production model, Buffer stock and discount inventory models with single price breaks. Selective inventory control.

UNIT - V

Replacement and Maintenance Analysis & DP

Replacement and Maintenance Analysis: Introduction – Types of Maintenance, Make or buy decision. Types of Replacement Problems, Determination of Economic Life of an Asset, and Simple Probabilistic Model for Items which completely fail-Individual Replacement Model, Group Replacement Model.

Dynamic Programming (DP): Introduction –Bellman's Principle of Optimality – Applications of Dynamic Programming, Solution of Linear Programming Problem by DP.

Text Books:

1. Sharma S.D., Operations Research: Theory, Methods and Applications, 15th Edition, KedarNathRam Nath, 2018.
2. Taha H.A., Operations Research, 9th Edition, Prentice Hall of India, New Delhi, 2020.

Reference Books:

1. Hiller F.S., and Liberman G.J., Introduction to Operations Research, 7th Edition, Tata McGraw Hill, 2010.
2. Sharma J.K., Operations Research: Theory and Applications, 4th Edition, Laxmi Publications, 2009.
3. Prem kumar Gupta and Hira, Operations Research, 3rd Edition, S Chand Company Ltd., New Delhi, 2003.
4. Pannerselvam R., Operations Research, 2nd Edition, Pentice Hall of India, New Delhi, 2006.
5. Sundaresan.V, and GanapathySubramanian.K.S, Resource Management Techniques: Operations Research, A.R Publications, 2015

Course Title	COMPOSITE MATERIALS (Open Elective)				M. Tech. RE III Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299306	OE	L	T	P	C	Continuous Internal Assessment	End Exams	Total
		3	0	0	3	40	60	100
Mid Exam Duration: 2Hrs					End Exam Duration: 3Hrs			

Course Objectives:

- The objective of this course is to Sensors based on HBLS Smart Materials - Piezoelectric Sensors Magnetostrictive Sensors Techniquesof Self Sensing MEMS Sensors Low bandwidth - High strain generating (LBHS) materials machines more effectively.

Course Outcomes: On successful completion of this course, the students will be able to

CO 1	To understand Introduction to Smart Materials.
CO 2	To understand High bandwidth - Low strain generating (HBLS) Smart Materials.
CO 3	To understand the Low bandwidth - High strain generating (LBHS) materials.
CO 4	To understand the Sensors based on HBLS Smart Materials - Piezoelectric Sensors Magnetostrictive Sensors Techniquesof Self Sensing MEMS Sensors.

UNIT-I

Introduction to Smart Materials

Introduction to Smart Materials: What is Intelligence? Artificial intelligence Vs. embedded Intelligence, Definition of smart material, need for smart materials, classifications of smart systems, components of a smart systems, smart system applications, the role of Smart Materials in developing Intelligent Systems and Adaptive Structures.

UNIT - II

High bandwidth - Low strain generating (HBLS) Smart Materials

Piezoelectric Materials – constitutive relationship, electromechanical coupling coefficients, piezoelectric constants, piezoceramic materials, variation of coupling coefficients in hard and soft piezoceramics, polycrystalline vs single crystal piezoelectric materials, polyvinyldene fluoride, piezoelectric composites. Magnetostrictive Materials – constitutive relationship, magneto-mechanical coupling coefficients, Joule Effect, Villari Effect, Matteuci Effect, Wiedemann effect, Giant magnetostriction in Terfenol-D, Terfenol-D particulate composites, Galfenol and Metglas materials.

UNIT - III

Low bandwidth - High strain generating (LBHS) materials

Low bandwidth - High strain generating (LBHS) materials: Shape Memory Alloys (SMA) – Introduction, Phenomenology, Influence of stress on characteristic temperatures, Modelling of shape memory effect. Vibration control through shape memory alloys. Design considerations, multiplexing embedded NiTiNOL actuators. Electro-active Polymers (EAP)- Introduction, Phenomenology, Influence of stress on characteristic temperatures.

UNIT - IV

Smart actuators

Based on HBLS smart materials: Piezoelectric Actuators – Induced Strain actuation model, Unimorph and Bimorph Actuators, Actuators embedded in composite laminate, Impedance matching in actuator design, Feedback Control, Pulse Drive, Resonance Drive. Magnetostrictive Actuators Magnetostrictive Mini Actuators, Thermal instabilities, Discretely distributed actuation, Manetostrictive Composites.

Based on LBHS Smart Materials - Shape Memory Alloy based actuators for Shape Control, Electro-active Polymers for Work-Volume Generation.

UNIT - V

Smart sensors:

Sensors based on HBLS Smart Materials - Piezoelectric Sensors Magnetostrictive Sensors Techniquesof Self Sensing MEMS Sensors.

Sensors based on LBHS Smart Materials - EAP based sensors, SMA based encoders, Optical Fibre based Sensing.

Text Books:

1. M.V. Gandhi, B.D. Thompson" Smart Materials and Structures" Springer Science & Business Media, 31-May-1992.

Reference Books:

1. Brian Culshaw, Smart Structures and Materials, Artech House, 2000.
2. Gauenzi, P., Smart Structures, Wiley, 2009.
3. Cady, W. G., Piezoelectricity, Dover Publication

<table>
<tr><td colspan="2">Course Title</td><td colspan="5">DISSERTATION PHASE – 1</td><td colspan="3">M. Tech. RE III Sem</td></tr>
<tr><td>Course Code</td><td>Category</td><td colspan="3">Hours/Week</td><td>Credits</td><td colspan="3">Maximum Marks</td></tr>
<tr><td rowspan="2">2299307</td><td rowspan="2">Project</td><td>L</td><td>T</td><td>P</td><td>C</td><td>Continuous Internal Assessment</td><td>End Exam</td><td>Total</td></tr>
<tr><td>0</td><td>0</td><td>20</td><td>10</td><td>100</td><td>00</td><td>100</td></tr>
<tr><td colspan="6">Internal Assessment</td><td colspan="3"></td></tr>
<tr><td colspan="9">Course Objectives: The course is designed to students,
•</td></tr>
<tr><td colspan="9">Course Outcomes: On successful completion of this course, the student will be able to</td></tr>
<tr><td>CO 1</td><td colspan="8">Students will learn to survey the relevant literature such as books, national/international refereed journals and contact resource persons for the selected topic of research.</td></tr>
<tr><td>CO 2</td><td colspan="8">Students will be able to use different experimental techniques.</td></tr>
<tr><td>CO 3</td><td colspan="8">Students will be able to use different software/ computational/analytical tools.</td></tr>
<tr><td>CO 4</td><td colspan="8">Students will be able to design and develop an experimental set up/ equipment/test rig.</td></tr>
<tr><td>CO 5</td><td colspan="8">Students will be able to conduct tests on existing set ups/equipment’s and draw logical conclusions from the results after analyzing them.</td></tr>
</table>

The Project Work will start in semester III and should preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution. Seminar should be based on the area in which the candidate has undertaken the dissertation work as per the common instructions for all branches of M. Tech. The examination shall consist of the preparation of report consisting of a detailed problem statement and a literature review. The preliminary results (if available) of the problem may also be discussed in the report. The work has to be presented in front of the examiners panel set by Head and PG coordinator. The candidate has to be in regular contact with his guide and the topic of dissertation must be mutually decided by the guide and student.

Course Title	CO-CURRICULAR ACTIVITIES				M. Tech. RE III Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299308	PR	L	T	P	C	Continuous Internal Assessment	End Exam	Total
		0	0	0	2	--	--	--
Course Objectives: The course is designed to students, • The objective of the co-curricular is to enable the student to take up investigative study in the field of Mechanical engineering and to publish paper in conference/journal/attending work shop.								

The following are the rules and regulation for Mechanical Relevant Projects:

1. The student has to spend 30Hrs in the semester on any relevant topic and submit a report forevaluation.
2. The project is evaluated for 50 marks in the semester by a committee consisting of head of thedepartment, project mentor and one senior faculty member of the department.
3. In case, if a student fails, he/she shall resubmit the report.

M.TECH.-
IV- SEMESTER SYLLABUS

Course Title	DISSERTATION PHASE – 2					M. Tech. RE IV Sem		
Course Code	Category	Hours/Week			Credits	Maximum Marks		
2299401	Project	L	T	P	C	Continuous Internal Assessment	End Exam	Total
		0	0	32	16	50	50	100
Internal Assessment						External Assessment		
Course Objectives: The course is designed to students, •								
Course Outcomes: On successful completion of this course, the student will be able to								
CO 1	Students will develop attitude of lifelong learning and will develop inter personal skills to deal wtihpeople working in diversified field will.							
CO 2	Students will learn to write technical reports and research papers to publish at national andinternational level.							
CO 3	Students will develop strong communication skills to defend their work infront of technically qualified audience.							

It is a continuation of Project work started in semester III. He has to submit the report in prescribed format and also present a seminar. The dissertation should be presented in standard format in a reputed journal as provided by the department. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) of solution and results and discussion. The report must bring out the conclusions of the work and future scope for the study.

The work has to be presented in front of the examiners panel consisting of an approved external examiner, an internal examiner and a guide, co-guide etc. as decided by the Head and PG coordinator. The candidate has to be in regular contactwith his guide.