PONDICHERRY UNIVERSITY

DEPARTMENT OF GREEN ENERGY TECHNOLOGY

MADANJEET SCHOOL OF GREEN ENERGY TECHNOLOGIES
PUDUCHERRY- 605 014

B.Tech. Energy Science and Technology

Regulation and Syllabus (Draft)

PROGRAMME UNDER NATIONAL EDUCATIONIONAL POLICY (NEP2020)

MARCH 2024

1. Admission:

1.1 Eligibility

a) Candidates for admission to the first semester of the 8 semester B.Tech. degree programme should be required to have passed:

The Higher Secondary Examination of the (10+2) curriculum (Academic Stream) prescribed by the different State Boards/ Central Boards or any other examination equivalent there to with minimum of 45% marks (40% marks in case of candidates belonging to reserved category) in aggregate of subjects – Mathematics, Physics and Chemistry.

b) Candidates for admission through Lateral entry into second year (third semester) of the 8 semester B.Tech. degree programme should be required to have passed:

Passed Minimum THREE years Diploma /TWO years (Lateral Entry) Diploma in Engg., /Technology examination with at least 50% marks (45% marks in case of candidates belonging to reserved category).

1.2 Admission Process

Selection of the eligible candidates shall be done by the Pondicherry University through common university entrance test (CUET) or any other mode of examination as decided by the Admission Committee of the Pondicherry University.

2. Age Limit:

As per applicable AICTE norms.

3. Duration of the Programme :

The Bachelor of Technology degree programme shall extend over a period of 8 semesters spread over 4 academic years – two semesters constituting one academic year. The duration of each semester shall normally be 90 days.

4. Program Structure

- The medium of instruction is English.
- A student admitted to the B.Tech programme in a particular branch of engineering will earn the degree in that branch by fulfilling all the requirements prescribed in the regulations during the course of study.
- The student is also permitted to opt for earning an **Honors degree in the same discipline of Technology (or) a Minor degree in another discipline of Technology** in addition to the degree in their own discipline. The student will be allowed to exercise this option at the end of

first year based on his academic performance in the first year. The students admitted through lateral entry can exercise this option at the end of third semester, based on the GPA scored in the third semester examination.

- The student opting for B.Tech degree with **Honors or B.Tech degree with Minor** is required to earn additional 21 credits starting from the **third semester**. The students admitted in the second year through lateral entry and opting for Honors / Minor degree will earn the additional 21 credits starting from the **third semester**.

5. Eligibility for the award of B.Tech. Degree:

No candidate shall be eligible for the award of the degree of Bachelor of Technology, unless he/she has undergone the course for a period of 8 semesters (4 academic years) / 6 semesters (3 academic years for Lateral Entry candidates) in the Faculty of Madanjeet School of Green Energy Technologies and has passed the prescribed examinations in all the semesters. Details regarding the possible exit for a B.Tech student – in line with one of the goals of the National Education Policy (NEP) 2020 are provided in section 13.

6. Branches of Study:

The University offers B.Tech. programmes in the following branches:

- Computer Science & Engineering
- Electronics & Communication Engineering
- Energy Science and Technology
- Materials Science and Technology

The branch allocation shall be ordinarily done at the time of admission of the candidate to the first semester.

7. Course Structure and Subjects of Study:

Definition of Credit:

1 Hour Lecture (L) per week	1 Credit
1 Hour Tutorial (T) per week	1 Credit
2 Hours Practical (P) per week	1 Credit

Range of Credits: The total credits of all the branches for the four-year B. Tech. degree Programme shall be in the range of 160 to 172 (Minor variation is allowed as per AICTE guidelines). “Minor Degree or Honors will cumulatively require additional 20 (or) 21 credits in the specified area in

addition to the credits essential for obtaining the Under Graduate Degree in Major Discipline".

Type of Degree	B.Tech (XXX)	B.Tech (XXX) (Hons.)	B.Tech (XXX) with Minor (YYY)
Credits Requirements **	160 -172	160 -172 + (20/21)	160-172 + (20/21)

** Minimum credit requirements specified in the AICTE regulations are discipline specific permitting minor deviations from the norms.

The subjects of study shall include theory, practical courses and project work/internships as given in the curriculum and shall be in accordance with the prescribed syllabus.

The curriculum of every programme will have courses that are categorized as follows:

Sl. No	Category	Minimum Credits #
1.	Humanities, Social Sciences and Management Courses (HSM)	12
2.	Basic Science Courses (BSC)	21
3.	Engineering Science Courses (ESC)	23-28
4.	Professional Core Courses (PCC)	62-72 2/3 Theory & 1/3 Practical
5.	Professional Elective Courses (PEC)	9-16
6.	Open Elective Courses (OEC)	9 -16
7.	Professional Activity Courses (PAC) (Includes Project work, Seminar, Internship)	16-18
8.	Mandatory Courses (MC) [Environmental Sciences, Sports and Yoga (or) NSS/NCC, Induction Program, Indian Constitution,Essence of Indian Knowledge Tradition, etc.]	0 (6-9 Credits Equivalent)

The minimum credit requirement in each category is only normative and the actual credit distribution for various disciplines as specified by AICTE are given in annexure-1.

Each course will have either one or more of three components namely Lecture (L), Tutorial(T) and Practice (P). Each course is assigned credits as detailed below:

- Theory courses will carry either 3 or 4 credits - 3 credits for courses with 3 lecture periods per week and 4 credits for courses with 3 lecture periods and 1 tutorial period (or) 2 practical period per week.
- All Elective courses including online courses will carry maximum 3 (or) 4 credits. The student can earn the credits towards the Open Elective Courses (OEC) by completing the online courses offered in NPTEL anytime between third and seventh semester on prior approval of the courses by the Academic Courses Committee of the Institute. Credits earned through the NPTEL courses will be confined to 2 or 3 credits and subject to a maximum of 9 credits during the entire program of study.

- Practical courses will normally carry either 1 or 2 credits; 1 credit for courses with 2 hr practice periods per week and 2 credit for courses with 4 hr practice periods per week.
- Out of total credits required for successful completion of the degree, 14 to 22 credits can be assigned for Project work and/or Internship.
- Mandatory non-credit courses carry zero credit. However requires a pass of 40%.

8. Examinations:

The theory and practical examinations shall comprise continuous internal assessment throughout the semester in all subjects as well as university examinations conducted by Pondicherry University at the end of the semester (November / December or April / May).

8.1. Evaluation Scheme

All Credit courses are evaluated for 100 marks comprising of Internal assessment and end-semester exam.

For Theory Course, the weightage of internal assessment is 40% and end semester examination is 60%

For Practical course, the weightage of internal assessment is 60% and end semester examination is 40%

For Project, the weightage of internal assessment is 60% and end semester examination is 40%

8.2. Internal Assessment (Theory)

Total Internal Assessment mark for a theory course is 40 marks. The breakup is as follows:

Criteria	Maximum Marks
Theory Course **Category I. Theory courses:** **Sec A:** 5 Questions of 2 Marks each (10 Marks) (Knowledge: 2, Comprehension: 2, Application: 2, Analysis:1) **Sec B:** 04 out of 5 Questions of 5 Marks each (20 Marks) (Knowledge: 1, Comprehension: 2, Application: 1, Analysis:1) **Questions from all units of syllabus** **Category II. Theory cum Practical courses:** **i. Theory component:** Examination shall be conducted for 30 marks and reduced to 25 marks. **ii. Practical Component:** 5 Questions of 2 Marks each (10 Marks) Based on Lab experiment, the examination shall be conducted for 10 marks and reduced to 5 marks. **Total Marks: 30 (Theory: 25 Marks + Practical: 05 Marks)**	30

b) Percentage of Attendance	5
c) Assignment(s) (In theory only)	5
Total	**40**

Marks for Attendance are as follows:

Below 75%	0
75% - 80%	1
81% - 85%	2
86% - 90%	3
91% - 95%	4
96% - 100%	5

The Dean/Head of the Dept./Centre of the University schedules the Internal Assessment tests for all courses. All faculty members are expected to conduct this Internal Assessment tests for 2 hours duration. The faculties are also requested to preserve the answer sheets of Internal Assessment tests until declaration of results.

8.3. Internal Assessment (Practical)

Faculty in-charge of Lab courses shall evaluate the practical course for 60 marks. The break up is as follows:

Criteria	Maximum Marks
a) Laboratory Exercises and Record	30
b) Mid-Semester Exam (Average of 2 exams)	15
c) Internal Viva-Voce	5
d) Percentage of Attendance	10
Total	**60**

Marks for Attendance are as follows:

Below 75%	0
75% - 80%	2
81% - 85%	4
86% - 90%	6
91% - 95%	8
96% - 100%	10

8.4. Internal Assessment (Project)

The Project work carried out in the eighth semester shall be assessed as follows:

Criteria	Marks
a) Continuous Assessment (Guide)	25
b) Project Evaluation Committee	35
Total	**60**

8.5 End Semester Exam Evaluation

The end-semester exam pattern is as follows:

Course	Maximum Marks
a) Theory Course **Category I. Theory courses:** **Sec A:** 10 Questions of 2 Marks each (20 Marks) (Knowledge: 3, Comprehension: 2, Application: 3, Analysis:2) **Sec B:** 05 out of 7 Questions of 4 Marks each (20 Marks) (Knowledge: 1, Comprehension: 2, Application: 1, Analysis:3) **Sec C:** 02 Either/OR choice questions of 10 Marks each (20 Marks) (Application: 1, Analysis:1) **Questions from all units of syllabus**	60
Category II. Theory cum Practical courses: **i. Theory component:** Examination shall be conducted for 60 Marks and reduced to 40 Marks. **ii. Practical Component:** Based on Lab experiment result/Observation/Record//Viva-voce exam/Practical exams. The examination shall be conducted for 40 Marks and reduced to 20 Marks. **Total Marks: 60 (Theory: 40 Marks + Practical: 20 Marks)**	60
b) Practical Course (Based on Lab experiment result/Observation/Record/Practical exam/ Viva-voce)	40
c) Internship /Project Work (Based on Seminar/Project Work/Project report/Presentation and viva-voce)	40

8.6 End- Semester Examination and Evaluation

- End semester examinations shall be conducted for all courses offered in the department/centres after ensuring that the required number of classes and related activities are completed. The duration of the end semester examination may be 3 hours.
- A schedule of End semester examinations will be announced by the department/centre about 15 days ahead of the conduct of examinations.
- The responsibility of question paper setting, invigilation and valuation of answer papers lie with the course teachers. However, all assessments shall be conducted under the uniform practices of the department approved in the programme committee.
- However, the departments/faculty members are free to decide the components of continuous assessment and the methods of assessment based on the nature of the course and are expected to communicate these to students and respective HODs at the beginning of the semester.
- Mid semester /end semester examinations schedule notified by the University in the academic calendar shall be uniformly followed.

8.7 Minimum Marks for Pass

A student shall be declared to have passed the course only if she/he gets,

- A minimum of 40% marks in both Internal and End semester exams
- Internal marks are carried forward for 3 attempts for qualifying and afterwards the student has to score minimum pass mark from the external exam only.

8.8 Supplementary examination

- A student who gets F grade in a course shall be permitted to register for the supplementary examination in the following semester or in the subsequent semesters.
- A student who gets F grade in a course shall be given an option either to retain the previously awarded continuous assessment mark or to improve it, and the higher mark out of these two options will be considered for the supplementary examination.
- A student who gets Ab grade in a course/practicum/vocational course/internship/practicum or any other hands-on skill related course is mandated to repeat the course and undergo all the stages of assessment in subsequent semesters.

8.9 Attendance Requirement

- No student who has less than 75% attendance in any course shall be permitted to participate in end semester examination and she/he shall be given ‘Ab’ grade, -failure due

to lack of attendance she/he shall be required to repeat that course as and when it is offered.

8.10 Letter Grades and Grade Points

Performance of students in each paper will be expressed as marks as well as Letter Grades.

Range of Marks	Assigned Grade	Grade Points
91-100	O (outstanding)	10
81-90	A+ (Excellent)	9
71-80	A (Very good)	8
61-70	B+ (Good)	7
51-60	B (Above average)	6
46-50	C (Average)	5
40-45	P (Pass)	4
<40	F (Fail)	0
Not Applicable	Ab (Absent)	0

In case of fractions the marks shall be rounded off to nearest integer. The class interval K will be calculated by the formula given below:

$$K = (X-50)/6$$

Where, X is the highest mark secured.

According to K value, one of the following grading schemes will be followed.

(i) If K ≥ 5, then the grades shall be awarded as given in Table II.

Table II		
Range of Marks in %	**Letter Grade Points for**	**Letter Grade Points for**
X to (X-K)+1	O	10
(X-K) to (X-2K)+1	A+	9
(X-2K) to (X-3K)+1	A	8
(X-3K) to (X-4K)+1	B+	7
(X-4K) to (X-5K)+1	B	6
(X-5K) to 50	C	5
40 – 49	P	4
Below 40	F	0
Absent (Lack of Attendance)	Ab	0

(ii) If K<5, then the grades shall be awarded as given in Table III.

Table III		
Range of Marks in %	**Letter Grade Points for**	**Letter Grade Points for**
80-100	O	10
71-79	A+	9
66-70	A	8
61-65	B+	7
56-60	B	6
50-55	C	5
40-49	P	4
Below 40	F	0
Absent (lack of attendance)	Ab	0

The Semester Grade Point Average (SGPA) is computed from the grades as a measure of the student's performance in a given semester. The SGPA is based on the grades of the current term, while the Cumulative GPA (CGPA) is based on the grades in all courses taken after joining the programme of study.

8.11 Computation of SGPA and CGPA

The following procedure shall be followed to compute the Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA):

The SGPA is the ratio of the sum of the product of the number of credits with the grade points scored by a student in all the courses taken by a student and the sum of the number of credits of all the courses undergone by a student, i.e. **SGPA** (Si) = Σ(Ci x Gi) / ΣCi
Where, Ci is the number of credits of the i^{th} course and Gi is the grade point scored by the student in the i^{th} course.

(i) Example for Computation of SGPA where candidate has not failed in any course.

Semester	**Course**	**Credit**	**Letter Grade**	**Grade point**	**Credit Point** (Credit x Grade)
I	Course 1	3	A	8	3 X 8 = 24
I	Course 2	4	B+	7	4 X 7 = 28
I	Course 3	3	B	6	3 X 6 = 18
I	Course 4	3	O	10	3 X 10 = 30
I	Course 5	3	C	5	3 X 5 = 15
I	Course 6	4	B	6	4 X 6 = 24
		20			139
	SGPA				139/20=6.95

(ii) Example for Computation of SGPA where candidate has failed in one course.

Semester	Course	Credit	Letter Grade	Grade point	Credit Point (Credit x Grade)
I	Course 1	3	A	8	3 X 8 = 24
I	Course 2	4	B+	7	4 X 7 = 28
I	Course 3	3	B	6	3 X 6 = 18
I	Course 4	3	O	10	3 X 10 = 30
I	Course 5	3	C	5	3 X 5 = 15
I	Course 6	4	F	0	4 X 0 = 00
		20			115
	SGPA				115/20=5.75

(iii) Example for Computation of SGPA where candidate has failed in two courses.

Semester	Course	Credit	Letter Grade	Grade point	Credit Point (Credit x Grade)
I	Course 1	3	A	8	3 X 8 = 24
I	Course 2	4	B+	7	4 X 7 = 28
I	Course 3	3	F	0	3 X 0 = 00
I	Course 4	3	B	6	3 X 6 = 18
I	Course 5	3	C	5	3 X 5 = 15
I	Course 6	4	F	0	4 X 0 = 00
		20			85
	SGPA				85/20=4.25

The CGPA shall also be calculated in similar way as shown in examples (i), (ii) and (iii) of SGPA for all subjects taken by the students in all the semesters. However, if any student fails more than once in the same subject, then while calculating CGPA, the credit and grade point related to the subject in which the student fails in multiple attempts will be restricted to one time only. The SGPA and CGPA shall be rounded off to 2 decimal points and reported in the transcripts.

In case of audit courses offered, the students may be given (P) or (F) grade without any credits. This may be indicated in the mark sheet. Audit courses will not be considered towards the calculation of CGPA.

8.12 Grade Card

The University shall issue a Grade card for the students, containing the marks and grades obtained by the student in the previous Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA).

The grade card shall list:

a. The title, semester and course code of the courses taken by the student.
b. The credits associated with the course.
c. The marks and grade secured by the student.
d. The total credits earned by the student in that semester
e. The SGPA of the student.
f. The total credits earned by the students till that semester.

g. The CPGA of the student.

On successful completion of the programme, students with a CGPA of 9.00 and above who passed all the courses in first attempt shall be awarded the degree in First Class with Distinction. University Rank in a programme will be awarded to the student who secures the highest CGPA in a batch and passed all the courses in first attempt.

Students with CGPA between 6.00 and 8.99 shall be placed in **First Class,**
Students with CGPA between 5.00 and 5.99 shall be placed in **Second Class**, and
Students with CGPA between 4.00 and 4.99 shall be placed in **Pass Class**.

9. Procedure for completing the B.Tech. Course :

A candidate can join/rejoin the course of study of any semester only at the time of its normal commencement and only if he/she has satisfied the course requirements for the previous semester and further has registered for the university examinations of the previous semester in all the subjects as well as all arrear subjects if any.

However, the entire B.Tech course should be completed within 7 years (14 semesters) and six years (12 semesters) for students admitted under lateral entry.

10 Award of Class and Rank in B.Tech degree:

i) A candidate who satisfies the course requirements for all semesters and who passes all the examinations prescribed for all the eight semesters (six semesters for lateral entry candidates) within a maximum period of 7 years (6 years for lateral entry candidates) reckoned from the commencement of the first semester to which the candidate was admitted shall be declared to have qualified for the award of B.Tech. degree.

ii) A candidate who qualifies for the award of the B.Tech. degree passing in all subjects pertaining to the semesters 3 to 8 in his/her first appearance within 6 consecutive semesters (3 academic years) and in addition secures a CGPA of 8.50 and above for the semesters 3 to 8 shall be declared to have passed the examination in **FIRST CLASS** with **DISTINCTION**.

iii) A candidate who qualifies for the award of the B.Tech degree by passing in all subjects relating to semesters 3 to 8 within a maximum period of eight semesters after his/her commencement of study in the third semester and in addition secures CGPA not less than 6.0 shall declared to have passed the examination in **FIRST CLASS**.

iv) All other candidates who qualify for the award of B.Tech. degree shall be declared to have passed the examination in **SECOND CLASS**.

v) For the Award of University ranks and Gold Medal for each branch of study, the CGPA secured from the 1st to 8th semester alone should be considered and it is mandatory that the candidate should have passed all the subjects from the1st to 8th semester in the first attempt. Rank certificates would be issued to the first ten candidates in each branch of study.

11. Provisions for Honors/Minor degree along with B.Tech. degree:

11.1 B.Tech with Honors Degree in the same discipline

- The student shall be given an option to earn an Honors degree in the same discipline of B.Tech. at the end of first year based on his academic performance in the first year.
- A student is eligible to exercise this option if he has passed all the subjects offered in the first year and has earned a CGPA of not less than 7.5.
- The student is required to earn a minimum of 21 credits starting from the third semester onwards to become eligible for the award of Honors degree. A minimum of 12 credits shall be earned by the student over and above 160 credit for the programme by completing additional courses starting from the third onwards, as prescribed in the honors course basket. The syllabuses of these courses are framed so as to cover advanced topics in that programme discipline.
- In view of NEP syllabus offering diploma after two years, decision to allow existing diploma students as lateral entry at the end of first year is being put on hold for want of clarification by NEP regulation on lateral entry by non-NEP students into NEP programme. Students registered for honors course securing the credits shall be listed as additional credit earned in that semester mark sheet.
- A student is eligible to get the Honors degree only on completing the programme in 'First Class with Distinction' class.
- A student can exercise the option to withdraw from the Honors degree at any time after entry.
- Details about the courses completed and credits earned for Honors degree will appear ~~only~~ in the 'Consolidated Grade Sheet'. These details will be listed under the heading 'Credits Earned for Honors degree'. In the case of students who have either withdrawn from Honors degree or become ineligible for Honors degree by not securing 'First Class with Distinction', the credits earned for the courses registered and successfully completed for Honors degree will be listed under the heading 'Additional Credits Earned' in the respective semesters and as in consolidated mark sheet.
- The CGPA will be calculated for all the courses credited by the students inclusive of major and honors courses.
- Nomenclature of Honors Degree is 'B.Tech.(Honors) in XXX', where XXX is Discipline in

which the student has enrolled.

11.2 B.Tech with Minor degree in another Engineering/Technology discipline

- The student shall be given an option to earn a minor degree in another discipline of student choice at the end of first year based on his academic performance in the first year.
- A student is eligible to exercise this option if he has passed all the subjects offered in the first year in the first attempt itself and has earned a CGPA of not less than 7.5.
- Minor degree in a particular discipline of engineering/technology shall be offered for a batch of students if and only if a minimum of 5 eligible students opt for it.
- The student is required to earn minimum of 21 credits starting from the third semester onwards from the minor course basket of the department, to become eligible for the award of minor degree. 21 credits shall be earned by the student by completing additional courses starting from the third to seventh semester. The curricular content of these minor basket courses are framed in such a way that that these courses will essentially cover the core minimum knowledge required to be fulfilled for award of degree in the programme discipline in which the student chooses to earn the minor degree.
- The students admitted in the second year through Lateral Entry Scheme will also be given a chance to opt for Minor degree. However, the decision to admit lateral entry students from non-NEP courses to NEP course is put on hold for clarity of regulation of lateral entry in NEP programme.
- A student can exercise the option to withdraw from the Minor degree at any time after entry.
- Details about the courses completed and credits earned for Minor degree will appear in the 'Consolidated Grade Sheet'. These details will be listed under the heading 'Credits Earned for Minor degree'. In the case of students who have either withdrawn from Minor degree or become ineligible for Minor degree by not securing 'First Class with Distinction', the credits earned for the courses registered and successfully completed for Minor degree will be listed under the heading 'Additional Credits Earned' in the respective semesters and as in consolidated mark sheet.
- Nomenclature of Minor Degree is 'B.Tech. in XXX with Minor in YYY', where XXX is Discipline in which the student is enrolled and YYY is Discipline which the student has opted as Minor.
- The CGPA will be calculated for all the courses credited by the students inclusive of major and minor courses.

12. Provision for withdrawal:

Based on the recommendation of the Head of the Institution, a candidate with valid reasons may be granted permission by the University to withdraw from writing the entire semester examination. The withdrawal application shall be valid only if it is made earlier than the commencement of the last

theory examination pertaining to that semester. Withdrawal shall be permitted only once during the entire program. A candidate who has withdrawn is also eligible to be awarded DISTINCTION provided the candidate satisfies the other necessary conditions. But, they are not eligible to be awarded a rank.

13. Provisions for exits in B.Tech. course:

(For courses where AICTE specifies exit in the model curriculum)

The curriculum and the syllabus for all B.Tech programmes have been planned in compliance with the NEP guidelines proposed by AICTE. Accordingly, students joining B.Tech programmes shall have all benefits NEP offers in terms of exercising exit option during the course of study. Every B.Tech programme governed under this school board shall adopt the NEP guidelines, as and when proposed/amended by AICTE, and the following scheme will be applied for all such B.Tech programmes specified by AICTE.

NEP 2020 suggests that a student can exercise exits at multiple stages of the course of study. As per AICTE norms, a student can have two possible exits before the completion of the degree programme and may get a UG Diploma /Certificate or B.Voc. degree in the relevant discipline if he/she fulfills the following conditions: (Subject to change as per AICTE guidelines).

13.1 Diploma/Certificate in the relevant branch of study

A student should be able to get a Certificate if

After completion of first year, the students should pass 2 additional courses at the ITI level of any suitable skill based courses earning six credits to quality for the Certification.

A student should be able to get a Diploma if he/she completes:

After the completion of second year, the students should pass 2 additional courses at the Diploma level or any 2 suitable skill based courses earning six credits to qualify for the Diploma.

13.2 B.Voc. in the relevant branch of study

After the completion of third year, the students should pass 2 additional courses at the Degree level or any 2 suitable skill based courses earning six credits to qualify for the B.Voc.

13.3 Award of Class in B.Voc. degree

A candidate who satisfies the course requirements for all semesters and who passes all the examinations within a maximum period of 6 years (5 years for lateral entry candidates) reckoned from the commencement of the first semester to which the candidate was admitted shall be declared

to have qualified for the award of B.Voc. degree in the relevant discipline.

- A candidate who qualifies for the award of the B.Voc. degree passing in all subjects pertaining to semesters the 3 to 6 in his/her first appearance within 4 consecutive semesters (2 academic years) and in addition secures a CGPA of 8.50 and above for the semesters 3 to 6 shall be declared to have passed the examination in **FIRST CLASS** with **DISTINCTION**.
- A candidate who qualifies for the award of the B.Voc. degree by passing in all subjects relating to semesters 3 to 6 within a maximum period of six semesters after his/her commencement of study in the third semester and in addition secures CGPA not less than 6.5 shall declared to have passed the examination in **FIRST CLASS.**
- All other candidates who qualify for the award of B.Voc. degree shall be declared to have passed the examination in **SECOND CLASS**

13.4 Re-entry to complete the program

A student exiting with B.Voc. should be entitled to re-enrol in the programme of the same B.Tech. discipline. Only students admitted to the B.Tech programme and exercised an exit option are eligible for readmission to the B.Tech programme under the same discipline. It is suggested that all credits will be transferred, if the student enrol back within a limited period (3 years) of exiting. In case a student enrol after that, then the decision on the transfer of credits should be based on the changes in the curriculum the student studied. A candidate after exit may rejoin the program only at the commencement of the semester at which he/she discontinued, provided he/she pays the prescribed fees to the University. The total period of completion of the B.Tech program reckoned from the commencement of the first semester to which the candidate was admitted shall not in any case exceed 7 years, including of the period of discontinuance.

13.5 Completion Possibility in other Institutions

A student can earn B.Voc. in one institution and complete the degree program in another institution (same B.Tech. discipline only). *(Note: If these exit options are accepted for multiple B.Tech. programs, it is suggested that AICTE actively communicate these to the industry and other bodies, so they recognize these and accept them as bona-fide credentials for the purposes of recruitment and/or eligibility for admission to programs, appearing in competitive examinations, etc*.).

14. Academic Bank of Credits (ABC)

The scheme of Academic Bank of Credits (ABC) for students as per NEP 2020 will promote flexibility in curriculum to

i). provide option of mobility for learners across any Higher Education Institutes (HEIs) of their

choice

ii). provide option to gain the credits through the approved digital platforms such as MOOCs etc.,

iii). facilitate award of certificate/diploma/degree in line with the accumulated credits in ABC

iv). execute Multiple Entry and Exit system with credit count, credit transfer and

15. Revision of Regulations and Curriculum:

The University may from time-to-time revise, amend or change the regulations of curriculum and syllabus as and when found necessary.

GENERAL COURSE STRUCTURE & THEME

A. Definition of Credit:

1 Hr. Lecture (L) per week	1 Credit
1 Hr. Tutorial (T) per week	1 Credit
1 Hr. Practical (P) per week	0.5 Credit
2 Hours Practical (P) per week	1 Credit

B. Range of Credits: A typical Model Four-year Under Graduatedegree program in Energy Science and Technology has about 160 credits

C. Structure of UG Program: The structure of B.Tech. program in Energy Science and Technology shall have essentially the following categories of courses with the breakupof credits as given:

Structure of UG Program:

The structure of UG program in Science and Technology shall have essentially the following categories of courses with the breakupof credits as given:

S.No.	Category	Suggested Breakup of Credits
1	Humanities, Social Sciences and Management Courses	12*
2	Basic Science Courses	21*
3	Engineering Science Courses Including Workshop, Drawing, Basics of Electrical & Electronics/Mechanical/Computer etc.	28*
4	Professional Core Courses	62*
5	Professional Elective Courses Relevant to Chosen Specialization/Branch	12*

6	Open Electives from other Technical and /or Emerging Subjects	9*
7	Project Work, Seminar and Internship In Industry (or) Elsewhere	16*
8	Mandatory Courses [Environmental Sciences, Sports and Yoga (or) NSS/NCC, Induction Program, Indian Constitution, Essence of Indian Knowledge Tradition, etc.]	0
	Total	**160***

Minor variation is allowed as per need of the respective disciplines.

Category-Wise Courses

HUMANITIES, SOCIAL SCIENCES & MANAGEMENT COURSES

(Total 4 Courses to be taken; 2 Compulsory Courses + 2 Other Courses)

Sl.	Code No.	Subject	Semester	Credits
1	HSMC 101	Communicative English (Compulsory)	2	3
2	HSMC 102	Universal Human Values (Compulsory)	2	3
3	HSMC 303	Industrial Psychology	5	3
4	HSMC 304	Professional Ethics	5	3
5	HSMC 305	Project Management	6	3
6	HSMC 306	Finance & Accounting	6	3
			Total Credits:	**12**

BASIC SCIENCE COURSES [BSC]

(All 8 Courses to be taken; All Compulsory Courses)

Sl.No.	Code No.	Subject	Semester	Credits
1	BSC 101	Physics	1	3
2	BSC 102	Physics Lab	1	2
3	BSC 103	Mathematics-1 (Calculus & Linear Algebra)	1	3
4	BSC 104	Biology for Engineers	1	3
5	BSC 105	Chemistry-1	2	3
6	BSC 106	Chemistry- Lab	2	2
7	BSC 107	Mathematics-2 (ODE, Complex variables)	2	3
8	BSC 208	Mathematics-3 (PDE, Prob/Stat)	3	3
			Total Credits:	**22**

ENGINEERING SCIENCE COURSES [ESC]

(All 8 Courses to be taken; 1 Compulsory Course + 7 Other Courses)

Sl.No.	Code No.	Subject	Semester	Credits
1	ESC 101	Basic Electronic Engineering	1	4

2	ESC 102	Engineering Graphics & Design	1	4
3	ESC 103	Basic Electrical Engineering	2	4
4	ESC 104	Programming for Problem Solving	2	4
5	ESC 105	Workshop/Manufacturing Practices	2	4
6	ESC 106	Design Thinking + Idea Lab (Compulsory)	2	2
7	ESC 207	Engineering Mechanics*	3	3
8	ESC 208	Applied Thermodynamics*	3	3
			Total Credits:	**28**

**It will be different for other disciplines; For example, CSE, ECE etc., except MST and EE.*

MANDATORY COURSES

(Minimum 2 Courses to be taken as compulsory)

S.No.	Code No.	Subject	Semester	Credits
1	MC 101	Induction Program **(Two weeks duration)**	1	0
2	MC 102	Sports & Yoga (or) NSS/NCC	1	0
3	MC 203	Environmental Sciences	3/4	0
4	MC X04	Indian Constitution (or) Essence of Indian Knowledge Tradition	5/6/7	0
			Total Credits:	0

PROFESSIONAL CORE COURSES [PCC]

(Minimum 20 Courses to be taken with the total the total credits of 61)

S.No.	Category	SEM	Course Code	SUBJECT	Credits
1	PCC	**3**	PCC-EST 201	Electrical Machines	4
2	PCC	**3**	PCC-EST202	Fluid Mechanics	3
3	**PCC**	**3**	**PCC-EST 210**	**Lab-I Electrical Machines & Controls**	2
4	PCC	**4**	PCC-EST 203	Heat and Mass Transfer	3
5	PCC	4	PCC-EST 204	Fuels and Combustion Technology	4
6	PCC	**4**	PCC-EST 205	Bioenergy	3
7	PCC	**4**	PCC-EST 206	Materials Science	3
8	PCC	**4**	PCC-EST 207	Design of Fluid Machinery	3
9	**PCC**	**4**	**PCC-EST 220**	**Lab-II Combustion Technology & Bioenergy Lab**	2
10	PCC	**4**	PCC-EST 301	Solar Photovoltaic Energy Conversion	4
11	PCC	5	PCC-EST 302	Power Plant Engineering	4
12	PCC	**5**	PCC-EST 303	Nuclear Energy Technology	3
13	PCC	**5**	PCC-EST 304	Solar Thermal Technology	3
14	PCC	**5**	PCC-EST 305	Wind Energy Technology	3

15	**PCC**	**5**	**PCC-EST 310**	**Lab-III Solar Thermal & Wind Energy Lab**	2
16	PCC	**6**	PCC-EST 306	SPV Power Plant Design and Installation	4
17	PCC	**6**	PCC-EST 307	Biorefineries	3
18	PCC	**6**	PCC-EST308	Energy Audit and Management	3
19	PCC	**6**	PCC-EST 309	Power Systems Dynamics and Smart Grid Operations	3
20	**PCC**	**6**	**PCC-EST 320**	**Lab-IV Design, modeling and Simulation of Energy Systems**	2
Total Credits					**61**

PROFESSIONAL ELECTIVES [PEC]

(Three/Four Courses to be taken with the total the total credits of 12)

S.No.	Category	Course Code	Name	Semester	Credits
1	PEC-H	PEC-EST 401	Electric Vehicle Technology	4/6	4
2	PEC	PEC-EST 403	Organic Solar Photovoltaics	4/6	3
3	PEC	PEC-EST 404	Additive Manufacturing for energy applications	4/6	3
4	PEC	PEC-EST 405	Waste to energy conversion	4/6	3
5	PEC	PEC-EST 410	Bioprocess Engineering	4/6	3
6	PEC-H	PEC-EST 406	Solar Energy for Industrial Process Heat	5/7	4
7	PEC-H	PEC-EST 407	Biomethanation and Biomass gassification	5/7	3
8	PEC-H	PEC-EST 408	Wind Resource Assessment and Siting	5/7	3
9	PEC-H	PEC-EST 409	Hydrogen and Fuel Cell Technology	5/7	4
10	PEC	PEC-EE 411	Design of Heat-Exchange Equipment	5/7	3
11	PEC	PEC-EST412	Carbon Footprint & CO_2 Sequestration	5/7	3
12	PEC	PEC-EST 413	Power Electronics and Drives	5/7	3
13	PEC-H	PEC-EST 414	Green Buildings and Sustainable Development	8	3
14	PEC-H	PEC-EST 415	Advanced Techniques for Material Characterization	8	3
15	PEC	PEC-EST 416	Battery Energy Storage	4/6	3
16	PEC	PEC-EST 417	Artificial Intelligence and Machine learning for Energy Engineering	5/7	3
17	PEC	PEC-EST 418	Thermal Energy Storage	5/7	3
18	PEC	PEC-EST 419	Computational Fluid Dynamics for Energy Engineering	6	4

19	PEC	PEC-EST 420	Small and Microhydropower Systems	5/7	3

OPEN ELECTIVE COURSES

(03 Courses from any other Departments. Honors students have option to replace these three courses with department courses for their honors credit requirement)

Open Electives Offered for other department students in Green Energy Technology Dept. (Level 400 & above)

Sl.	Category	Code No.	Subject	Semester	Credits
1	OEC-1	OEC-XX-YYY	From other department	7	3
2	OEC-2	OEC-XX-YYY	From other department	7	3
3	OEC-3	OEC-XX-YYY	From other department	8	3
				Total Credits:	**9**

These courses are designed and offered only to outside dept students. It should be designed in such a way that they constitute part of course basket of 21 CREDITS to obtain Minor from the Department.

PROJECT

(All 4 Courses to be taken as compulsory)

Sl.	Code No.	Subject	Semester	Credits
1	PROJ-EST 301	Micro Project	6	2
2	PROJ-EST 402	Mini Project	7	5
3	PROJ-EST 403	Seminar	7	1
4	PROJ-EST 404	Major Project	8	8
			Total Credits:	**16**

PROFESSIONAL ELECTIVES FOR HONORS IN ENERGY SCIENCE AND TECHNOLOGY [PEC-H]

Registration is Mandatory on the 3th Semester

Additional any six/seven courses to be taken from PEC-H pool with the total minimum credit of 21

S.No.	Category	Course Code	Name	Semester	Credits
1	PEC-H	PEC-EST401	Electric Vehicle Technology	4/6	4
2	PEC-H	PEC-EST 406	Solar Energy for Industrial Process Heat	5/7	4
3	PEC-H	PEC-EST 407	Biomethanation and Biomass gassification	5/7	3
4	PEC-H	PEC-EST 408	Wind Resource Assessment and Siting	5/7	3
5	PEC-H	PEC-EST 409	Hydrogen and Fuel Cell Technology	5/7	4
6	PEC-H	PEC-EST 414	Green Buildings and Sustainable Development	8	3
7	PEC-H	PEC-EST 415	Advanced Techniques for Material Characterization	8	3
8	PEC-H	PEC-EST 419	Computational Fluid Dynamics for Energy Engineering	6	4

Minor Program

For B.Tech with MAJOR and MINOR in any one other programs from the below given Minor course basket, student must acquire an additional of 21 credits from the respective chosen Minor Course Basket. These students must acquire a total of 160+21 credits.

Minor Programs are:

- Materials Science and Technology
- Environmental Engineering and Management.
- Electronics and Communication Engineering.

Minor in Energy Science and Technology - COURSE BASKET

[The other Dept. students who opting to take MINOR PROGRAM must take minimum of seven courses and acquire 21 credits. Registration is mandatory on 3th Semester for MINOR PROGRAM]

S.No.	Category	Course Code	Subject	Semester	Credits
MINOR CORE COURSES					
1	PCC	PCC-EST 204	Fuels and Combustion Technology	3	4
2	PCC	PCC-EST 201	Electrical Machines	3	4
3	PCC	PCC-EST 302	Power Plant Engineering	3	4
MINOR ELECTIVE - ANY THREE					
4	PEC	PCC-EST 301	Solar Photovoltaic Energy Conversion	4	**3**
5	PEC	PEC-EST 205	Bioenergy	6	3
6	PEC	PEC-EST 304	Solar Thermal Technology	6	3
7	PEC	PEC-EST 305	Wind Energy Technology	6	3
8	PEC	PEC-EST 308	Energy Audit and Management	6	3
9	PEC	PEC-EST 201	Electric Vehicle Technology	6	4
10	PEC	PEC-EST 306	SPV Power Plant Design and Installation	7	3
11	PEC	PEC-EST 307	Power Electronics and Drives	7	3
12	PEC	PEC-EST 309	Power Systems Dynamics and Smart Grid Operations	7	3
13	PEC	PEC-EST 403	Biomethanation and Biomass gasification.	7	3

INDUCTION PROGRAM

The Essence and Details of Induction program can also be understood from the 'Detailed Guide on Student Induction program', as available on AICTE Portal.

(Link:https://www.aicteindia.org/sites/default/files/Detailed%20Guide%20on%20Student%20Induction%20program.pdf).

Induction program (Mandatory)	Three-week duration
Induction program for students to be offered right at the start of the first year.	• Physical activity • Creative Arts • Universal Human Values • Literary • Proficiency Modules • Lectures by Eminent People • Visits to local Areas • Familiarization to Dept./Branch & Innovations

Mandatory Visits/ Workshop/Expert Lectures:

a. It is mandatory to arrange one industrial visit every year for the students of each branch.

b. It is mandatory to conduct a one-week workshop during the winter break after 5^{th} semester on professional/ industry/ entrepreneurial orientation.

c. It is mandatory to organize at least one expert lecture per semester for each branch by inviting resource persons from domain specific industry/reputed research institutions.

Evaluation Scheme (Suggestive only):

d. For Theory Courses:
(The weightage of Internal assessment is 40% and for End Semester Exam is 60%). The student has to obtain at least 40% marks individually both in internal assessment and End semester exams to pass.

e. For Practical Courses:
(The weightage of Internal assessment is 60% and for End semester exam is 40%). The student has to obtain at least 40% marks individually both in internal assessment and end semester exams to pass.

f. For Summer Internship / Projects / Seminar etc.
Evaluation is based on work done, quality of report, performance in viva-voce presentation,etc.

Note: The internal assessment is based on the student's performance in mid semester tests (twobest out of three), quizzes, assignments, class performance, attendance, viva-voce in practical, lab record, etc.

g. Mapping of Marks to Grades

Each course (Theory/Practical) is to be assigned 100 marks, irrespective of the number ofcredits, and the mapping of marks to grades may be done as per the following table:

Range of Marks	Assigned Grade
91-100	A^+
81-90	A
71-80	B^+
61-70	B
51-60	C^+
46-50	C
40-45	D
< 40	F (Fail due to less marks)
-	FA (Fail due to shortage of attendance and therefore, to repeat the course)

h. Open Electives Course (OEC): Any **3** courses (from any department), based on their interest and project. Students can opt one OEC in online (SWAYAM /NPTEL/MOOC) mode. Students can register OECs even from their 6^{th} semester onwards. They can complete OEC-3 in the 6^{th} (or) 7^{th} semester, so that they can do their project work at any outside institute/industry with the consent of the Faculty in-charge.

i. Industry Internship: Internship in industry, start-up or R&D lab in $2^{nd}/3^{rd}$ year summer is compulsory (audit). The internshipmust be properly evaluated.

Course Code	Definition
L	Lecture
T	Tutorial
P	Practical
C	Credits
BSC	Basic Science Courses
ESC	Engineering Science Courses
HSMC	Humanities, Social Sciences and Management Courses
PCC	Professional Core Courses
PEC	Professional Elective Courses
OEC	Open Elective Courses
MC	Mandatory Courses

j. Course level coding scheme: Three-digit number used as suffix with the Course Codefor identifying the level of the course. Digit at hundred's place signifies the year in which course is offered. e.g.

101, 102 … etc. for first year.
201, 202 …. etc. for second year.
301, 302 … etc. for third year.
401, 402 … etc. for fourth year.

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B.Tech Energy Science and Technology

Course Structure

SEMESTER 1

Sl.No.	Category	Code	Course Title	L	T	P	Total H	Credits
1.	BSC	BSC 101	Physics	2	1	0	3	3
2.	BSC	BSC 102	Physics Lab	0	0	4	4	2
3.	BSC	BSC 103	Mathematics-1	2	1	0	3	3
4.	BSC	BSC 104	Biology for Engineers	2	0	2	3	3
5.	ESC	ESC 101	Basic Electronics Engineering	2	1	2	5	4
6.	ESC	ESC 102	Engineering Graphics & Design	2	1	2	5	4
7.	HSMC	HSMC 101	Communicative English	1	0	2	5	3
8.	MC	MC 101	Sports & Yoga (or) NSS/NCC	0	0	2	2	0
			Total				30	**22**

SEMESTER 2

Sl.No.	Category	Code	Course Title	L	T	P	Total H	Credits
1.	BSC	BSC 105	Chemistry	2	1	0	3	3
2.	BSC	BSC 106	Chemistry Lab	0	0	4	4	2
3.	BSC	BSC 107	Mathematics II	2	1	0	3	3
4.	ESC	ESC 103	Basic Electrical Engineering	2	1	2	5	4
5.	ESC	ESC 104	Programming for Problem Solving	2	1	2	5	4
6.	ESC	ESC 105	Workshop/Manufacturing Practices	2	1	2	5	4
7.	HSMC	HSMC 102	Universal Human Values	2	1	0	3	3
8.	HSC	ESC 106	Design Thinking & Idea Lab	0	0	2	2	2
			Total				30	**25**

First Year Exit:

Two Skill course in Science/ Electrical Engg. Subjects ITI level in earning six credits or equivalent Professional Apprenticeship in Industry/ MSME/Professional activities, duly certified by Dept. Programme Committee.

APPROVED CERTIFICATION.

1. Certificate of competence in repair and maintenance of AC/DC Motors & Generators.
2. A certificate of competence in domestic and low-tension electrical wiring.
3. Certified Science Laboratory Attendant
4. Any other equivalent skill course prescribed by Dept. UG Board of Studies

SEMESTER 3

Sl.	Category	Course Code	Course Title	L	T	P	Total H	Credits
1.	BSC	BSC 208	Mathematics III	2	1	0	3	3
2	ESC	ESC 207	Engineering Mechanics	2	1	0	3	3
3.	ESC	ESC 208	Applied Thermodynamics	2	1	0	3	3
4.	MC	MC 202	Environmental Science	2	0	0	2	0
5.	PCC	PCC-EST 201	Electrical Machines	2	1	2	5	4
6	PCC	PCC-EST 202	Fluid Mechanics	2	1	0	3	3
	PCC	PCC-EST 203	Heat and MassTransfer	3	0	0	3	3
7.	PCC	PCC-EST 210	Energy Lab - I	0	0	4	4	2
Total							26	**21**

SEMESTER 4

Sl.	Category	Course Code	Course Title	L	T	P	Total H	Credits
1.	PCC	PCC-EST 204	Fuels and Combustion Technology	2	1	2	5	4
2.	PCC	PCC-EST 205	Bioenergy	2	1	0	3	3
3.	PCC	PCC-EST 206	Materials Science	2	1	0	3	3
4.	PCC	PCC-EST 207	Design of Fluid Machinery	2	1	0	3	3
5.	PCC	PCC-EST 220	Energy Lab - II	0	0	4	4	2
6.	PEC		Professional Elective-1	3	0	0	3	3
7.	PEC		Professional Elective-2	3	0	0	3	3
Total							24	**21**

ALL PASS STUDENTS WITHOUT ARREAR IN FIRST TWO SEMESTERS SECURING CGPA 7.5 SHALL BE CRITERION FOR ALLOWING STUDENTS TO OPT FOR HONORS DEGREE.

II Year Exit:

DIPLOMA IN ENERGY SCIENCE and TECHNOLOGY Specialization in _____

Requirement: two skill courses or skill training/ practice/project/ apprenticeship equivalent to six credits.

List of Skill Courses:

- Mechanical Engineering: Production Technology/ Ref & AC/ Biofuels
- Electrical Engineering : Roof-top Solar Systems/ Electrical Machines and Drives

SEMESTER 5

Sl.	Category	Code	Course Title	L	T	P	Total H	Credits
1.	PCC	PCC-EST 301	Solar Photovoltaic Energy Conversion	2	1	2	5	4
2.	PCC	PCC-EST 302	Power Plant Engineering	2	1	2	5	4
3.	PCC	PCC-EST 303	Nuclear Energy Technology	2	1	0	3	3
4.	PCC	PCC-EST 304	Solar Thermal Technology	2	1	0	3	3
5.	PCC	PCC-EST 305	Wind Energy Technology	2	1	0	3	3
6.	PCC	PCC-EST 310	Energy Lab - III	0	0	4	4	2
7.	HSMC	HSMC 303	Industrial Psychology	3	0	0	3	3
						Total	26	**22**

8.	PEC		Honors Professional Elective-4	3/4 credit

SEMESTER 6

Sl.	Category	Code	Course Title	L	T	P	Total H	Credits
1.	PCC	PCC-EST 306	SPV Power Plant Design and Installation	2	1	2	5	4
2.	PCC	PCC-EST 307	Biorefineries	2	1	0	3	3
3.	PCC	PCC-EST 308	Energy Audit and Management	2	1	0	3	3
4.	PCC	PCC-EST 309	Power Systems Dynamics and Smart Grid Operations	2	1	0	3	3
5.	PCC	PCC-EST 320	Energy Lab - IV	0	0	4	4	2
6.	HSMC	HSMC 305	Project Management	2	1	0	3	3
7.	PROJ	PROJ-EST 301	Mini Project	0	0	4	4	2
						Total	25	**20**

8.	PEC		Honors Professional Elective-5	3/4 credit
9.	PEC		Honors Professional Elective-6	3/4 credit

Evaluation of Mini Project

- Students may undertake mini research project under the direction of the faculty in- charge, normally 3 hrs/week.
- Submit a detailed report describing the project and results has to be submitted to the Department.
- Presentation of the entire work is to be done before the evaluation committee and a successful oral defence of the project work before the committee.

Third Year Exit: B.Voc. in ENERGY SCIENCE

Additional mandatory credits: 6 [Two Skill course credits 6 or Project/Trainee certified equivalent by the department programme committee]

Specialization:

A. *Solar Energy*
B. *Energy Storage & E-mobility*
C. *Bioenergy*
D. Wind *Energy*

SEMESTER 7

Sl.	Category	Code	Course Title	L	T	P	Total H	Credits
1.	PEC	PEC-EST 4XX	Professional Elective-3	3	0	0	3	3
2.	OEC	OEC-EST 4XX	Open Elective-1	2	1	0	3	3
	PEC	PEC-EST 4XX	Honors Professional Elective-7					
3.	OEC	OEC-EST 4XX	Open Elective-2	2	1	0	3	3
	PEC	PEC-EST 4XX	Honors Professional Elective-8					
4.	OEC	OEC-EST 4XX	Professional Elective-4	3	0	0	3	3
5.	PROJ	PROJ-EST402	Minor Project	0	0	10	10	5
6.	SEM	PROJ-EST 403	Seminar	0	0	2	2	1
			Total				24	**18**

7.	PEC		Honors Professional Elective-9	3/4 credits
8.	PEC		Honors Professional Elective-10	3/4 credits

Minor Research Project

- Students may undertake minor/short research project under the direction of the faculty in-charge, normally 3 hrs/week.
- Submit a detailed report describing the project and results has to be submitted to the Department.
- Presentation of the entire work is to be done before the evaluation committee and a successful oral defence of the project work before the committee.

Evaluation of Seminar Course

- **For seminar,** each student shall prepare a paper on any topic of interest in the field of specialization – Energy Science and Technology.
- He/she shall get the paper approved by the faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class.
- Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper presentation and his/her participation in the seminar.

SEMESTER 8

Sl.	Category	Code	Course Title	L	T	P	Total H	Credits
1.	OEC	OEC-XXX 4XX	Open Elective-3 (SWAYAM/NPTEL/MOOC)	2	0	1	3	**3**
2.	PROJ	PROJ-EST 404	Major Project	0	0	16	16`	8
			Total				19	**11**

Total Credits	**160**
Total Credits for B.Tech. EST Honors B.Tech. EST with Minor	**160+21 = 181**

Major Research Project

- Students are required to carry out a research/industry project for **one full semester** related to Materials Science and Technology and submit a project report describing the details of the entire project work has to be submitted to the Department, usually in a prescribed format.
- Each student is assigned with a supervisor from among the faculty members of the DGET of Pondicherry University.
- Arrangement could also be made to pursue research project at institutions/industry other than the DGET of PU. In such circumstance, the student is assigned with two supervisors; an internal supervisor/advisor from the DGET of PU and an external supervisor from the institutions where the research project is carried out.
- Presentation of the entire work is to be done before the evaluation committee and a successful oral defence of the project work before the committee.

Degree to be awarded:

B.Tech. Energy Science and Technology

B.Tech. Energy Science and Technology with Honors

B.Tech in Energy Science and Technology with Minor in (chosen discipline).

BSC 101	Engineering Physics	L	T	P	C
		2	1	0	3

Course Objective:

- To impart knowledge of optical measurement and optical instruments and lasers.
- To learn basic concept of quantum mechanics and electromagnetic theory
- To understand structure of materials, structure-property correlations and various methods of its characterization.

Course Outcomes:

By the end of the course students would be able to**:**

- Students shall acquire knowledge of differential equations and apply it to wave equations and analysis of the intensity variation of light due to interference and polarization and its propagation in fibre and the use of Laser in Science and engineering.
- Students can apply the knowledge of quantum mechanics to set Schrödinger's equations.
- Students shall be familiar with some of the basic laws related to electromagnetism and Maxwell's equation as well as properties of dielectrics.
- Students are able to understand key principles and application of nuclear physics.
- Identify planes in crystal and explain fundamental concepts of magnetism, analyze the properties of semiconducting materials and describe various applications of superconductors.

Unit I: Engineering Optics

Interference: in thin film due to reflected light, wedge shaped film, Newton' Rings, Applications, Polarization: types of polarization, optical activity, specific rotation and Laurentz half shade polarimeter, Lasers: characteristics, Gas Laser, solid state Laser and semiconductor lasers, Applications of Lasers, Optical fibres: Acceptance cone, Numerical aperture, applications, Oscillations: free oscillations, forced oscillations and damped oscillation, resonance and it's condition.

Unit II: Quantum Mechanics

Wave and particle duality of radiation – de Broglie concept of matter waves – Wave function and its physical significance, Heisenberg's uncertainty principle and it's application – Schrodinger's wave equation – eigen values and eigen functions, Applications in one dimension: Particle in a box, finite potential well, Harmonic oscillator. Introduction to quantum computing.

Unit III: Electromagnetism

Differential and integral calculus: Operator, Concept of gradient, divergence and curl, Ampere's law, Faraday law, Gauss–Divergence theorem, integral and differential forms of Maxwell equations and their physical significance, EM waves in free space. Dielectrics: polarization, Types of Dielectric polarization, dielectric constant, polar - non polar dielectrics.

Unit IV: Crystal Structure

Fundamental concepts, Crystal systems Cubic structure: Number of atoms, co-ordination number, packing fraction, Atomic radius, Miller indices, relation between 'ρ' and 'a'.

Nuclear Physics: Nuclear properties Introduction to mass defect & packing fraction, Nuclear reaction: Q value of Nuclear reaction,- Radioactivity – properties of α, β and γ rays, GM Counter.

Unit V: Physics of Advanced Materials

Types of magnetic materials, ferrites and garnets, magnetic domain and hysteresis curve, Semiconductors, conductivity of semiconductors, Hall Effect Superconductors: definition – Meissner effect – type I & II

superconductors, Nanomaterials: introduction and properties – synthesis: top-down and bottom-up approach, Introduction to SCADA, XRD, FESEM, VSM and applications.

Text books:

1. Introduction to Electrodynamics –David R. Griffiths.
2. Concept of Modern Physics – Arthur Beizer. Tata McGraw-Hill Publishing Company Limited.
3. Optics –Ajoy Ghatak. MacGraw Hill Education (India) Pvt. Ltd.
4. Science of Engineering Materials- C.M. Srivastava and C. Srinivasan. New Age International Pvt.Ltd.
5. Engineering Physics – M.N. Avadhanulu and P.G. Kshirsagar.S.Chand and Company LTD.
6. Engineering Physics - R.K. Gaur and S. L. Gupta. Dhanpat Rai Publications Pvt. Ltd.-New Delhi.
7. Nanotechnology: An Introduction to Synthesis, Properties and Applications of Nanomaterials- Thomas Varghese , K. M. Balakrishna

Reference Books:

8. The Feynman Lectures on Physics Vol I, II, III.
9. Introduction to Solid State Physics – Charles Kittel. John Willey and Sons
10. Solid State Physics – A.J. Dekker. McMillan India –Limited.
11. Fundamental of Physics - Halliday and Resnik. Willey Eastern Limited.

BSC 102	Engineering Physics Lab	L	T	P	C
		0	0	4	2

Course Objectives:

- To impart experimental skills through laboratory experiments
- To motivate the students to familiarize electrical, magnetic, optical measurements
- To impart knowledge on physical and structural characterization of various types of materials

Course Outcome:

- Students shall be in a position to relate the theory course with application
- Learn the skill of setting up a physical measurement, presentation and analysis of experimental data
- Develop deep understanding of fundamental concepts through experiental approach

List of Experiments

Electrical

- Carey Foster's Bridge: To measure resistance per length and specific resistance
- Band gap of Semiconductor: To determine the energy band gap of a given semiconductor
- Ferroelectric Material: To measure dielectric constant & Curie temperature of ferroelectric material Photoelectric Effect: To study the photoelectric effect and determination of Planck's constant

Electronics

- P-N Junction diode: To study the forward and backward characteristics of P-N Junction diode:
- Zener diode: To study the reverse bias characteristics of Zener diode
- Operational amplifier: To determine the Summing amplifier, Differentiator and Integrator
- FET: To perform the forward and transfer characteristics of FET
- LCR circuit: To study the resonance condition of a series LCR circuit.

Magnetic

- Measurement of magnetic susceptibility: Quincke's Method / Gouy's balance.
- Current carrying coil: To determine the variation in magnetic field with distance along the axisof a current carrying coil and estimate the radius of the coil.
- Hall Effect: To determine the Hall coefficient, carrier density and mobility of semiconductor.

- Magnetic Hysteresis: To draw B-H curve of ferromagnetic iron and determine hysteresis loss.

Properties of Matter

- To determine the thermal conductivity of metal by Searle's method
- To determine the thermal conductivity of a bad conductor by Lee's disc
- Torsional pendulum - Determination of rigidity modulus of wire and moment of inertia of thedisc
- Determination of Young's modulus; Non-uniform bending and Uniform Bending

Optical

- Laser: To study the laser diffraction, laser beam profile and beam quality
- Optical Fibre: To determine the Numerical Aperture, fibre loss, LED /Laser Diodecharacteristics
- Fabry-Perot interferometry: To find out separation of wavelength of sodium D1 & D2 lines
- Laurent's Half shade polarimeter – determination of specific rotatory power

Reference Books

1. A.C. Melissinos, J. Napolitano, Experiments in Modern Physics, Academic Press (2003)
2. Avadhanulu, Dani and Pokley, Experiments in Engineering physics, S. Chand & Co (2002).
3. S.L. Gupta and V. Kumar, Practical physics, Pragathi Prakash (2005)
4. R.K. Shukla, Anchal Srivastava, Practical Physics, New age international, 2011.
5. C.L Arora, B.Sc. Practical Physics, S. Chand & Co., 2012.

BSC 103	Mathematics – I	L	T	P	C
		2	1	0	3

Course Objective

- To impart skills in problem solving using calculus, differentiation and other mathematical functions
- To learn the application of standard series.
- To imbibe the concept of utilizing the multiple integrals in solving engineering problems.

Course Outcomes:

By the end of the course students would be able:

- To apply differential and integral calculus to notions of curvature and to improper integrals. Also, shall have a basic understanding of Beta and Gamma functions.
- To apply the tool of power series and Fourier series for learning advanced Engineering Mathematics.
- To deal with functions of several variables that are essential in most branches of engineering.
- To acquaint the student with mathematical tools needed in evaluating multiple integrals and their usage.

Unit I: Basic Calculus

Curvature, evolutes and involutes; Evaluation of definite and improper integrals; Beta and Gamma functions and their properties; Applications of definite integrals to evaluate surface areas and volumes of revolutions.

Unit II: Single-variable Calculus (Differentiation)

Rolle's Theorem, Mean value theorems and applications; Extreme values of functions; Linear approximation; Indeterminate forms and L' Hospital's rule.

Unit III: Sequences and series

Limits of sequence of numbers, Calculation of limits, Infinite series; Tests for convergence; Power series, Taylor and Maclaurin series; Taylor theorem, convergence of Taylor series, error estimates.

Unit IV: Multivariable Calculus (Differentiation)

Limit, continuity and partial derivatives, directional derivatives, gradient, total derivative; Tangent plane and normal line; Maxima, minima and saddle points; Method of Lagrange multipliers.

Unit V: Multivariable Calculus (Integration)
Multiple Integration: Double integrals (Cartesian), change of order of integration in double integrals, Change of variables (Cartesian to polar), Applications: areas and volumes, Center of mass and Gravity (constant and variable densities); Triple integrals (Cartesian), orthogonal curvilinear coordinates, Simple applications involving cubes, sphere and rectangular parallelepipeds; Scalar line integrals, vector line integrals, scalar surface integrals, vector surface integrals, Gradient, curl and divergence, Theorems of Green, Gauss and Stokes.

Text Books

1. G.B. Thomas and R.L. Finney, Calculus and Analytic geometry, 9th Ed, Pearson, 2002.
2. Erwin Kreyszig, Advanced Engineering Mathematics, 9th Edition, John Wiley & Sons, 2006.
3. Ramana B.V., Higher Engineering Mathematics, Tata McGraw Hill, 11th Reprint, 2010.
4. Veerarajan T., Engineering Mathematics for first year, Tata McGraw-Hill, New Delhi, 2008.
5. N.P. Bali and Manish Goyal, A text book of Engineering Mathematics, Laxmi Publications, 2008.
6. 6. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 36th Edition, 2010.

BSC 104	Biology for Engineers	L	T	P	C
		2	0	2	3

Course Objectives:
1. Introduction to Basics of Biology which includes the unit of life the cell, different types of cells and classification of living organisms.
2. Understanding what are biomolecules present in a cell, their structure function and their role in a living organism. Application of certain bio molecules in Industry.
3. Brief introduction to human physiology, which is essential for bioengineering field.
4. Understanding the hereditary units, that is genes and genetic materials (DNA and RNA) present in living organisms and how they replicate and pass and preserve vital information in living organisms.
5. How biology can be applied in our daily life using different technology, for production of medicines to transgenic plants and animals to designing new biotechnological products

Outcomes:
1. Define the cells, its structure and function, and Different types of cells and basis for classification of living organisms.
2. Explain about biomolecules its structure and function and their role in a living organism. How biomolecules are useful in Industry & explain about human physiology
3. Demonstrate the concept of biology and its uses in combination with different technologies for production of medicines and production of transgenic plants and animals

Unit-I Introduction to Basic Biology [9]
Cell: What is a Cell, Cell theory, Cell shapes, structure and function of a Cell, Cell cycle chromosomes, The Plant Cell and animal Cell, protoplasm, prokaryotic and eukaryotic Cell, Plant Tissue and Animal Tissue. Brief introduction to five kingdoms of classification.

Unit-II Introduction to Bio-molecules [9]
Lipids, Carbohydrates, Proteins, Amino acid, nucleic acid (DNA and RNA) and their types.
Enzymes and their application in Industry. Large scale production of enzymes by Fermentation.

Unit-III Human Physiology [9]
Digestive systems, Respiratory system (two kinds of respiration – aerobic and anaerobic) Respiratory organs, respiratory cycle. Excretory system, Circulatory system, Reproductive system, Central nervous system and Endocrine system.

Unit-IV Genes, Replication of DNA, And Introduction to recombinant DNA Technology [9]

Prokaryotic gene and Eukaryotic gene structure, gene replication, Transcription and Translation in Prokaryote and Eukaryotes. Recombinant DNA technology and cloning introduction.

Unit-V Application of Biology [9]

Brief introduction to Production of vaccines, Enzymes, antibodies, Cloning in microbes, plants and animals, Basics of biosensors, biochips, Bio fuels, and Biosensors. What is Tissue engineering? And its application, transgenic plants and animals, Bio engineering (production of artificial limbs, joints and other parts of body).

Text Books:

1. Cell and Molecular Biology-P.K.Gupta
2. Cell Biology-Verma and Agarwal
3. Cell Biology-Rastogi
4. N. A. Campbell, J. B. Reece, L. Urry, M. L. Cain and S. A. Wasserman, "Biology: A global approach", Pearson Education Ltd, 2018.
5. T Johnson, Biology for Engineers, CRC press, 2011 Molecular Biology and Biotechnology 2nd ed. J.M. Walker and E.B. Gingold. Panima Publications. PP 434.

Reference Books:

1. Alberts et.al. The molecular biology of the cell, 6/e, Garland Science, 2014
2. De Robertis EDP & EMF De Robertis. 2001. Cell and Molecular biology. Lippincott Williams &Wilkins.Bombay.
3. E. E. Conn, P. K. Stumpf, G. Bruening and R. H. Doi, "Outlines of Biochemistry", John Wiley and Sons, 2009.
4. John Enderle and Joseph Bronzino Introduction to Biomedical Engineering, 3/e, 2012 Principles of Biochemistry. 2nd ed. 1993. A.L. Lehninger, D.L.Nelson.M.Cox. Paniama Publications. PP. 1090.
6. Introductory Microbiology. 1995, by Trevor Gross.
7. Molecular Biology by G. Padmanabhan, K. SivaramSastry, C. Subramanyam, 1995, Mac Millan.
9. Genetic Engineering –SandhyaMitra.
10. Molecular Biology and Biotechnology by Meyers, RA, A comprehensive Desk reference (VCH Publishers).

ESC 101	Basic Electronics Engineering	L	T	P	C
		2	1	2	4

Course Objectives:

- To understand the language of electronics, elements and their functionality
- Basic understanding of analog systems and their applications
- Basic understanding of digital systems and their applications

Course Outcome:

- To learn the basics of electronic components and concepts of circuits
- To understand the concept and application of Operational amplifiers.
- To learn about the wired and wireless communication systems.
- To learn the basics of digital electronics
- To apply the knowledge of analog and digital electronics to many systems.

Unit I: Basic Circuits Concepts [12]

Passive components: Resistance, Inductance, Capacitance; series, parallel combinations; Kirchhoff's law: Voltage, Current; Linearity. Signal sources: Voltage and Current sources; Non-ideal sources; Representation under assumption of Linearity; controlled sources: VCVS, CCVS, VCCS, CCCS; concept of Gain, Transconductance, Transimpedance, Superposition theorem, Thevenin's theorem, Norton's theorem

Unit II: The Operational Amplifier and Oscillator [12]

Basic model; Virtual ground concept; Inverting Amplifier, Non-inverting Amplifier, Integrator, Differentiator, Summing Amplifier and their applications. Basic feedback theory; positive and negative feedback; concept of

stability; Oscillator. Waveform generator using Op-Amp for Square Wave, Triangular Wave, Wien Bridge Oscillator for sinusoidal waveform

Unit III: Communication Systems **[12]**

Introduction - Wired and Wireless Communication system - EMW and propagation, Antenna, Broadcasting and Communication - Internet/Intranet -Optical fiber

Unit IV: Digital Electronics **[12]**

Number systems, Binary arithmetic - Logic gates: OR, NOT, AND, NOR, NAND, XOR, XNOR gate; Truth tables - Multiplexers, Demux, Encoder, Decoder - Logic Function Representation – Combinational circuits: SOP, POS form; K-map - Latch, flip-flop: S-R flip-flop; JK flip-flop, Master-Slave flip-flop.

Unit V: Application of Electronic System **[12]**

Instrumentation system: Transducer, Strain Gauge, DMM, Oscilloscope - Regulated power supply - Remote control, Character Display, Clock, Counter, Measurements, Data Logging, Audio-Video system

Text Books:

1. Robert Boylestad and Louis Nashelsky, "Electronic Devices and Circuit Theory" PHI; 8th Edition.200
2. Thomas L. Floyd, "Electronic Devices" 8th Edition, Pearson Education, Inc., 2007
3. A.S. Sedra and K.C. Smith, "Microelectronic Circuits", 6th Edition, Oxford University Press, 2006

Reference Book:

1. J. Millman and C.C. Halkias, Integrated Electronics: Analog and Digital Circuits and Systems, McGraw-Hill, Tokyo, 1972, ISBN: 9780070423152, 0070423156
2. H. Taub and D. Schilling, Digital Integrated Electronics, Tata McGraw Hill, New Delhi, 2008, ISBN 10: 0070857881 ISBN 13: 9780070857889

ESC 102	Engineering Graphics & Design	L	T	P	C
		2	1	2	4

Course Objective:

- To explore relevance of engineering drawing to the varied design applications in engineering and technology.
- To enhance the ability to communicate engineering information by engineering drawings;
- To develop further the skill of representing design concepts and solutions using both freehand and accurate drawings;
- To develop an accurate level of draughtsmanship that respects established draughting codes, practices, and conventions.
- To develop a knowledge of two-dimensional (2D) computer-aided draughting (CAD).

Course Outcome:

- Prepare and understand drawings.
- Identify various D curves used in Engineering Drawing and their applications.
- Use the principles of orthographic projections.
- By studying about projections of solids students will be able to visualize three dimensional objects and that will enable them to design new products.
- Design and fabricate surfaces of different shapes.
- Expose to computer-aided geometric design.
- Expose to creating working drawings.

Unit I: Traditional Engineering Graphics **[12]**

Principles of engineering graphics; orthographic projection; descriptive geometry; drawing principles; isometric projection; surface development; perspective; reading a drawing; sectional views; dimensioning & tolerances; true length, angle; intersection, shortest distance.

Unit II: Computer Graphics **[12]**

Engineering graphics software; -spatial transformations; orthographic projections; model viewing; co-ordinate systems; multi-view projection; exploded assembly; model viewing; animation; spatial manipulation; surface modelling; solid modelling; introduction to building information modelling (BIM).

Unit III: Introduction to Engineering Drawing **[12]**

Principles of engineering graphics and their significance, usage of drawing instruments, lettering, conic sections including the rectangular hyperbola (general method only); cycloid, epicycloid, hypocycloid and involute; scales – plain, diagonal and vernier scales;

Unit IV: Projections **[12]**

Orthographic projections: principles of orthographic projections-conventions - projections of points and lines inclined to both planes; projections of planes inclined planes - auxiliary planes; projections of regular solids: those inclined to both the planes- auxiliary views; draw simple annotation, dimensioning and scale. floor plans that include: windows, doors, and fixtures such as wc, bath, sink, shower, etc.

Unit V: Sectioning of Solids, Isometric Projections **[12]**

Sectioning of solids: Section planes perpendicular to one plane and parallel or inclined to other plane. Isometric projections: Isometric scale, drawing of isometric projections from given orthographic views.

Text Books:

1. N. D. Bhatt, Engineering Drawing, Charotar Publishing House, 46th Edition, 2003.
2. K. V. Nataraajan, A text book of Engineering Graphic, Dhanalakshmi Publishers, Chennai, 2006.
3. K. Venugopal and V. Prabhu Raja, Engineering Graphics, New Age International (P) Ltd, 2008.
4. Dhananjay A. Jolhe, Engineering Drawing with an Introduction to Autocad, Mc GrawHill Education, 2017.

Engineering Graphics & Design Lab

List of Experiments

1. Lines, lettering and dimensioning.
2. Geometrical Constructions.
3. Orthographic projections.
4. Projections of points and straight lines
5. Projections of planes.
6. Projections of solids.
7. Section of solids.
8. Isometric Projections.

HSMC 101	Communicative English	L	T	P	C
		2	0	2	3

Course outcome: Students will be able to:

- The student will acquire basic proficiency in English including reading and listening comprehension, writing and speaking skills.

Unit I: Vocabulary Building **[9]**

The concept of Word Formation, Root words from foreign languages and their use in English, Acquaintance with prefixes and suffixes from foreign languages in English to form derivatives, Synonyms, antonyms, and standard abbreviations.

Unit II: Basic Writing Skills **[9]**

Sentence Structures, Use of phrases and clauses in sentences, Importance of proper punctuation, Creating coherence, Organizing principles of paragraphs in documents, Techniques for writing precisely.

Unit III: Identifying Common Errors in Writing **[9]**

Subject-verb agreement, Noun-pronoun agreement, Misplaced modifiers, Articles, Prepositions, Redundancies, Clichés.

Unit IV: Nature and Style of Sensible Writing [9]
Describing, Defining, Classifying, Providing examples or evidence, Writing introduction and conclusion.

Unit V: Writing Practices and Oral Communication [9]
Comprehension, Précis Writing, Essay Writing. Listening Comprehension, Pronunciation, Intonation, Stress and Rhythm, Common Everyday Situations: Conversations and Dialogues, Communication at Workplace, Interviews, Formal Presentations

TextBooks:

1. AICTE's Prescribed Textbook: English (with Lab Manual) ISBN: 978-93-91505-097
2. Effective Communication Skills. Kul Bhushan Kumar, Khanna Book Publishing, 2022.
3. Practical English Usage. Michael Swan. OUP. 1995.

Reference Books:

4. Remedial English Grammar. F.T. Wood. Macmillan.2007
5. On Writing Well. William Zinsser. Harper Resource Book. 2001
6. Study Writing. Liz Hamp-Lyons and Ben Heasly. Cambridge University Press. 2006.
7. Communication Skills. Sanjay Kumar and PushpLata. Oxford University Press. 2011.
8. Exercises in Spoken English. Parts. I-III. CIEFL, Hyderabad. Oxford University Press.

English Lab

List of Practicals:

1. How to introduce oneself ?
2. Know your friend
3. Introduction to Phonemic symbols
4. Articulation of sounds in English with proper manner
5. Practice and exercises on articulation of sounds
6. Read Pronunciations/transcriptions from the dictionary
7. Practice and exercises on pronunciations of words
8. Introduction to stress and intonation
9. Rapid reading sessions
10. Extempore
11. Group discussion
12. Participating in a debate
13. Presentation techniques
14. Interview techniques

MC 101	Sports/Yoga or NSS/NCC	L	T	P	C
		0	0	2	0

Course outcome:

- To make the students understand the importance of sound health and fitness principles as they relate to better health.
- To expose the students to a variety of physical and yogic activities aimed at stimulating their continued inquiry about Yoga, physical education, health and fitness.
- To create a safe, progressive, methodical and efficient activity-based plan to enhance improvement and minimize risk of injury.
- To develop among students an appreciation of physical activity as a lifetime pursuit and a means to better health.

Unit I: Introduction to Physical Education
Physical Education- Meaning, definition, aims, Objectives and Changing trends. Meaning, importance and components of Physical Fitness & Wellness, Preventing Health Threats through Lifestyle Change, and Positive Lifestyle. Ancient & Modern Olympics (Summer & Winter), Olympic Symbols, Ideals, Objectives & Values, Awards and Honours in the field of Sports in India (Dronacharya Award, Arjuna Award, Dhayanchand Award, Rajiv Gandhi Khel Ratna Award etc.).

Unit II: Kinesiology, Biomechanics & Sports
Meaning & Importance of Kinesiology & Biomechanics in Physical Edu. & Sports, Newton's Law of Motion & its application in sports, Friction and its effects in Sports. Concept of Postures and Causes of Bad Posture. Training, Warming up and limbering down, Skill, Technique & Style, Meaning and Objectives of Planning.

Unit III: Psychology & Sports
Definition & Importance of Psychology in Physical Edu. & Sports, Define & Differentiate Between Growth & Development, Adolescent Problems & Their Management, Emotion: Concept, Type & Controlling of emotions, Meaning, Concept & Types of Aggressions in Sports. Psychological benefits of exercise. Anxiety & Fear and its effects on Sports Performance. Motivation, its type & techniques. Understanding Stress & Coping Strategies.

Unit IV: Yoga and Lifestyle
Meaning & Importance of Yoga, Elements of Yoga, Introduction - Asanas, Pranayama, Meditation & Yogic Kriyas, Yoga for concentration & related Asanas (Sukhasana; Tadasana; Padmasana & Shashankasana), Relaxation Techniques for improving concentration - Yog-nidra. Asanas as preventive measures, asanas for hypertension, obesity, back pain, diabetes, asthema, etc.

Unit V: Doping and sports medicine: Meaning and Concept of Doping, Prohibited Substances & Methods, Side Effects of Prohibited Substances. Sports Medicine: First Aid – Definition, Aims & Objectives.Sports injuries: Classification, Causes & Prevention. Management of Injuries: Soft Tissue Injuries and Bone & Joint Injuries

Text Books:
1. Modern Trends and Physical Education by Prof. Ajmer Singh.
2. Light On Yoga by B.K.S. Iyengar.
3. Health and Physical Education – NCERT (11th and 12th Classes)

NSS/NCC: Standard.

BSC 105	Engineering Chemistry	L	T	P	C
		2	1	0	3

Course objectives:
- To familiarize the students with the basic concepts of chemistry in various topics relevant to their course of study.
- To impart the knowledge and insights for applying the various aspects of chemistry to energy technologies.

Course outcome:
By the end of the course students would be able to:
- Understand the fundamental concepts of atomic structure, chemical bonding, and molecular orbitals, and apply them to classify materials and comprehend band theory in solids.
- Analyze chemical thermodynamics, equilibrium conditions, and reaction kinetics, enabling them to calculate enthalpy, free energy changes, and rate constants for various chemical processes.
- Demonstrate knowledge of electrochemical cells, EMF, and concentration cells, along with the ability to identify corrosion mechanisms, types, and protective measures.
- Gain insights into basic concepts of organic chemistry, fuels, and polymers, including hydrocarbon properties, polymer synthesis, and the analysis of coal and calorific value.
- Grasp water technology principles, including hardness evaluation, different types of hardness, and techniques for water softening.

Unit I: Fundamental concepts of atomic structure and chemical bonding [9]
Introduction, atomic structure and interatomic bonding, molecular orbitals of diatomic molecules, classifications of materials, band theory of solids, liquid crystal, and its applications, and point defects in solids. Structure and applications of graphite and fullerenes. Concepts of nanomaterials and their application in emerging trends.

Unit II: Chemical thermodynamics, equilibrium, and kinetics [9]
Enthalpy and free energy changes in chemical reactions; relevance of cp and cv in gas phase reactions, chemical potential; heat capacity of solids, absolute entropy and third law of thermodynamics, Maxwell relations, Chemical potential, Equilibrium conditions for closed systems, Phase and reaction equilibria, Phase rule, Real gas, and real solution. Rate of reversible, consecutive, and parallel reactions, steady state approximation, chain reactions, enzyme-catalyzed homogeneous and heterogeneous surface-catalyzed chemical reactions, and photochemical kinetics.

Unit III: **Electrochemistry and corrosion [9]**
Electrochemical cells and EMF, Applications of EMF, concentration cell with and without transference. Dry corrosion and wet corrosion, mechanisms, types of corrosion, Differential metal corrosion, differential aeration corrosion, intergranular, Passivity, Pitting, Polarization - Chemical conversion coatings and organic coatings- Paints, enamels.

Unit IV: Organic chemistry, Fuels, and Polymers [9]
Hydrocarbons (Alkane, Alkene, Alkyne) structure, stereochemistry, physical and chemical properties, chemical reactivity, separation. Classification of fuels, analysis of coal, and determination of calorific value (Bomb calorimeter and Dulong's methods). Basic concepts of polymer-blend and composites, conducting, and biodegradable polymers. Preparation and application of some industrially essential polymers (BunaS, Buna-N, Neoprene, Nylon-6, nylon-6,6, and Terylene). General methods of synthesis of organometallic compounds (Grignard reagent) and their applications.

Unit V: Water technology [9]
Introduction, water analysis: i. Hardness-determination by EDTA method-numerical problems, ii. Alkalinity-determination by double indicator method-numerical problems, iii. Determination of dissolved oxygen by Winkler's method and iv. Determination of chemical oxygen demand - numerical problems. Boiler scales-formation and ill effects, prevention of scales by external method (hot lime-soda process). Desalination by electrodialysis.

List of Textbooks:
1. Physical Chemistry by G.W. Castellan (Addison Wesley Publishing Company).
2. ATKINS' Physical Chemistry by Peter Atkins, Julio de Paula (Oxford press).
3. Organic Chemistry (Volume 1) by I. L. Finar (Richard Clay and Company Ltd.)
4. Dara, S.S.; A Textbook of Engineering Chemistry (Tenth edition); S. Chand, 2003

Reference Books:
1. Principle of Physical Chemistry by Puri, Sharma, Pathania (Vishal Publication)
2. Physical Chemistry by S. Glasstone
3. Polymer Chemistry by Fre W., Billmeyer
4. Engineering Chemistry: Wiley

BSC 106	Engineering Chemistry Lab	L	T	P	C
		0	0	4	2

Course Objectives:
- To impart scientific approach and to familiarize with the experiments in chemistry relevant for research projects in higher Studies.

- Recognize how chemistry tackles issues related to society, the economy, and the environment.
- Appreciate the importance of chemistry as well as why it is a necessary component of the curriculum.

Course outcomes:

After the completion of the course the students will be able to

1. Gain knowledge of and experience with several quantitative chemical analysis techniques to develop experimental abilities that may be used to a variety of analyses.
2. Gain practical experience using TLC to identify pharmaceuticals and develop abilities necessary to synthesise organic polymers.
3. Acquire the ability to understand, explain and use instrumental techniques for chemical analysis.
4. Accurately plan, conduct, and record scientific experiments, as well as analyse and interpret the findings.

Suggested Topics for Laboratory Experiments:

Section A: Inorganic Chemistry

1. Titration with $KMnO_4$
   - (i) Estimation of oxalic acid
   - (ii) Estimation of Mohr's salt
   - (iii) Estimation of water of crystallization in Mohr's salt.
2. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.
3. Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.
4. Complexometric titrations using disodium salt of EDTA
   - (i) Estimation of Mg^{2+}, Zn^{2+}
   - (ii) Estimation of Ca^{2+} by substitution method
   - (iii) Estimation of Calcium content in milk.

Section B: Organic Chemistry

1. Purification of organic compound by crystallisation (from water and alcohol) and distillation.
2. Criteria of purity: Determination of M.P./B.P.
3. Separation of mixtures by chromatography: Measure the Rf value in each case (combination of two compounds to be given)
   - (i) Identify and separate the components of a given mixture of 2 amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by radial/ascending paper chromatography.
   - (ii) Identify and separate the sugars present in the given mixture by radial/ascending paper chromatography

Section C: Physical Chemistry

1. Perform the following potentiometric titrations:
   - (i) Strong acid *vs*. strong base
   - (ii) Weak acid *vs*. strong base
   - (iii) Dibasic acid *vs*. strong base
   - (iv) Potassium dichromate *vs.* Mohr's salt.
2. Determination of cell constant
3. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
4. pH metric titration of
   - (i) strong acid with strong base
   - (ii) weak acid with strong base
   - (iii) determination of dissociation constant of a weak acid.
5. Perform the following conductometric titrations:
   - (i) Strong acid *vs.* strong base
   - (ii) Weak acid *vs*. strong base.
6. Gravimetric analysis to determine the quantity of an analyte based on the mass of a solid

Conduct of Experiments & Evaluation:

A minimum of 10 experiments shall be offered in the laboratory and evaluated for the grade.

Text Books:

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C.(1989),Vogel's Textbook of Quantitative Chemical Analysis, 5th Edn., John Wiley and Sons Inc.
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012),Vogel's Textbook of Practical Organic Chemistry, Pearson.
3. Mann, F.G.; Saunders, B.C. (2009), Practical Organic Chemistry, Pearson Education.

Reference Books:

1. Khosla, B.D.; Garg, V.C.;Gulati, A.(2015), Senior Practical Physical Chemistry, R. Chand & Co.
2. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P.(2003), Experiments in Physical Chemistry, 8th Edition, McGraw-Hill, New York.
3. Kapoor, K.L. (2019), A Textbook of Physical Chemistry, Vol.7, 1st Edition, McGraw Hill Education
4. Dr. J. N. Gurtu and Amit Gurtu, Advanced Physical Chemistry Experiments

BSC 107	Mathematics – II	L	T	P	C
		2	1	0	3

Course Objectives

- Understand the fundamental concepts and operations related to matrices and apply matrix techniques to solve various engineering problems
- Solve first-order ordinary differential equations using different methods
- Analyze and solve second-order linear differential equations with variable coefficients
- Understand complex variable differentiation. Apply differentiation techniques to solve problems involving conformal mappings, Mobius transformations, and finding harmonic conjugates.
- Explore complex variable integration concepts.

Course outcome:

Students will be able to:

- The essential tool of matrices and linear algebra in a comprehensive manner.
- The effective mathematical tools for the solutions of differential equations that model physical processes.
- The tools of differentiation and integration of functions of a complex variable that are used in various techniques dealing engineering problems.

Unit I: Matrices [9]

Linear Systems of Equations; Linear Independence; Rank of a Matrix; Determinant, Inverse of a matrix, rank-nullity theorem; System of linear equations; Symmetric, skew-symmetric and orthogonal matrices; Determinants; Eigenvalues and eigenvectors; Orthogonal transformation; Diagonalization of matrices; Cayley-Hamilton Theorem.

Unit II: First order ordinary differential equations [9]

Exact, linear and Bernoulli's equations. Equations not of first degree: equations solvable for p, equations solvable for y, equations solvable for x and Clairaut's type.

Unit III: Ordinary differential equations of higher orders [9]

Second order linear differential equations with variable coefficients: Euler-Cauchy equations, solution by variation of parameters; Power series solutions: Legendre's equations and Legendre polynomials, Frobenius method, Bessel's equation and Bessel's functions of the first kind and their properties.

Unit IV: Complex Variable – Differentiation [9]

Differentiation, Cauchy-Riemann equations, analytic functions, harmonic functions, finding harmonic conjugate; elementary analytic functions (exponential, trigonometric, logarithm) and their properties; Conformal mappings, Mobius transformations and their properties.

Unit V: Complex Variable – Integration [9]

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

Text Books

1. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Edition, John Wiley & Sons, 2006.
2. Veerarajan T., Engineering Mathematics for first year, Tata McGraw-Hill, New Delhi, 2008.
3. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, 9th Edition, Wiley India, 2009.
4. D. Poole, Linear Algebra: A Modern Introduction, 2nd Edition, Brooks/Cole, 2005.
5. S. L. Ross, Differential Equations, 3rd Edition, Wiley India, 1984.
6. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall India, 1995.
7. E. L. Ince, Ordinary Differential Equations, Dover Publications, 1958.
8. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 7th Ed., Mc-Graw Hill, 2004.
9. N.P. Bali and Manish Goyal, A text book of Engineering Mathematics, Laxmi Publications, Reprint, 2008.
10. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 36th Edition, 2010.

General Instructions:

1. The tutorial classes in Engineering Mathematics-II are to be conducted batchwise. Each class should be divided into three batches for the purpose.
2. The internal assessment of the students for 20 marks will be done based on assignments, surprise tests, quizzes, innovative approach to problem solving and percentage attendance.
3. The minimum number of assignments should be eight covering all topics.

ESC 103	Basic Electrical Engineering	L	T	P	C
		2	1	2	4

Objectives

1. Understand the basic terminology/definitions of electrical and electronics engineering
2. Apply the knowledge of theorems/laws to analyze the simple circuits
3. Use the principles of electromagnetic induction in electrical applications.

Course outcome

1. Recall basic concepts of Electrical Engineering
2. Illustrate basics of AC circuits
3. Explain operative principle of transformer with background of magnetic circuits
4. Classify and compare different types of Electrical machines
5. Classify different electrical measuring equipment and understanding their principles

UNIT I: D.C circuit analysis and network theorems [12]

Circuit concepts and concept of network, Active and passive elements, voltage and current sources, concept of linearity and linear network, unilateral and bilateral elements, R L and C as linear elements, source transformation, Kirchoff's Law: loop and nodal methods of analysis, star delta transformation, network theorems: Thevenin's theorem, Norton's theorem, maximum power transfer theorem.

UNIT II: Steady state analysis of single phase ac circuits [12]

AC fundamentals: Sinusoidal, square and triangular waveforms-average and effective value, form the peak factors, concept of phasors, phasors representation of sinusoidally varying voltage and current, analysis of

series-parallel RLC circuits. Apparent, active and reactive powers, power factor, causes and problems of low power factor, power factor improvement, resonance in series and parallel circuits, bandwidth and quality factors.

UNIT III: Three phase ac circuits [12]

Three phase system: Its necessity and advantages, meaning of phase sequence, star and delta connections, balanced supply and balanced load, line and phase voltage/current relation, three phase power measurements. **Measurement instruments:** Types of instruments: construction and working principle of PMMC and MI type voltmeter and ammeters, single phase dynamometer type wattmeter and induction type energy meter, use of shunts and multipliers.

UNIT IV: Introduction of power system [12]

general layout of electrical power system and function of its elements, standard transmission and distribution voltages, concept of grid. **Magnetic circuit:** Concepts, analogy between electric and magnetic circuit, magnetic circuits with DC and AC excitation, magnetic leakage, BH curve, hysteresis and eddy current losses, magnetic circuit calculation, mutual coupling. **Single Phase Transformer:** Principle of operation, construction, emf equation, equivalent circuit, power losses, efficiency, Introduction to auto transformers.

UNIT V: Principle of Electromechanical energy conversion [12]

DC Machines: Types, emf equation of generator and torque equation of motor, characteristics and applications of DC motors. Three Phase Induction Motor: Type, principle of operation, slip-torque Characteristics, applications. Single Phase Induction Motor: Principle of operation and introduction to methods of starting, applications. Three Phase Synchronous Machines: Principle of operation of alternator and synchronous motor, applications.

List of text books:

1. 2.V.Deltoro, “Principle of Electrical Engg.” PHI.
2. 3.M.A Mallick, Dr. I. Ashraf, “Fundamental of Electrical Engg,” Word Press, Lucknow.
3. 4.A. Hussain, “Basic Electrical Engg” Dhanpat Rai & sons.
4. 5.I J Nagrath,“Basic Electrical Engg” ,TMH

Electrical engineering lab: List of Experiments:

1. Verification of Thevenin's Theorem.
2. Verification of Superposition Theorem.
3. Verification of Maximum Power Transfer Theorem.
4. To study V-I characteristics of diode.
5. To study the input & output characteristics of BJT in CE configuration.
6. To study the full wave rectifier circuit with &without filter and determine the ripple factor.
7. To study the phenomenon of resonance in series RLC circuit.
8. Determination of losses in single-phase transformer by OCT and SCT.
9. To calibrate a single phase induction type energy meter.
10. To study the running and reversing of a three phase SCIM.
11. Study of OP Amp based inverting and non inverting amplifier.

ESC 104	Programming for Problem Solving	L	T	P	C
		2	1	2	4

Course Objectives

- Develop a foundational understanding of Python programming language and gain proficiency in utilizing Python data structures like strings, lists, tuples, sets, and dictionaries, along with understanding their operations and functions.
  Master Object-Oriented Programming (OOP) concepts in Python,
- Develop skills in data visualization using libraries like PyPlot
- Gain an understanding of scientific computing concepts such as linear algebra, solving nonlinear equations, numerical integration, and solving ordinary differential equations (ODEs) using Python.
  Explore data manipulation and analysis using the Pandas library

Course outcome: Students will be able to:

- to provide learners with insight into Python programming
- develop programming skills to solve engineering problems
- learn programming environments, important instructions, data representations,
- intermediate level features, Object Oriented Programming, and file data processing of Python.
- Lays the foundation for scientific computing, develops web applications,
- Machine Learning and Artificial Intelligence-based applications and tools, Data Science and DataVisualization applications.

Unit I: Basics of Python [12]

Getting Started with Python Programming - Running code in the interactive shell, Editing, Saving, and Running a script. Using editors - Anaconda, colab. Basic coding skills - Working with data types, Numeric data types and Character sets, Keywords, Variables and Assignment statements, Operators, Expressions, Working with numeric data, Type conversions, Comments in the program, Input Processing, and Output, Formatting output. How Python works. Detecting and correcting syntax errors. Using built-in functions and modules in the math module. Control statements - Selection structure - if-else, if-elif-else. Iteration structure - for, while. Testing the control statements. Lazy evaluation.

Unit II: Functions and Python Data Structures [12]

Functions - Hiding redundancy and complexity, Arguments and return values, Variable scopes and parameter passing, Named arguments, Main function, Working with recursion, Lambda functions. Strings - String function. Lists - Basic list Operations and functions, List of lists, Slicing, Searching and sorting lists, List comprehension. Work with tuples. Sets. Dictionaries -Dictionary functions, dictionary literals, adding and removing keys, accessing and replacing values, traversing dictionaries, reverse lookup.

Unit III: Object-Oriented Programming [12]

Design with classes - Objects and Classes, Methods, Instance Variables, Constructors, Accessors and Mutators. Structuring classes with Inheritance and Polymorphism. Abstract Classes. Exceptions - Handle a single exception, Handle multiple exceptions.

Unit IV Visualization and File Handling [12]

Plotting - An Interactive Session with PyPlot, Basic Plotting, Logarithmic Plots, More Advanced Graphical Output, Plots with multiple axes, Mathematics and Greek symbols, The Structure of matplotlib, Contour and Vector Field Plots. File Processing - The os and sys modules, Introduction to file I/O, Reading and writing text files, Working with CSV files.

Unit V: Scientific Computing [12]

Linear Algebra, Solving Nonlinear Equations, Numerical Integration, Solving ODEs. Data Manipulation and Analysis – Pandas: Reading Data from Files Using Pandas, Data Structures: Series and DataFrame, Extracting Information from a DataFrame, Grouping and Aggregation.

Text Books:

1. Kenneth A Lambert., Fundamentals of Python : First Programs, 2/e, Cengage Publishing, 2016
2. David J. Pine, Introduction to Python for Science and Engineering, CRC Press, 2021

Reference Books:

1. Wes McKinney, Python for Data Analysis, 2/e, Shroff / O'Reilly Publishers, 2017
2. Allen B. Downey, Think Python: How to Think Like a Computer Scientist, 2/e, Schroff, 2016
3. Michael Urban and Joel Murach, Python Programming, Shroff/Murach, 2016
4. David M.Baezly, Python Essential Reference. Addison-Wesley Professional; 4/e, 2009.
5. Charles Severance. Python for Informatics: Exploring Information,
6. http://swcarpentry.github.io/python-novice-gapminder/Computer Programming for Engineers Lab

At least 08 experiments should be performed from the following list:

1. Run code in the interactive shell, edit, save, and run a script. Explore Anaconda and Colab environments

2. Implement if-else, for, and while statements. Experiment with lazy evaluation using different scenarios
3. Create functions with different parameter types, use recursion to solve problems. Explore lambda functions.
4. Perform basic operations on strings and lists. Work with tuples, sets, and dictionaries. Use list comprehensions
5. Implement classes, methods, instance variables, and constructors, and explore inheritance. Apply polymorphism and handle exceptions
6. Plot basic graphs, logarithmic plots, multiple axes plots, and contour plots. Use mathematical symbols in plots
7. Use the os and sys modules, read and write text files, and process CSV files.
8. Perform linear algebra operations, solve nonlinear equations, and integrate numerically. Solve ordinary differential equations (ODEs).
9. Read data from files, create Pandas Series and DataFrames, extract information, and perform grouping and aggregation
10. Define a project related to energy systems, use Python to analyze and visualize data, implement OOP principles, and present findings

ESC 105	Workshop/Manufacturing Practices	L	T	P	C
		2	1	2	4

Course Objectives

- Workshop practice is the backbone of the real industrial environment, which helps develop and enhance the technical hand skills required by technicians working in various engineering industries and workshops.
- Irrespective of the branch, the use of workshop practices in day-to-day industrial and domestic life helps dissolve the problems.
- To use hand tools and machinery in Carpentry, welding shop, Foundry, Fitting shop and SheetMetal work.
- To provide knowledge on various manufacturing methods and CNC machining
- To provide knowledge on basic electrical and electronics circuits design
- To manufacture engineering products or prototypes and workshop Practices

Course Outcomes

Understand the appropriate tools, materials, and instruments required for specific operations in the workshop.
Apply techniques to perform basic operations with hand tools and power tools such as a center lathe machine and drilling machine using the given job drawing.
Understand the figures of the hand tools used in fitting, carpentry, foundry, welding shop and machine tools such as lathe machine and drilling machine.
Understand a report related to hand tools and machine tools description referring to library booksand laboratory manuals.
Understand report of procedures followed for a given task in fitting, carpentry, foundry, sheet metals, welding and machine shops.
Understand reports of procedures followed for a given task in various manufacturing processes.
Understand the report of procedures followed for a given task in basic electrical and electronics circuit design.
Apply safety consciousness and show teamwork.

Conduct of Experiments & Evaluation:

Minimum of twelve workshop assignment shall taught and evaluated from the prescribed topics

Unit – I

Introduction to the Workshop: Workshop layout. Importance of various sections/shops of the workshop. Types of jobs done in each shop. General safety rules and work procedures in the workshop.
Fittings: Sketch, specification and applications of fitting work holding tools-bench vise, V-block with clamp and C-clamp. Sketch, specification, material ,applications and methods of using fitting marking and measuring tools-marking table, surface plate, angle plate, universal scribing block, try-square, scriber, divider, centre punch, letter punch, calipers, vernier caliper, etc. Types, sketches, specifications, materials, applications, and methods of using fitting cutting tools hacksaw, chisels, twist drills, taps, files, dies. Types, sketch, specification, material, applications and methods ofusing of fitting finishing tools-files, reamers. Sketch, specification and applications of miscellaneous tools-hammer, spanners, screw drivers sliding screw wrench. Demonstration of various fitting operations such as chipping, filing, scraping, grinding, sawing, marking, drilling, andtapping. Preparation of simple and male- female joints. Safety precautions.
Tin Smithy: Concept and conversions of SWG and other gauges in use.. Use of wire gauge. Types of sheet metal joints and applications. Types, sketches, specifications, materials, applications, and methods of using tin smithy tools-hammers, stakes, scissors/snips, etc. Demonstration of various tinsmithy tools and sheet metal operations such as shearing, bending and joining. Preparation of tin smithy job. Safety precautions.

Unit – II
Carpentry: Types, sketch, specification, material, applications and methods of using of carpentry tools-saws, planner, chisels, hammers, pallet, marking gauge, vice, try square, rule, etc. Types of woods and their applications. Types of carpentry hardwares and their uses. Demonstration of carpentry operations such as marking, sawing, planning, chiseling, grooving, boring, joining, etc. Preparation of wooden joints. Safety precautions.
Pipe Fitting: Types, specification, material and applications of pipes. Types, specification, materialand applications of pipe fittings. Types, specifications, material, applications and demonstration of pipe fitting tools. Demonstration of pipe fitting operations such as marking, cutting, bending, threading, assembling, dismantling, etc. Types and application of various spanners such as flat, fix, ring, box, adjustable, etc. Preparation of pipe fitting jobs. Safety precautions.

Unit - III
Metal Joining: Types, specification, material and applications of arc welding transformers. Types, specification, material and applications of arc welding accessories and consumables. Demonstrationof metal joining operations- arc welding, soldering and brazing. Show effect of current and speed. Also demonstrate various welding positions. Demonstrate gas cutting operation. Preparation of metal joints. Safety precautions.

Unit - IV
Manufacturing Methods- Introduction to casting, forming, machining, joining, advanced manufacturing methods, CNC machining, Additive manufacturing, Plastic moulding, glass cutting

Unit - V

Electrical: Study of various electrical symbols and tools. Study of electrical components. One-way and two-way control. Lamp is controlled from three different places, including living room wiring. Godown wiring. Hospitals' room wiring, fan wiring, tube light wiring, and volt ammeter method.
Electronics: PN Junction diode characteristics A) Forward bias B) Reverse bias, Zener diode characteristics and Zener as voltage Regulator, Full Wave Rectifier with & without filters, Input and output characteristics of BJT in CE Configuration, Input and output characteristics of FE in CS Configuration, Common Emitter Amplifier Characteristics, Common Base Amplifier Characteristics, Common Source amplifier Characteristics, Measurement of h-parameters of transistor in CB, CE, CC configurations, Switching characteristics of a transistor, SCRCharacteristics. Types of Clippers at different reference voltages, Types of Clampers at different reference voltages, The steady state output waveform of clampers for a square wave input

Text Books
1. Hajra Choudhury S.K., Hajra Choudhury A.K. and Nirjhar Roy S.K., "Elements of Workshop Technology", Vol. I 2008 and Vol. II 2010, Media promoters and publishers private limited, Mumbai.
2. Kalpakjian S. And Steven S. Schmid, "Manufacturing Engineering and Technology", 4thedition, Pearson Education India Edition, 2002.

3. Rao P.N., “Manufacturing Technology”, Vol. I and Vol. II, Tata McGrawHill House, 2017.

References

1. Gowri P. Hariharan and A. Suresh Babu,”Manufacturing Technology – I” Pearson Education,2008.
2. Roy A. Lindberg, “Processes and Materials of Manufacture”, 4th edition, Prentice Hall India,1998.

ESC 106	Design Thinking & Idea Lab	L	T	P	C
		1	0	2	2

Course Objectives:

Students will be able to:

1. Analyze emotional experience and Inspect emotional expressions to better understand users while designing innovative products.
2. Develop new ways of creative thinking and learn the innovation cycle of Design Thinking process for developing innovative products.
3. Propose real-time innovative engineering product designs and Choose appropriate frameworks, strategies, techniques during prototype development.

Course outcome:

1. To learn all the skills associated with the tools and inventory associated with the IDEA Lab.
2. Learn useful mechanical and electronic fabrication processes.
3. Learn necessary skills to build useful and standalone system/ project with enclosures.
4. Learn necessary skills to create print and electronic documentation for the system/project

Unit I : Emotions and Basics of Design Thinking

Understanding Emotions: Experience & Expression, Assessing Empathy, Application with Peers, Definition of Design Thinking, Need for Design Thinking, Objective of Design Thinking, Concepts & Brainstorming, Stages of Design Thinking Process (explain with examples) –Empathize, Define, Ideate, Prototype, Test.

Unit II: Problem Fixing and Process of Product Design

Understanding Creative thinking process, Understanding Problem Solving, Testing Creative Problem Solving, Process of Engineering Product Design, Design Thinking Approach, Stages of Product Design, Examples of best product designs and functions, Assignment – Engineering Product Design.

Unit III: Design Thinking & Customer Centricity

Practical Examples of Customer Challenges, Use of Design Thinking to Enhance Customer Experience, Parameters of Product experience, Alignment of Customer Expectations with Product Design.

Unit IV: Electronic component familiarization

understanding electronic system design flow. Schematic design and PCB layout and Gerber creation using EagleCAD. Documentation using Doxygen, Google Docs, Overleaf. Version control tools - GIT and GitHub. Basic 2D and 3D designing using CAD tools such as FreeCAD, Sketchup, Prusa Slicer, FlatCAM, Inkspace, OpenBSP and VeriCUT.

Basic hand tools: Tape measure, combination square, Vernier caliper, hammers, fasteners, wrenches, pliers, saws, tube cutter, chisels, vice and clamps, tapping and threading. Adhesives Introduction to Power tools: Power saws, band saw, jigsaw, angle grinder, belt sander, bench grinder, rotary tools. Various types of drill bits,

Unit V: Mechanical cutting processes

3-axis CNC routing, basic turning, milling, drilling and grinding operations, Laser cutting, Laser engraving etc. Basic welding and brazing and other joining techniques for assembly. Concept of Lab aboard a Box. 3D

printing and prototyping technology – 3D printing using FDM, SLS and SLA. Basics of 3D scanning, point cloud data generation for reverse engineering. Prototyping using subtractive cutting processes. 2D and 3D Structures for prototype building using Laser cutter and CNC routers. Basics of IPR and patents; Accessing and utilizing patent information in IDEA Lab

Text books:

Design Thinking

1. Karmic Design Thinking by Prof. Bala Ramadurai,
2. Design: Creation of Artifacts in Society by Prof. Karl Ulrich, U. Penn
3. Change by Design by Tim Brown.

Idea Lab

1. The Big Book of Maker Skills: Tools & Techniques for Building Great Tech Projects. Chris Hackett. Weldon Owen; 2018. ISBN-13: 978-1681884325.
2. The Total Inventors Manual (Popular Science): Transform Your Idea into a Top-Selling Product. Sean Michael Ragan (Author). Weldon Owen; 2017. ISBN-13: 978-1681881584.
3. Make: Tools: How They Work and How to Use Them. Platt, Charles. Shroff/Maker Media. 2018. ISBN-13: 978-9352137374
4. The Art of Electronics. 3rd edition. Paul Horowitz and Winfield Hill. Cambridge University Press. ISBN: 9780521809269
5. Practical Electronics for Inventors. 4th edition. Paul Sherz and Simon Monk. McGraw Hill. ISBN-13: 978-1259587542

Reference Books:

6. Encyclopedia of Electronic Components (Volume 1, 2 and 3). Charles Platt. Shroff Publishers. ISBN-13: 978-9352131945, 978-9352131952, 978-9352133703
7. Building Scientific Apparatus. 4th edition. John H. Moore, Christopher C. Davis, Michael Coplan and Sandra C. Greer. Cambridge University Press. ISBN-13: 978-0521878586
8. Programming Arduino: Getting Started with Sketches. 2nd edition. Simon Monk. McGraw Hill. ISBN-13: 978-1259641633
9. Make Your Own PCBs with EAGLE: From Schematic Designs to Finished Boards.
10. Simon Monk and Duncan Amos. McGraw Hill Education. ISBN-13 : 978-1260019193.
11. Pro GIT. 2nd edition. Scott Chacon and Ben Straub. A press. ISBN-13: 978-1484200773
12. Venuvinod, PK., MA. W., Rapid Prototyping – Laser Based and Other Technologies, Kluwer, 2004.
13. Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing", Springer, 2010
14. Chapman W.A.J, "Workshop Technology", Volume I, II, III, CBS Publishers and distributors, 5th Edition,2002.

Laboratory Activities:

1. Schematic and PCB layout design of a suitable circuit, fabrication and testing of the circuit.
2. Machining of 3D geometry on soft material such as soft wood or modelling wax.
3. 3D scanning of computer mouse geometry surface. 3D printing of scanned geometry using
4. FDM or SLA printer.
5. 2D profile cutting of press fit box/casing in acrylic (3 or 6 mm thickness)/cardboard, MDF
6. (2 mm) board using laser cutter & engraver.
7. 2D profile cutting on plywood /MDF (6-12 mm) for press fit designs.
8. Familiarity and use of welding equipment.
9. Familiarity and use of normal and wood lathe.
10. Embedded programming using Arduino and/or Raspberry Pi.
11. Design and implementation of a capstone project involving embedded hardware, software
12. and machined or 3D printed enclosure.

HSMC 102	Universal Human Values – II Understanding Harmony and Ethical Human Conduct	L	T	P	C
		2	1	2	3

Course Objective

- To help the students appreciate the essential complementarily between 'Values' and 'Skills' to ensure sustained happiness and prosperity which are the core aspirations of all human beings.

- To facilitate the development of a holistic perspective among students towards life and profession as well as towards happiness and prosperity based on a correct understanding of the human reality and the rest of existence.

Course outcome: Upon completion of this course, the students will be able to

- Demonstrate the necessity of relationship with family, society and nature. Familiarize with the challenges ahead and proposed solutions.
- Formulate and design human cyber security policies, plans and procedures for organizations.
- Apply standard security countermeasure tools to sustain human relationships and nature.es.
- Recognize the necessity of human values and relationship.
- Demonstrate the learning in their real life.

Unit I: Introduction **[9]**

Need, Basic Guidelines, Content and Process for Value Education Purpose and motivation for the course, recapitulation from Universal Human Values-I Self-Exploration–what is it? - Its content and process; 'Natural Acceptance' and experiential Validationas the process for self-exploration - Continuous Happiness and Prosperity- A look at basic Human Aspirations Right understanding, Relationship and Physical Facility- the basic requirements for fulfilment of aspirations of every human being with their correct priority Understanding Happiness and Prosperity correctly- A critical appraisal of the current scenario - Method to fulfil the above human aspirations: understanding and living in harmony at various levels.

Unit II: Understanding Harmony in the Human Being **[9]**

Harmony in Myself! Understanding human being as a co-existence of the sentient 'I' and the material 'Body' Understanding the needs of Self ('I') and 'Body' - happiness and physical facility Understanding the Body as an instrument of 'I' (I being the doer, seer and enjoyer) Understanding the characteristics and activities of 'I' and harmony in 'I' - Understanding the harmony of I with the Body: Sanyam and Health; correct appraisal of Physical needs, meaning of Prosperity in detail -Programs to ensure Sanyam and Health.

Unit III: Understanding Harmony in the Family and Society **[9]**

Harmony in Human-Human Relationship- Understanding values in human-human relationship; meaning of Justice (nine universal values in relationships) and program for its fulfilment to ensure mutual happiness; Trust and Respect as the foundational values of relationship - Understanding the meaning of Trust; Difference between intention and competence Understanding the meaning of Respect, Difference between respect and differentiation; the other salient values in relationship Understanding the harmony in the society (society being an extension of family): Resolution, Prosperity, fearlessness (trust) and co-existence as comprehensive Human Goals

Unit IV: Understanding Harmony in the Nature and Existence **[9]**

Whole existence as Coexistence - Understanding the harmony in the Nature -Interconnectedness and mutual fulfilment among the four orders of nature- recyclability and self-regulation in nature -Understanding Existence as Co-existence of mutually interacting units in all-pervasive space -Holistic perception of harmony at all levels of existence.

Unit – 5: Implications of the above Holistic Understanding of Harmony on Professional Ethics **[9]**

Natural acceptance of human values, Definitiveness of Ethical Human Conduct Basis for Humanistic Education, Humanistic Constitution and Humanistic Universal Order -Competence in professional ethics: a. Ability to utilize the professional competence for augmenting universal human order b. Ability to identify the scope and characteristics of people friendly and eco-friendly production systems, c. Ability to identify and develop appropriate technologies and management patterns for above production systems. -Case studies of typical holistic technologies, management models and production systems-Strategy for transition from the present state to Universal Human Order: a. At the level of individual: as socially and ecologically responsible engineers, technologists and managers b. At the level of society: as mutually enriching institutions and organizations. Sum up.

Text books

1. P.R Gaur, R Asthana, G.P Bagaria, Human Values and Professional Ethics (2nd revised edition) Excel Books, New

Delhi, 2019
2. A Nagaraj, Jeevan Vidya: Ek Parichaya, Jeevan Vidya Prakashan, Amarkantak, 1999.

Reference Books:

1. A. N Tripathi, Human Values, New Age Intl. Publishers, New Delhi, 2004.
2. Lawrence, C. (2016). Cyber security for Dummies, John Wiley & Sons Inc., 2nd Edition, pp.213--432.
3. AICTE STUDENT INDUCTION PROGRAM HANDBOOK-https://fdp-si.aicteindia.
4. org/download/Guidelines/G012%20SIP%20Hand%20Book%20v2.pdf

BSC 208	Mathematics – III	L	T	P	C
		2	1	0	3

Course Objectives:

- Develop a deep understanding of Laplace Transformation and its applications
- Master the complex form of Fourier series and Fourier Transformation
- Gain proficiency in Z-Transform and its applications
- Acquire knowledge of probability and statistics
- Develop skills in numerical methods

Course outcome:

- Apply Laplace transformations to solve ODEs and understand convolution theorems.
- Perform Fourier transformations and comprehend their complex forms.
- Analyse discrete-time systems using Z-transforms and employ initial and final value theorems.
- Solve partial differential equations using separation of variables and Laplace transformations.
- Apply interpolation and extrapolation techniques for data analysis.
- Implement Newton-Gregory and Gauss formulas for polynomial approximation.
- Compute numerical integrals using techniques like trapezoidal and Weddle quadrature formulas.

Unit I: Laplace Transformation [9]

Laplace Transformation and its applications, Inverse Laplace Transformation, Convolution Theorem, Solution of ODE by Laplace Transformation. Solution of PDE by Laplace Transformation

Unit II: Fourier Transform [9]

The complex form of Fourier series, Fourier Transformation and inverse Fourier Transformation, sine, cosine Transformation, Inverse Transformations -simple
illustration.

Unit III: Z-Transform [9]

Inverse Z-Transform- Properties Initial and final value theorems- convolution theorem- Difference equations, Solution of Difference equations using Z-Transformation.

Unit-IV: Probability and statistics [9]

probability of events, Bayes theorem, probability distributions, measures of central tendency (mean, median, and mode), variance, skewness, and kurtosis, covariance, sample and a population, law of large numbers and the central limit theorem, point estimation, maximum likelihood estimation, interval estimation, confidence intervals, types of error, p-value that helps in making a decision, t-test, two-sample t-test, and the paired t-test,

Unit V: Numerical Method [9]

Finite difference, Symbolic relations, Interpolation and Extrapolation, Newton Gregory forward and backward formula, Gauss forward and backward formula, and Numerical Integration: Trapezoidal r rd th rule, Weddle quadrature formula.

Text Books

1. Erwin Kreyszig, Advanced Engineering Mathematics, 9th Edition, John Wiley & Sons.
2. Ramana B.V., Higher Engineering Mathematics, Tata McGraw Hill New Delhi,2010.
3. Probability and statistics for data science,D.C Agarwal, Pradeep K Joshi, Shree Sai publishers, First edition

Reference Books:

4. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 44th Edition.
5. R. J. Beerends ,H. G. Ter Morsche ,J. C. Van Den Berg, E. M. Van De Vrie, Fourier and Laplace Transforms, Cambridge University Press.
6. Sastry S.S, Introductory Methods of Numerical Analysis, PHI.

ESC 207	Engineering Mechanics	L	T	P	C
		2	1	0	3

Course Objective:

1. Compute the force, moment & their application through solving of simple problems on coplanar forces.
2. Understand the concept of equilibrium of rigid bodies.
3. Know the existence of friction & its applications through solution of problems on above.
4. Locate the C.G. & find M.I. of different geometrical figures.
5. Know the application of simple lifting machines.
6. Understand the principles of dynamics.

Course Outcome

1. Define and classify Mechanics
2. Define and classify the forces and its system.
3. Compute the force and apply it for solving problems on coplanar forces.
4. Understand and apply resolution of forces.
5. Understand composition of forces and apply it to solve problems.
6. Understand Moment of force, Varignon‟s theorem with applications, couple.

Unit-I: Introduction **[9]**

Specification of the force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space, Degrees of freedom - Equilibrium Equations, Kinematics – Kinetics – De' Alembert's principle, Degree of Constraints – Free body diagrams.

Unit-II: Spatial Force systems **[9]**

Concurrent force systems - Equilibrium equations – Problems, Problems (Vector approach) – Tension Coefficient method, Problems (Tension Coefficient method), Parallel force systems - problems, Center of Parallel force system – Problems.

Unit-III: Coplanar Force Systems **[9]**

Introduction – Equilibrium equations – All systems, Problems on Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of sections, Method of members, Friction – Coulomb's laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Unit-IV: Mechanics of Deformable Bodies **[9]**

Stress & Strain at a point- Normal and shear stresses, Axial deformations – Problems on prismatic shaft, tapered shaft and deformation due to self-weight, Deformation of Stepped shaft due to axial loading, Poisson's Ratio – Bulk Modulus - Problems, change in dimensions and volume. Centroid & Moment of Inertia: Centroid and M.I. – Arial – Radius of Gyration, Parallel axis– Perpendicular axis theorem – Simple Problems.

Unit-V: Dynamics of Particles **[9]**

Rectilinear Motion – Kinematics Problems, Kinetics – Problems, Work & Energy – Impulse Moment, Curvilinear Motion – Normal and tangential components.

Textbooks:

1. Engineering Mechanics (In SI Units), S. Timoshenko, D.H. Young, J.V. Rao and Sukumar Pati, McGraw Hill Publishers, 2017,5th edition.

2. Vector Mechanics for Engineers - Statics and Dynamics, Ferdinand P. Beer, E. Russell Johnston Jr., et al., McGraw Hill Publishers, 2019, 12th edition.
3. Mechanics of Materials, Gere and Timoshenko, CBS Publishers, 2011, 2nd edition.

Reference Books:

1. Mechanics of Materials (SI edition), R. C. Hibbeler, Pearson publication, 2018.
2. Engineering Mechanics: Statics, SI Version, J. L. Meriam, L. G. Kraige, et al., Wiley India edition, 2017
3. Engineering Mechanics: Dynamics, SI Version, J.L. Meriam , L.G. Kraige, et al., Wiley India edition, 2018
4. Engineering Mechanics, S S Bhavikatti, New Age International Private Limited, 2021, 8th edition.

ESC 208	Applied Thermodynamics	L	T	P	C
		2	1	0	3

Course Objective

- To Explain in detail Basic Components of Rankine cycle. Methods to improve cycle performance. Types of Boilers with their working principles and applications.
- To Know the function of nozzles. Thermodynamic analysis of nozzles. Steam condensers and their requirement.
- To Study the different types of Turbines. Conditions for maximum efficiency. Parsons reaction turbine.
- To study the different types of gas turbines. Applications of gas turbines. Efficiency improvement methods

Course Outcome

- Apply thermodynamic concepts to analyze the performance of gas power cycles.
- Apply thermodynamic concepts to analyze the performance of vapour power cycles.
- Understand combustion of fuels and performance of I C engines.
- Understand the principles and applications of refrigeration systems.
- Apply Thermodynamic concepts to determine performance parameters of refrigeration and air-conditioning systems.
- Understand the working principle of Air compressors and Steam nozzles, applications, relevance of air and identify methods for performance improvement.

Unit -I **[9]**

Air standard cycles: Carnot, Otto, Diesel, Dual and Stirling cycles, p-v and T -s diagrams, description, efficiencies and mean effective pressures. Comparison of Otto and Diesel cycles.

I.C.Engines: Classification of IC engines, Combustion of SI engine and CI engine, Detonation and factors affecting detonation, Performance analysis of I.C Engines, Heat balance, Morse test, IC Engine fuels, Ratings and Alternate Fuels.

Unit - II **[9]**

Gas power Cycles: Gas turbine (Brayton) cycle; description and analysis. Regenerative gas turbine cycle. Intercooling and reheating in gas turbine cycles. Introduction to Jet Propulsion cycles.

Unit - III **[9]**

Vapour Power Cycles: Carnot vapour power cycle, drawbacks as a reference cycle. Simple Rankine cycle; description, T-S diagram, analysis for performance. Comparison of Carnot and Rankine cycles. Effects of pressure and temperature on Rankine cycle performance. Actual vapour power cycles. Ideal and practical regenerative Rankine cycles, open and closed feed water heaters. Reheat Rankine cycle. Characteristics of an Ideal working fluid in vapour power cycles.

Unit - IV **[10]**

Refrigeration Cycles: Vapour compression refrigeration system; description, analysis, refrigerating effect. Capacity, power required units of refrigeration, COP, Refrigerants and their desirable properties, alternate Refrigerants. Air cycle refrigeration; reversed Carnot cycle, reversed Brayton cycle, vapour absorption refrigeration system.

Pscychrometrics and Air-conditioning Systems:

Psychometric properties of Air, Psychometric Chart, Analyzing Air-conditioning Processes; Heating, Cooling, Dehumidification and Humidification, Evaporative Cooling. Adiabatic mixing of two moist air streams. Cooling towers.

Unit - V **[9]**

Reciprocating Compressors: Operation of a single stage reciprocating compressors. Work input through p-v diagram and steady state steady flow analysis. Effect of Clearance and Volumetric efficiency. Adiabatic, Isothermal and Mechanical efficiencies. Multi-stage compressor, saving in work, Optimal intermediate pressure, inter-cooling, minimum work for compression.

Steam nozzles: Flow of steam through nozzles, Shape of nozzles, effect of friction, Critical pressure ratio, Supersaturated flow.

Text Books:

1. Thermal Engineering / Rajput / Lakshmi Publications.
2. Gas Turbines / V. Ganesan / TMH.
3. Thermal Engineering /P.L. Ballaney / Khanna Publishers, NewDelhi.

Reference Books:

1. Gas Turbines and Propulsive Systems / P. Khajuria & S.P. Dubey / Dhanapatrai Pub.
2. Thermal Engineering / R.S. Khurmi & J.K. Gupta / S. Chand Pub.
3. Thermodynamics and Heat Engines / R. Yadav / Central Book Depot

MC 201	Energy, Environment and Climate Change Environmental Science	L	T	P	C
		2	0	0	0

Course objective

- To enable the students to impart the knowledge of energy sources and global/Indian scenario
- To understand the nexus between energy, environment and sustainable development
- To acquaint with the economic and environmental Perspective of renewable energy sources
- To familiarize the climate change and policy
- To impart the knowledge of the strategies for addressing climate change negotiation

Course outcome

- After studying this course, students would be able to understand the energy consumption models
- Acquire the knowledge on conventional and non-conventional energy
- Understanding the concept and theories of ecosystems - energy flow
- To realize the environmental sustainability index and global measure
- Experiencing the geopolitics of GHG control, Carbon market and emission trading mechanisms

Unit I: Energy

Introduction to the nexus between energy, environment and sustainable development, Overview of global/ India's energy scenario. Energy consumption models – Specific Energy Consumption.

Unit II: Energy Sources and Systems

Conventional and Non-Conventional Energy. Sources of Conventional energy, Historical, economic and Environmental Perspective. Renewable energy sources: Solar Energy, Wind Energy, Bioenergy, Hydropower, Nuclear fission and fusion-Geothermal energy, Fuel Cell & Tidal Power, Concepts and Technologies

Unit III: Ecology and Environment

Concept and theories of ecosystems, - energy flow in major man-made ecosystems- agricultural, industrial and urban ecosystems - sources of pollution from energy technologies and its impact on atmosphere - air, water, soil, and the environment - environmental laws on pollution control, energy efficiency and economics, security – equity – environmental sustainability index and global measure

Unit IV: Climate change and policy

Introduction to the climate system; Earth's heat budget; and sources and sinks. Global Warming, CO2 Emissions, Impacts, Climate Breakdown: biological, socio-cultural, political, environmental consequences of a changing climate, Mitigation, Sustainability, vulnerability, and resilience. Climate Policy: Kyoto protocol;

UNFCCC; IPCC; Geopolitics of GHG control; Carbon market - CDM and other emission trading mechanisms; Non-CO2 GHGs; Relevance for India

Unit V: Sustainable development:
Balancing environmental concerns, material consumption, and economic growth. Strategies for addressing climate change Climate negotiations. Energy mismatches and visioning for a sustainable future Energy transitions, technologies and behaviors.

Text Books:
1. Energy and the Environment, Ristinen, Robert A. Kraushaar, Jack J. AKraushaar, Jack P. Ristinen, Robert A., 2nd Edition, John Wiley, 2006.
2. Peter E Hodgson (2010), Energy, the Environment and Climate Change, Publisher:
Imperial College Press.
3. Richard Wolfson, (2011), Energy, Environment, and Climate, Publisher: W. W. Norton & Company; 2nd Edition.

Reference books
1. Energy and the Challenge of Sustainability, World energy assessment, UNDP, New
York, 2000.
2. Global energy perspectives / edited by Nebojsa Nakicenovic, Arnulf Grubler and Alan McDonald, Cambridge University Press, 1998
3. J.M. Fowler, Energy and the environment,. 2nd Ed., McGraw Hill, New York, 1984

PCC-EST-201	Electrical Machines	L	T	P	C
		2	1	2	4

Course objective: -Students will be able to-
1. Learn Performance characteristics of machine
2. To understand the dynamics of the machine
3. To understand how to determine stability of machine
4. Learn the synchronous machine

Course Outcomes: -
Students will be able to:
1:Formulation of electrodynamic equations of all electric machines and analyze the performance characteristics
2: Knowledge of transformations for the dynamic analysis of machines
3: Knowledge of determination of stability of the machines under small signal and transient conditions
4: Study about synchronous machine

Unit -1 **[9]**
Stability, Primitive 4 Winding Commutator Machine. Commutator Primitive Machine
Complete Voltage Equation of Primitive 4 Winding Commutator Machine

Unit-2 **[9]**
Torque Equation Analysis of Simple DC Machines using the Primitive
Machine Equations. □ The Three Phase Induction Motor. - Transformed Equations - Different Reference Frames for Induction Motor Analysis Transfer - Function Formulation

Unit-3 **[9]**
Three Phase Salient Pole Synchronous Machine
Parks Transformation, Steady State Analysis

Unit -4 **[9]**
Large Signal Transient - Small Oscillation Equations in State Variable form
Dynamical Analysis of Interconnected Machines

Unit-5 **[9]**
Large Signal Transient Analysis using Transformed Equations

DC Generator /DC Motor System - Alternator /Synchronous Motor System

Suggested reading

1. D.P. Sengupta& J.B. Lynn," Electrical Machine Dynamics", The Macmillan Press Ltd. 1980
2. R Krishnan "Electric Motor Drives, Modeling, Analysis, and Control", Pearson Education., 2001
3. P.C. Kraus, "Analysis of Electrical Machines", McGraw Hill Book Company,1987
Model Curriculum of Engineering & Technology PG Courses [Volume-I] [309]
4. I. Boldia& S.A. Nasar,,"Electrical Machine Dynamics", The Macmillan Press Ltd. 1992
5. C.V. Jones, "The Unified Theory of Electrical Machines", Butterworth, London. 1967.

PCC-EST-202	Fluid Mechanics	L	T	P	C
		2	1	0	3

Course Objective:

1. Acquiring knowledge on the fundamentals of fluid mechanics, fluids and its properties.
2. An understanding of fluid statistics and usage of instruments such as manometers, forces on submerged bodies.
3. Study of Buoyancy, metacentre, continuity equation and different functions
4. Application of Bernoulli's equation to measure energy levels
5. Using different fluid equipment's to calculate fluid flow and using dimensional analysis to solve flow problems.
6. Understanding the phenomenon of losses during flow in pipes.
7. Study of Laminar flow and the viscous effects.
8. Evaluating the various parameters connected to flow around immersed bodies.

Course Outcome

1. Examine the fundamental of fluid mechanics and fluids and apply the basic equations to find the force on submerged surfaces.
2. Calculate using known formula to calculate the center of buoyancy and find the velocity and acceleration.
3. Calculate various flow parameters using fluid flow meters and using dimension analysis to predict flow phenomena.
4. Use Euler's and Bernoulli's equations and the conservation of mass to determine velocities & pressures. Calculate frictional losses through pipes and to calculate the drag and lift, displacement, momentum and energy thickness.

Unit - I **[9]**

Fluid and continuum, Physical properties of fluids, Rheology of fluids. Pressure-density-height relationship, manometers, pressure transducers, pressure on plane and curved surfaces, the center of pressure, buoyancy, stability of immersed and floating bodies, fluid masses subjected to linear acceleration and uniform rotation about an axis.

Unit – II **[9]**

Types of fluid flows: Continuum & free molecular flows. Steady and unsteady, uniform and non- uniform, laminar and turbulent flows, rotational and irrotational flows, compressible and incompressible flows, subsonic, sonic and supersonic flows, sub-critical, critical and supercritical flows-, one-, two- and three-dimensional flows, streamlines, continuity equation for 3D and 1D flows, circulation, stream function and velocity potential. Dimensional analysis, Buckingham's Pi theorem, important dimensionless numbers and their significance,

Unit - III **[9]**

Potential Flow: source, sink, doublet, and half-body. Equation of motion along a streamline and its integration, Bernoulli's equation and its applications- Pitot tube, orifice meter, venturi meter and bend meter, hot-wire anemometer and LDA, notches and weirs, momentum equation and its application to pipe bends. Similarity Laws: geometric, kinematics, and dynamic similarity, undistorted and distorted model studies.

Unit - IV [9]

Equation of motion for laminar flow through pipes, Stokes' law, transition from laminar to turbulent flow, turbulent flow, types of turbulent flow, isotropic, homogenous turbulence, scale and intensity of turbulence, measurement of turbulence, eddy viscosity, mixing length concept and velocity distribution in turbulent flow over smooth and rough surfaces, resistance to flow, minor losses, pipe in series and parallel, power transmission through a pipe, siphon, water hammer, three reservoir problems and pipe networks.

Unit – V **[9]**

Boundary layer thickness, boundary layer over a flat plate, laminar boundary layer, application of momentum equation, turbulent boundary layer, laminar sub-layer, separation and its control, Drag and lift, drag on a sphere, a two-dimensional cylinder, and an aerofoil, Magnus effect. Introduction to compressible flow

Text Books:

1. Fluid Mechanics by F.M. White, Tata Mcgraw Hill, 7th edition, 2011.
2. Fluid Mechanics by R.W. Fox and A.T. McDonald, Wiley, 10th edition, 2021.
3. Fluid Mechanics by P. K. Kundu, I. M. Cohen and D. R. Dowling, Academic Press and Elsevier, 2012

Reference Books:

1. Fox & Donald, "Introduction to Fluid Mechanics" John Wiley &Sons Pvt Ltd,
2. Cengel & Cimbala, "Fluid Mechanics" TMH, New Delhi.
3. White,F.M. "Fluid Mechanics" TMH, New Delhi.
4. Munsen et al ,"Fundamental of Fluid Mechanics" Wiley Newyork Ltd
5. Garde, R.J., " Fluid Mechanics", SciTech Publications Pvt. Ltd
6. I.H. Shames, "Mechanics of Fluids", McGraw Hill, Int. Student, Education.

PCC-EST-203	Heat and Mass Transfer	L	T	P	C
		2	1	0	3

Course Objectives:

1. Build a solid foundation in heat transfer, exposing students to the three basic modes namely conduction, convection and radiation.
2. Rigorous treatment of governing equations and solution procedures for the three modes, along with solution of practical problems using empirical correlations.
3. The course will also briefly cover boiling and condensation heat transfer, and the analysis and design of heat exchangers.

Course Outcome:

1. Students will gain a deep understanding of the fundamental principles and laws governing heat and mass transfer.
2. Students will learn to analyze heat transfer by conduction, convection, and radiation.
3. Students will gain the skills to design and analyze various types of heat exchangers.
4. Students will develop an understanding of mass transfer mechanisms and be able to analyze mass transfer processes in different systems, including diffusion and convection.
5. Students will develop critical thinking skills and problem-solving abilities by applying heat and mass transfer principles to real-world engineering problems

Unit I Fundamentals of Heat Transfer **[9]**

Conduction: Fourier's law, steady-state heat conduction, unsteady-state heat conduction, thermal resistance concept, heat conduction in composite systems.

Convection: Convection heat transfer, forced convection, natural convection, external and internal flow, boundary layer concepts, heat transfer coefficients.

Radiation: Blackbody radiation, gray surfaces, view factors, radiation exchange between surfaces, radiation shields.

Unit II Mass Transfer **[8]**

Diffusion: Fick's law, steady-state diffusion, unsteady-state diffusion, mass transfer coefficients, molecular diffusion in gases, liquids, and solids.

Convection: Mass transfer by convection, film theory, mass transfer coefficients, Sherwood number, Nusselt number analogy.

Mass Transfer with Chemical Reaction: Mass transfer accompanied by chemical reaction, effectiveness factor, Thiele modulus.

Unit III Heat and Mass Transfer Equipment **[10]**

Classification of heat exchangers, analysis of heat exchanger performance, effectiveness-NTU method, LMTD method, fouling factors, heat exchanger design considerations, Introduction to heat and mass transfer equipment such as heat exchangers, evaporators, condensers, and cooling towers.

Unit IV Evaporation and Condensation **[9]**

Basic principles of evaporation and condensation, film-wise and drop-wise condensation, Nusselt's theory of condensation, condensation heat transfer coefficients.

Unit V Boiling and Heat Transfer **[9]**

Overview of phase change heat transfer, Definition of boiling, Critical heat flux (CHF) and boiling heat transfer coefficients, Pool boiling, Nucleate boiling heat transfer, Condensate heat transfer, Boiling and condensation in Engineering applications.

Textbooks:

1. R. Welty, C. E. Wicks, R. E. Wilson, G. Rorrer, Fundamentals of Momentum, Heat and Mass Transfer, 4th Ed.,Wiley, 2007.
2. W. J. McCabe, J. Smith, P. Harriot, Unit Operations of Chemical Engineering, Sixth Edition, McGraw Hill, 2005.
3. Holman, J. P., S. Bhattacharya, Heat Transfer, 10th Ed., Tata McGraw-Hill (2011). 4. D. Q. Kern, Process Heat Transfer, Tata-McGraw Hill,1997.
4. Sachdeva R C, Fundamentals of Engineering Heat and Mass Transfer, New Age Science Limited,
5. R.K.Rajput. Heat and mass transfer, S.Chand& Co.,2015
6. Nag P K., Heat and Mass Transfer, McGraw Hill,2011

References Books:

1. Yunus A Cengel, Heat Transfer: A Practical Approach, McGraw Hill,2015
2. Holman J P, Heat Transfer, McGraw Hill, 2011
3. Frank P. Incropera and David P. Dewitt, Heat and Mass Transfer, John Wiley and sons, 2011
4. Heat and Mass Transfer data book: C.P. Kothandaraman, S. Subramanya, New age International publishers,2014.
5. Kothandaraman, C.P., Fundamentals of Heat and Mass Transfer, New Age International, New Delhi.
6. F.P. Incropera and D. P. Dewit, Fundamentals of Heat and Mass Transfer, John Wiley , 4th Ed., 1998.
7. Louis C. Burmeister, Convective Heat Transfer, John Willey , 1993.

PCC-EST-210 ENERGY LABORATORY-I

PCC-EST-204	**Fuels and Combustion Technology**	L	T	P	C
		3	1	0	4

Course objective

- To enable the students to impart the knowledge of the Fuels and Combustion
- To facilitate the understanding of the physical and chemical properties of the fuels
- To acquaint with the combustion Processes
- To familiarize the fuel stoichiometry and analysis
- To impart the knowledge of the industrial furnaces and advance clean technology for fuels

Course outcome

- After studying this course, students would be able to understand solid, liquid and gaseous fuels
- Acquire the knowledge for the conversion of solid fuels to liquid and gases fuels
- Understanding of the petroleum refinery processes
- Realize the combustion stoichiometry and flue gases analysis
- Experiencing the carbon-di-oxide capture and storage

Unit I: Solid Fuels [12]

Coal: Origin, classification of coal, coal rank-Hilts law analysis, physical and chemical properties of coal; Calorific value of solid fuels- Action of heat on coal; Liquefaction of coal, direct and indirect liquefaction, Fischer-Tropsch and Mobil process. Gasification processes of coal- Lurgi and Winkler. Manufactured fuels-hard and soft coke, Agro fuels-solid fuel handling and storage.

Unit II: Liquid and Gaseous Fuels [12]

Origin and classification of petroleum crude oil; recovery of crude oil, properties – flash/fire point, octane and cetane number. Oil refinery -physical, chemical and catalytic processes. Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels.

Unit III: Theory of Combustion Process [12]

Combustion: Concept, 3Ts, ignition, auto- and force ignition. Burners and basic features/design of burners for solid, liquid, and gaseous fuels. Combustion Stoichiometry and thermodynamics. Heat of reaction, of higher heating value (HHV), lower calorific value (LHV), determination of calorific value by Bomb Calorimeter and Boy's calorific methods.

Unit IV: Fuel stoichiometry and analysis [12]

Stoichiometry: Estimation of air required for complete combustion. Mass basis and volume basis, air to fuel ratio, rich and lean mixture, excess air calculation. Estimation of dry flue gases and exhaust gases analysis, Orsat flue gas analyzer. Calculation of the composition of fuel & excess air supplied from exhaust gas analysis. Dew point of products; Flue gas analysis.

Unit V: Industrial furnaces and advance clean technology [12]

Industrial furnaces: Blast furnace and Open-hearth furnace for metal extraction. Heat distribution in furnaces and waste heat recovery: Recuperates and regenerators. Furnace insulation: Ceramic coating. Advance clean coal combustion and gasification and co-gasification: Pulverized, fluidized bed combustion, and recent advance technologies. Emission reduction and carbon-di-oxide capture and storage.

Text Books:

1. Fuels and Combustion, Samir Sarkar, Orient Longman Pvt. Ltd, 3rd edition, 2009
2. S.P. Sharma &Chander Mohan, Fuels & Combustion, Tata McGraw Hill Publishing Co.Ltd.,1984.
3. K. Kanneth, "Principles of combustion", Wiley and Sons, 2005.

Reference books:

1. Fuel Flexible Energy Generation, Solid, Liquid and Gaseous Fuels by John Oakey, Woodhead Publishing – Elsevier, 2016.
2. An introduction to combustion: Concept and applications – Stephen R Turns, Tata Mc. Graw Hill, 3rd edition, 2012
3. Modern Petroleum Technology, Vol 1, Upstream, Ed. by Richard A. Dave, IP, 6th ed.,John Wiley & Sons. Ltd.

PCC-EST-205	Bioenergy	L	T	P	C
		3	0	0	3

Course objective

- To enable the students to impart technology of biomass production and biofuel conversions
- To facilitate the understanding of the biosynthesis pathways in biological systems
- To acquaint with the biochemical conversions and biofuels products
- To familiarize the physical and chemical properties and biofuels standards
- To impart the knowledge of biofuels economy and entrepreneurship in biofuels

Course outcome

- After studying this course, students would be able to understand the biomass and bioenergy
- Acquire the knowledge on microbial culture, biomass harvest and biofuel production
- Understanding of various types of bioenergy conversion systems
- Realize various biofuel types and characteristics
- Perform testing of biogas plants and scale up the bioprocess
- Experiencing the challenges and solutions in biofuels conversion systems for efficient production

Unit I: Biological Systems [10]

Introduction to cellular systems, biomolecules, classification of biomolecules, Structure and functions of biomolecules, biochemical regulations, carbohydrates, proteins and amino acids, lipids and fatty acids, nucleic acids, enzyme cofactors, functional roles of biomolecules – energy carriers

Unit II: Biochemical Pathways and Chemical Kinetics [8]

Biosynthesis and breakdown of carbohydrates- Lipids- proteins and nucleic acids, TCA cycle - Glycolysis - Glycogensis - Gluconeogenesis - Pentose phosphate shunt - Urea cycle - Interconnection of Pathways - Metabolic regulations, Biocatalysis by enzymes and pathways, Rate limiting steps and conversion efficiency.

Unit III: Biomass Resources and Biochemical Conversions [10]

Renewable biomass, large scale culture of biomass and harvest, photosynthetic organism and photo bioreactors, microbial lipids and carbohydrate synthesis, biodegradation and biodegradability of substrate, Saccharification of biomass.

Unit IV: Thermochemical Conversions [9]

Thermochemical Conversion: Direct combustion, incineration, pyrolysis, gasification and liquefaction; Bio gasification, Waste to energy, Chemical Conversion: Hydrolysis & hydrogenation; solvent extraction of hydrocarbons, solvolysis of wood, bio-crude

Unit V: Biofuels Standards and energy economy [8]

Physical and chemical characteristics of biofuels, Bio blends - Indian and International standard specifications, Adaptation of biofuel in various applications, Biofuel economy, Biofuel roadmap of India, Policy issues, Regulatory issues and economic impact; Entrepreneurship in biofuel - Prospects & Challenges, Case studies.

Text Books:

1. Renewable Energy, Third Edition, Bent Sorensen, Academic Press August 2004
2. Lehninger's Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher, 2009.

Reference books:

1. Biochemistry 6th edition by Jeremy M Berg, Lubert Stryer, John L. Tymoczko, 2008.
2. Voet and Voet's Biochemistry, D. Voet and J. Voet 3rd Edition, John Wiley and Sons Inc., 2005.
3. Biochemistry, 5th Ed by Eric E Conn, Paul K Stumpf, George Bruening and Roy H Doi, 2009.
4. Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009.
5. Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.

6. Dictionary of Renewable Resources - 2nd Edition, Revised and Enlarged, Zoebelein, Hans, Wiley-VCH, 2001.

PCC-EST 206	Materials Science	L	T	P	C
		3	0	0	3

Objectives of the course:
The objective of the course will be to give the students a basic introduction to the different classes of materials relevant to engineering in general, and Chemical Engineering in particular. The intent of the course will be to relate the underlying molecular structure of the materials to their physical and chemical properties, and their processing and performance characteristics.

Unit I Introduction **[9]**
Introduction to materials, bonding between atoms: metallic bonding, ionic bonding, covalent bonding, Van der Waals bond, thermal expansion, elastic modulus and melting point of materials, Role of materials selection in design, structure-property-processing-performance relationships Miller indices of directions and planes, packing of atoms inside solids, close-packed structures, structure of ceramics, ionic solids, glass and polymers, density of various materials.

Unit II Defects and strength of Solids **[9]**
Imperfections in solids: vacancies, equilibrium concentration of vacancies, interstitial and substitutional impurities in solids, dislocations, types and characteristics of dislocations, interfacial defects, stacking faults. Structure of materials and Strength of Materials: Yield strength, tensile strength and ductility of materials: stress strain behaviour of metals, ceramics and polymers, tensile test, plastic deformation, necking, creep behaviour and fatigue.

Unit III Amorphous Solids and Composites **[9]**
Semi-crystalline materials: Classification, structure and configuration of ceramics, polymers, copolymers, liquid crystals and amphiphiles. Non-crystalline/amorphous materials: Silicates, glass transition temperature, viscoelasticity. Polymer nano-composite materials. Nanocomposites, role of reinforcement-matrix interface strength on composite behavior.

Unit IV Biomaterials **[9]**
Corrosion, Degradation and Recycling - Biomaterials, material related to catalyst such as zeolites, silica etc. and other selected materials.

Unit V Characterizations **[9]**
Introduction to experimental techniques: XRD, FT-IR, Raman and microscopic techniques for material characterization - highlighting links between molecular structure and macroscopic properties.

Suggested Books
1. V. Raghavan Materials Science and Engineering: A First Course, 5th Edition Prentice Hall India, 2004.
2. S. Upadhyaya and A. Upadhyaya, Material Science and Engineering, Anshan Publications, 2007.

Course Outcomes
Through this course the students should:
1) Have a broad knowledge of the discipline
2) Have an exposure to methods and techniques used in the discipline
3) Understand the flow of courses through the rest of their undergraduate education

PCC-EST 207	Design of Fluid Machinery	L	T	P	C
		2	1	0	3

Course Objective:
1. To provide the knowledge of basic principles, governing equations, and applications of turbo machines.

2. To provide the students with opportunities to apply fundamental thermo-fluid dynamics flow equations to Turbomachines.
3. To explain construction and working principles and evaluate the performance characteristics of Turbo Machines.

Course Outcome:
1. To learn about the application of mass and momentum conservation laws for fluid flows
2. To obtain the velocity and pressure variations in various types of simple flows
3. To analyse the flow in water pumps and turbines.
4. Ability classify, analyse and understand various type of steam turbine.
5. Ability to classify, analyse and understand various type of hydraulic turbine.
6. Understand the concept of radial power absorbing machine and the problems involved during its operation

Unit-I: **[9]**
Impact of jets: Introduction to hydrodynamic thrust of jet on a fixed and moving surface (flat and curved),– Series of vanes - work done and efficiency Hydraulic Turbines: Impulse and Reaction Turbines – Degree of reaction – Pelton Wheel – Constructional features - Velocity triangles – Euler's equation – Speed ratio, jet ratio and work done, losses and efficiencies, design of Pelton wheel – Inward and outward flow reaction turbines- Francis Turbine – Constructional features – Velocity triangles, work done and efficiencies.

Unit-II: **[9]**
Axial flow turbine (Kaplan) Constructional features – Velocity triangles- work done and efficiencies – Characteristic curves of turbines – theory of draft tubes – surge tanks – Cavitation in turbines – Governing of turbines – Specific speed of the turbine, Type Number– Characteristic curves, scale Laws – Unit speed – Unit discharge and unit power.

Unit-III: **[9]**
The rotary motion of liquids – free, forced, and spiral vortex flows Rotodynamic pumps- centrifugal pump impeller types, -velocity triangles-manometric head- work, efficiency and losses, H-Q characteristic, typical flow system characteristics, and pump operating point. Cavitation in centrifugal pumps- NPSH required and available- Type Number-Pumps in series and parallel operations. Performance characteristics- Specific Speed-Shape numbers – Impeller shapes based on shape numbers.

Unit-IV: **[9]**
Positive displacement pumps- reciprocating pump – Single acting and double acting- slip, negative slip and work required and efficiency- indicator diagram- acceleration head - effect of acceleration and friction on indicator diagram – speed calculation- Air vessels and their purposes, saving in work done to air vessels multi-cylinder pumps. Multistage pumps-selection of pumps-pumping devices-hydraulic ram, Accumulator, Intensifier, Jet pumps, gear pumps, vane pump, and lobe pump.

Unit-V: **[9]**
Compressors: classification of compressors, reciprocating compressor-single stage compressor, equation for work with and without clearance volume, efficiencies, multistage compressor, intercooler, free air delivered (FAD). Centrifugal compressor-working, velocity diagram, work done, power required, width of blades of impeller and diffuser, isentropic efficiency, slip factor and pressure coefficient, surging and chocking. Axial flow compressors: - working, velocity diagram, degree of reaction, performance. Roots blower, vane compressor, screw compressor.

Textbooks:
1. Som, Introduction to Fluid Mechanics and Fluid Machines, McGraw Hill Education India 2011
2. Bansal R. K., A Textbook of Fluid Mechanics and Hydraulic Machines, Laxmi Publications,2005.

Reference Books:
1. Cengel Y. A. and J. M. Cimbala, Fluid Mechanics, Tata McGraw Hill, 2013
2. Yahya S. M, Fans, Blower and Compressor, Tata McGraw Hill, 2005.
3. Shepherd D. G, Principles of Turbo Machinery, Macmillan, 1969.
4. Stepanoff A. J, Centrifugal and Axial Flow Pumps, John Wiley & Sons, 1991.
5. Rajput R. K, Fluid Mechanics and Hydraulic Machines, S. Chand & Co.,2006.

6. Subramanya, Fluid mechanics and hydraulic machines, 1e McGraw Hill Education India,2010

PCC-EST 220 ENERGY LABORATORY-II

PCC-EST 301	Solar Photovoltaic Energy Conversion	L	T	P	C
		3	1	0	4

Course Objectives

- Teach basics of semiconductor
- Teach Basics of solar cell materials
- Teach the basics of device engineering
- Teach about solar cell fabrication and characterization
- Teach about semiconductor based other energy devices

Course Outcome

- Develop understanding about semiconductor properties and characterizations
- Develop understanding about solar cell device fabrication and characterizations
- Develop understanding about other semiconductor based energy devices

Unit-I Properties of Semiconductor [9]

Semiconductors – Materials - atomic bonding - crystals structures, conductor – insulator and semiconductors, semiconductor: band diagram, direct & indirect bandgap - p & n type semiconductors - – Intrinsic & extrinsic semiconductor - doping and carrier concentration – 4-probe and Hall effect measurements - compound semiconductors - diffusion and drift of carriers, continuity equation – optical absorption – carrier recombination – semiconductor characterization techniques

Unit-II Semiconductors for Solar Cell [9]

Silicon: preparation of metallurgical, electronic and solar grade Silicon - Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method – imperfections – carrier doping and lifetime - Germanium - compound semiconductors: growth & characterization - amorphous materials – Transparent conducting oxides-Anti-reflection principles and coatings – organic materials

Unit-III Device fabrication [9]

Semiconductor junctions: Schottky barriers, MIS, P-N junction, p-i-n junction and its properties Homo & hetero junction solar cells, multijunction solar cells- Fabrication techniques: Diffusion, thin film technology-physical vapour deposition (PVD)- Electro-deposition-Molecular beam epitaxy (MBE)- Metal organic chemical vapour deposition (MOCVD)- Plasma enhanced chemical vapour deposition (PECVD)- Organic and Nano tech solar cells – contact & grid metalization.

Unit-IV Characterization and Analysis [9]

Device isolation & analysis - Ideal cell under illumination- solar cell parameters short circuit current, open circuit voltage, fill factor, efficiency; optical losses; electrical losses, surface recombination velocity, quantum efficiency - measurements of solar cell parameters; I-V curve & L-I-V characteristics, internal Quantum yield measurements – Effects of series and parallel resistance and Temperature - Loss analysis.

Unit: V. Thermo-energy devices [9]

Thermoelectric conversion: Principles and device processing, thermoelectric power systems. Thermo photovoltaic p r i n c i p l e s and device fabrication –Thermo-photovoltaic power systems

Text Books

1. Seminconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
2. Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube , Academic Press, New York , 1983
3. Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997.

Reference Books

1. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York,1995.
2. J. Nelson, The physics of solar cells, Imperial College Press, 2006.
3. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998
4. Practical Photovoltaics: Electricity from Solar Cells, by Richard Komp, ISBN:9780937948118, Publisher:Aatec Publications, Publication Date:February 2002.

PCC-EST 302	Power Plant Engineering	L	T	P	C
		3	1	0	4

Objectives:

To provide an overview of power plants and the associated energy conversion issues

Contents:

UNIT-1 **[12]**

Coal based thermal power plants, basic Rankine cycle and its modifications, layout of modern coal power plant, super critical boilers, FBC boilers, turbines, condensers, steam and heating rates, subsystems of thermal power plants, fuel and ash handling, draught system, feed water treatment, binary cycles and cogeneration systems.

UNIT-2 **[12]**

Gas turbine and combined cycle power plants, Brayton cycle analysis and optimization, components of gas turbine power plants, combined cycle power plants, Integrated Gasifier based Combined Cycle (IGCC) systems.

UNIT-3 **[12]**

Basics of nuclear energy conversion, Layout and subsystems of nuclear power plants, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, Pressurized Heavy Water Reactor (PHWR), Fast Breeder Reactors (FBR), gas cooled and liquid metal cooled reactors, safety measures for nuclear power plants.

UNIT-4 **[12]**

Hydroelectric power plants, classification, typical layout and components, principles of wind, tidal, solar PV and solar thermal, geothermal, biogas and fuel cell power systems

UNIT-5 **[12]**

Energy, economic and environmental issues, power tariffs, load distribution parameters, load curve, capital and operating cost of different power plants, pollution control technologies including waste disposal options for coal and nuclear plants.

Course Outcomes:

Upon completion of the course, the students can understand the principles of operation for different power plants and their economics.

Text Books:

1. Nag P.K., Power Plant Engineering, 3rd ed., Tata McGraw Hill, 2008.
2. El Wakil M.M., Power Plant Technology, Tata McGraw Hill, 2010.
3. Elliot T.C., Chen K and Swanekamp R.C., Power Plant Engineering, 2nd ed., McGraw Hill, 1998.

PCC-EST 303	Nuclear Energy Technology	L	T	P	C
		3	0	0	3

Course Objectives

- To describe the fundamental physics behind nuclear reactions
- To develop understanding on reactor physics and associated engineering aspects.
- To understand the various stages of nuclear fuel utilization and disposal.
- To familiarize with the current status of nuclear reactors and safety issues associated with nuclear power generation.

Course Outcome

- Learn the basic physics of nuclear reactions and nuclear energy generation
- Able to appreciate the physics and technological aspects of nuclear reactor and power generation
- To stay familiarized with current development in nuclear energy sector

UNIT-1 **[9]**

Introduction: The world-wide nuclear renaissance; comparison with other energy sources; public perception; non-proliferation and nuclear safeguards; financial costing; Nuclear energy programme in India.

UNIT-2 **[9]**

Reactor Physics: Mechanism of Nuclear Fission and Fusion, Nuclides, Radioactivity, Decay chains, Neutron reactions (scattering, absorption, fission), Fission process and product distribution; neutron energy distribution; moderation; delayed neutrons; neutron cycle reactor types, Fast Breeding, Design and construction of nuclear reactors, Heat transfer techniques in nuclear reactors; Reactor shielding.

UNIT-3 **[9]**

Nuclear Fuel Cycle: Characteristics of nuclear fuels and various cycles, mining; conversion; enrichment; refueling; transport; reprocessing; waste handling; storage; geological disposal.

UNIT-4 **[9]**

Thermal-hydraulics and Fuel Design: Radial and axial flux profiles; general thermodynamic considerations; heat transfer processes from fuel to coolant; primary coolant system: fluid flow; frictional losses in pipes; pumped flow; heat exchanger types; steam generation; coolant/moderator selection; coolant circuit considerations.

UNIT-5 **[9]**

Reactor Systems: Introduction to reactor system & Three stage Indian nuclear power programme. Classification of reactors, Characteristics, Selection criteria; Core configuration & cycle diagrams of thermal reactors (BWR, PWR, PHWR, AGR, HTGR, and AHWR) and Fast Reactors; process heat applications; transmutation of nuclear waste; safety systems and accidents.

Text Books

[1] Raymond M and Keith E. H. (2014); Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Seventh Edition, Butterworth-Heinemann
[2] Bodansky D. (2008); Nuclear Energy: Principles, Practices and Prospects, Second Edition, Springer Page | 28

Reference Books

[1] John K. S. and Richard E. F. (2007); Fundamentals of Nuclear Science and Engineering, Second Edition, CRC Press
[2] Lamarsh J. R. and Baratta A. J. (2001); Introduction to Nuclear Engineering, Third Edition, Pearson
[3] Oka Y. and Kiguchi T. (2014); Nuclear Reactor Design, Fourth Edition, Springer
[4] Bayliss C. and Langley K. (2003); Nuclear Decommissioning, Waste Management, and Environmental Site Remediation, First Edition, Butterworth-Heinemann
[5] Brookes L. G. (2013); The Economics of Nuclear Energy, Springer

PCC-EST 304	Solar Thermal Technology	L	T	P	C
		2	1	0	3

Course Objectives:

1. To acquire knowledge on solar radiation and its characteristics
2. To develop understanding the importance of heat transfer in solar thermal energy studies
3. To analyze the thermal characteristics of solar flat plate collectors
4. To study solar concentrating collectors and its features

Course outcome

1. Will be able to understand Solar Thermal Principles
2. Will be exposed to Solar Thermal Technologies
3. Will be able to Design Solar Thermal Systems
4. Will be able to carry out Performance Analysis and Optimization
5. Will be able to Integrate solar thermal systems in various sectors such as residential, commercial and industrial
6. Will be exposed to Emerging Technologies and Trends
7. Will be able to enhance Critical Thinking and Problem-Solving

Unit I: Solar Radiation Geometry [10]

Solar angles; the earth and solar constant; day length; angle of incidence on the tilted surface; variation of extraterrestrial radiation; solar radiation at the earth's surface, sunrise, sunset and day length local apparent time; solar radiation on tilted surfaces.

Unit II Solar Collectors: Thermal Analysis [9]

Flat plate collectors: Effective energy losses; thermal analysis; heat capacity effect; overall loss coefficient; collector efficiency factor; collector heat removal factor; efficiency of flat plate collectors; testing methods. Evacuated tube collectors: Types; thermal analysis; testing methods. Concentrating collectors: Designing and types; acceptance angle; geometric concentration ratio; optical efficiency; thermal efficiency; testing methods. Selective surfaces.

Unit III: Low Temperature Solar Thermal Energy Systems [10]

Solar water heating systems: Materials and components; Natural flow; Forced flow; applications, Flat plate collectors, Evacuated tube solar water heaters; Solar air heating systems: Description and classifications; porous and non-porous type; applications. Solar drying, Solar distillation, Solar pond, Solar cookers, Solar refrigeration and air conditioning. Solar drying: Working principle; open sun drying; direct solar drying; indirect solar drying; Designing of solar drier; psychrometric chart; energy balance equation. Solar distillation: Working principle; thermal efficiency; various designs of solar still. Solar pond: Description; Non-convective solar pond; operational problems; other solar ponds. Solar cookers: Types of solar cookers; first figure of merit and second figure of merit.

Unit IV: Medium and High Temperature Solar Thermal Energy Systems [8]

Solar concentrating systems: Materials for concentrators; types of concentrators, single axis and two axis tracking. Solar energy for industrial process heat: Hot water, hot air and steam based industrial process heat systems; Principles of solar engines; solar thermal power plants: parabolic trough, central receiver, parabolic dish, compact Fresnel linear reflector technology. Principle of absorption cooling; basics of absorption cooling; lithium bromide-water absorption system; vapor compression refrigeration Solar thermal power generation:

Unit V: Applications of Low, Medium and High-Temperature Solar Thermal Systems [16]

Domestic water heating, space heating, swimming pool heating, drying, cooking, cooling, Solar thermal power generation: overview of utility-scale solar power plants. Industrial process heat applications: integration of solar thermal energy into manufacturing, chemical processing, and other industrial sectors. Solar desalination: utilization of medium and high-temperature solar thermal energy for water desalination processes.

Text Books:

1.Duffle and Beckman, Solar Thermal Engineering Process, John Wiley & Sons, New York.
2. A Sreekumar and G Raam Dheep, Solar Thermal Energy Including Laboratory Experiments, New Age International Publishers, New Delhi 2020.
3. J.S. Hsieh, Solar Energy, Prentice Hall Inc. New Jerssey.

Reference Books:

1. P.J.Lunde, Solar Thermal Engineering, John Wiley & Sons, New York
2. N.C.Harris, C.E.Miller and I.E.Thomas, Solar Energy Systems Design, John Wiley &Sons, New York
3. Garg HP., PrakashJ.,SolarEnergy:Fundamentals&Applications,TataMcGrawHill,NewDelhi,1997
4. S.P.Sukhatme, Solar Energy, Tata Mc Grew Hill Company Ltd., New Delhi
5. F.Kreithand J.F.Kreider,PrinciplesofSolarEngineering,HemispherePublishingCoro.

PCC-EST 305	Wind Energy Technology	L	T	P	C
		2	1	0	3

Course Objective:

- Understanding the fundamentals of wind energy technology □
- Able to design and analyze the existing and innovative blade profile □
- Able to assess the performance of the wind turbine □
- Provide knowledge on methods and site selection approaches for wind turbines.
- To provide knowledge on aspects of Wind Power Project Planning & Structuring and Asset Management.

Course Outcome:

1. The course imparts an ability to contribute to the complex task of wind farm development.
2. Provide understanding of the various stages in wind energy project development
3. Ability to comprehend role of contracts in project management, financing, and risk management
4. Ability to provide quality assurance in wind energy project management

Unit I: FUNDAMENTALS OF WIND ENERGY [9]

Nature of atmospheric winds- Wind resource characteristics and assessment- Micro sitting– Anemometry, speed frequency distribution, the effect of height, the wind rose, Weibull distribution, atmospheric turbulence, gust wind speed, the impact of topography—influence of Reynolds's number, actuator disc, Betz coefficient.

Unit II: CONCEPTUAL AND COMPONENT DESIGN OF WIND TURBINES [9]

Classification of wind turbines, Rotor Diameter, Machine Rating, Rotational Speed, Blades, Power Control, Pitch Bearings, Rotor Hub, Gearbox, Generator, Mechanical Brake, Yaw Drive, Tower, Foundations. Tip Speed Ratio (TSR), Choice of the Number of Blades, Relationship of TSR and Coefficient of Performance (Cp), TSR in Field Conditions

Unit III: MECHANICS AND DYNAMICS [9]

Review of Fluid Flow Concepts, Airfoil terminology, Blade element theory, Blade design, General Principles Primer (stress, strain, vibrations), Rotor Dynamics, loads sources, loads types, Aero Servo Elasticity in Wind Turbines. Primer on Fatigue, Fatigue in Wind Systems

Unit IV: WIND TURBINE PERFORMANCE [9]

Power v/s Energy, Power Contained in Wind, Effective Useable Energy from Wind Turbine, Practical Limits of Energy Output, Net Power Output from the Turbine, Important Rules for Wind Turbines,
Power Curve, Wind-turbine Performance Measurement, Aerodynamic Performance Assessment, Dynamics, Estimation of Energy Capture, and The Performance Curves.

Unit V: WIND FARM AND WIND ENERGY ECONOMICS [9]

Onshore, offshore wind energy, wind farms, design of wind farms, Project Development, Visual and Landscape Assessment, Noise, Electromagnetic Interference, Ecological Assessment, Finance Engineering Economics Basics, Wind Turbine Cost Analysis,

TEXTBOOKS

1. Steve Parker, "Wind power", Gareth Stevens Publishing, 2004.
2. Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.
3. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994

PCC-EST 310 ENERGY LABORATORY-III

PCC-EST 306	Solar Photovoltaic Power System	L	T	P	C
		2	1	2	4

Course Objectives

- Teach basics of solar photovoltaic module
- Teach basics of solar PV systems and components
- Teach the basics of grid system and batteries
- Teach about solar power system design and installation
- Teach about space power systems

Course Outcome

- This course teaches about the solar photovoltaic power system from module assembly process to establishment and commissioning of solar photovoltaic power plant
- Students are expected to understand the technologies involved in the establishment and maintenance of solar photovoltaic power plant

Unit-I Solar PV Module [9]

Introduction: module and circuit design - identical and non-identical cells - module structuring and assembly - assembly materials – environmental protection – interconnect: types and assembly process – crystalline and thin film modules - issues with solar PV modules, bypass diode and blocking diode – module testing and analysis- thermal considerations - electrical considerations and output conditioning - mechanical protection & module testing and evaluation.

Unit-II SPV Systems & Components [9]

Introduction to PV systems - system components: module and array – Charge controllers – Inverters – Batteries – power conditioning and Regulation – Mechanical assemblies – Balance of System Components

Unit-III SPV Power Systems [9]

Types of SPV power systems: MW general power systems – Grid connected power systems – Remote area power systems – Specific purpose Photovoltaic systems: Space – Marine – Telecommunication – water pumping – refrigeration etc., Concentrator solar cells and systems. Space quality solar cells and satellite power systems – Photovoltaic power system for electrical vehicles: BLDC motors: power, drives and controllers – Battery bank and charging strategies - vehicle and circuit design.

Unit-IV Power System Design and Installation [9]

Power considerations and system design – Array integration: mechanical integration – electrical integration – utility integration – Inspection and commissioning - SPV power system maintenance: cleaning, shadowing, stability etc., and troubleshooting – Economics.

Unit-V Space Power Systems [9]

Solar Photovoltaic Power systems – Thermophotovoltaic power systems - Deep space power systems: Nuclear fusion systems, Radio-isotope Thermoelectric Generator power systems - Stirling Radioisotope Generator (SRG).

Text Books

1. Solid State electronic devices by Ben G. Streetman, Prentice-Hall of India Pvt. Ltd., New Delhi 1995.
2. Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial College Press, 2001.

Reference books

1. Photovoltaic Systems Engineering, Roger Messenger and Jerry Vnetre, CRC Press, 2003.
2. Generation Distribution and utilization of Electrical Energy, C.L.Wadhwa, Wiley Eastern Ltd., India(1989)
3. Electrical Power Systems Quality by Roger C.Dugan , Mark .F. Mc Granaghan, Surya Santaso, H.Wayne Beaty, Second Edition, Mc Graw Hill, 2002 4. Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, SBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.

PCC-EST 307	Biorefineries	L	T	P	C
		3	0	0	3

Course Objectives:

1. To outline the importance of Biorefineries in biomass to biofuel conversion
2. To able appreciate and adopt different process and concepts of Biorefineries
3. To learn complete valorization of biomass with Zero waste Management by Biorefineries

Course Outcome:

1. Learn various methodologies to convert biomass to biocrude.
2. Acquire knowledge on conversion of biomass feedstock to value added biomolecules.
3. Specifically understanding on developing end-to-end solution for biofuel production and commercially sustaining the process in algae based biofuel conversion process.

Unit I: Liquefaction of Biomass: **[6]**

Biomass Feedstock – Mechanical Process, Chemical Process, Thermochemical Conversion of Biomass Liquefaction by Pyrolysis - Hydrothermal Liquefaction (HTL). Gasification - Biochemical Conversion-Pretreatment, Enzymatic Hydrolysis, Fermentation.

Unit II: Biochemical Conversion & Metabolites: **[9]**

Introduction -Primary Metabolites -Saccharides -Lignin -Amino Acids, Peptides, and Proteins - Fatty Acids, Lipids -Organic Acids -Secondary Metabolites -Simple Phenols and Phenolic Acids -Polyphenols -Terpenes - Alkaloids - Stability of Isolated Compounds.

Unit III: Bio-separation Processes: **[12]**

Conventional Separation Approaches-Steam Distillation-Conventional Solid Liquid Extraction -Ultrasound-Assisted Extraction -Microwave-Assisted Extraction - Pressurized Subcritical Liquid Extraction -Supercritical Fluid Extraction -Separation and Purification of Phytochemicals from Plant Extracts and Dilute Solution in Bio-refineries -Liquid Liquid Extraction - Membrane Separation-Molecular Distillation

Unit IV: Bio-refinery Concepts: **[9]**

Classification of Biorefineries Whole crop, Oleochemical, and Lignocellulosic Feedstock Biorefineries, Adoptability of Biorefineries in Petrochemical Refineries. Case studies: Specific Feedstock Based Biorefinery Process Development.

Unit V: Algal Bio-refinery: **[9]**

Micro algae and Macro algae -Microalgae Biomass Production: Production Techniques -Down Stream Processing Integrated Bioprocess in Algae - Value Added Chemicals from Biomass - Algal Phytochemicals, Biodiesel, Proteins, Polyunsaturated Fatty Acids, Vitamins, Carotenoids - Industrial products: Phycobiliproteins, Phycocolloids and Phycosupplements.

Text Books:

1. Biofuels Engineering Process Technology by Caye M. Drapcho, Nghiem PhuNhuan, & Terry H. Walker, McGraw Hill Publishers (2008).
2. Bioprocess Engineering Principles; Pauline M Dorass, Academic Press.
3. Ladisch, M.R., (2001), Bioseparation Engineering: Principles, Practice and Economics, Wiley, Interscience.
4. Biochemical Engineering Fundamentals; James E. Bailey and David F.Ollis, Mc Graw Hill book company. 5. Pauline M. Doran. Bioprocess engineering principles. Academic press. 1995

Reference Books:

1. Biorefineries by Kurt Wagemann, Nils Tippkötter, Springer Cham, https://doi.org/10.1007/978-3-319-97119-3 (2019)
2. Biorefineries and Chemical Processes, by J Sadhukhan,, © 2014 John Wiley & Sons, Ltd

PCC-EST 308	Energy Audit and Management	L	T	P	C
		3	0	0	3

Course Objectives:

- To provide an understanding on ECA-2001 and its features
- Need for energy audit and method of its execution
- The role of energy and material balance calculation in energy auditing
- To study the energy conservation opportunities in various thermal utilities
- Energy conservation in electrical utilities

Course Outcome

- Students will develop a comprehensive understanding of various energy systems.
- Students will learn the principles of energy conservation and efficiency, including energy auditing methodologies, energy performance assessment techniques, and optimization strategies.
- Students will learn to conduct comprehensive energy audits of industrial, commercial, and residential facilities.
- Students will develop the skills to identify energy saving opportunities and recommend cost-effective energy conservation measures (ECMs)
- Students will learn to perform financial analysis and cost-benefit evaluations of energy conservation projects.
- Students will develop energy management plans and strategies to achieve energy efficiency goals.

Unit I: ECA-2001 & Energy Audit and Management [10]

Salient features of the ECA-2001, Key definitions, Powers and functions of BEE, State designated agencies, Schemes of BEE under ECA 2001, Need for energy audit, Types of energy audit, Identification of energy conservation (ENCON) opportunities, Technical and economic feasibility, Classification of ENCON measures, Energy audit report, Understanding of energy costs, Benchmarking, Plant energy performance, Fuel and energy substitution, Instruments and metering for energy audit.

Unit II: Material and Energy Balance. [5]

Introduction, Components of material and energy balance, Basic principles of materials and energy balance, Material balance procedure, Energy balance, Facility as an energy system, Energy analysis and Sankey Diagram.

Unit III: Energy Conservation in Thermal Utilities: Furnace, Boilers, Steam Systems [11]

Furnaces: Classification, general fuel economy measures in furnaces, excess air and heat distribution

losses, temperature control, draft control, case studies.
Boilers: Types, analysis of losses, performance evaluation, boiler blow down, energy conservation opportunities, FBC boilers, case studies.
Steam system: Properties of steam, assessment of steam distribution losses, steam leakages, steam trapping, condensate and flash steam recovery systems, identifying opportunity for energy saving, case studies.

. **Unit IV: Energy Conservation in Other Thermal Utilities:** [7]
Insulation and refractories: Insulation type and application, economic thickness of insulation, heat savings and application criteria, refractory-types, selection and application of refractories, case studies.
Waste heat recovery: Availability and reversibility, first and second law efficiency, classification, advantages and applications, commercially viable heat recovery devices, saving potential, case studies

Unit V: Energy Conservation in Electrical Utilities [12]
Electrical systems and bill analysis: Electricity billing, electrical load management, maximum demand control, Energy conservation opportunities in Lighting systems, Electric motors, VCR and VCR systems, HVAC & refrigeration system, Fans & blowers, Pumps, case studies.

Text Books:

1. Albert Thumann, Terry Niehus, William J. Younger, HandBook of Energy Audits, River Publishers, 9th Edition, 2012.
2. Giuliano Dall'O', Green Energy Audit of Buildings, Springer Publication, 2013.
3. Larry C. Witte, Philip S. Schmidt, David R. Brown, Industrial Energy Management and Utilization, 1st Edition, Springer Publication,1988.

References:

1. Carig B, Saith, Energy Management Principles, applications, benefit and saving, Per n Presss, Newyork
2. D Patrick and SW Fardo, Energy conservation, Prentice Hall, INC Engleweek Cliffs (NJ) 7632 3. Davida, Fuels of opportunity, characteristics and uses in combustion systems, Edition-2004, Publisher-Elsevier Ltd., UK
3. Stephen A. Roosa, Steve Doty, Wayne C. Turner, Energy Management Handbook, River Publishers, 9th Edition, 2018.
4. Ian M. Shapiro, Energy Audits and Improvements for Commercial Buildings, Wiley Publication, 2016.
5. F W Pyne, P gm Energy Conservation Manual, Fairmount Proem, INC. P.O. Box 14227 Atlanta, A30224.

PCC-EST-309	Power Systems Dynamics and Smart Grid Operations	L	T	P	C
		3	0	0	3

Course Objective
- To study steady state and dynamic modeling of generator
- To study dynamic modeling of Excitation Systems, Prime movers etc.
- To study response of SMIB and multi-machine systems for different cases.
- Ability to handle information processing and communications to the power grid.
- Understanding the development of the smart grid, Smart grid design, implementation, evaluation and management of smart electricity infrastructure

Course Outcomes:
At the end of this course, students will demonstrate the ability to
- Understand the concepts of power systems.
- Understand the various power system components.
- Evaluate fault currents for different types of faults.
- Understand the generation of over-voltages and insulation coordination.
- Understand basic protection schemes.
- Understand concepts of HVdc power transmission and renewable energy generation.

Module 1: Basic Concepts **(4 hours)**

Evolution of Power Systems and Present-Day Scenario. Structure of a power system: Bulk Power Grids and Micro-grids. Generation: Conventional and Renewable Energy Sources. Distributed Energy Resources. Energy Storage. Transmission and Distribution Systems: Line diagrams, transmission and distribution voltage levels and topologies (meshed and radial systems). Synchronous Grids and Asynchronous (DC) interconnections. Review of Three-phase systems. Analysis of simple three-phase circuits. Power Transfer in AC circuits and Reactive Power.

Module 2: Power System Components (15 hours)

Overhead Transmission Lines and Cables: Electrical and Magnetic Fields around conductors, Corona. Parameters of lines and cables. Capacitance and Inductance calculations for simple configurations. Travelling-wave Equations. Sinusoidal Steady state representation of Lines: Short, medium and long lines. Power Transfer, Voltage profile and Reactive Power. Characteristics of transmission lines. Surge Impedance Loading. Series and Shunt Compensation of transmission lines. Transformers: Three-phase connections and Phase-shifts. Three-winding transformers, autotransformers, Neutral Grounding transformers. Tap-Changing in transformers. Transformer Parameters. Single phase equivalent of three-phase transformers. Synchronous Machines: Steady-state 1performance characteristics. Operation when connected to infinite bus. Real and Reactive Power Capability Curve of generators. Typical waveform under balanced terminal short circuit conditions – steady state, transient and sub-transient equivalent circuits. Loads: Types, Voltage and Frequency Dependence of Loads. Per-unit System and per-unit calculations.

Module 3: Over-voltages and Insulation Requirements (4 hours)

Generation of Over-voltages: Lightning and Switching Surges. Protection against Over-voltages, Insulation Coordination. Propagation of Surges. Voltages produced by traveling surges. Bewley Diagrams.

Module 4: Fault Analysis and Protection Systems (10 hours)

Method of Symmetrical Components (positive, negative and zero sequences). Balanced and Unbalanced Faults. Representation of generators, lines and transformers in sequence networks. Computation of Fault Currents. Neutral Grounding. Switchgear: Types of Circuit Breakers. Attributes of Protection schemes, Back-up Protection. Protection schemes (Over-current, directional, distance protection, differential protection) and their application.

Module 5: Introduction to DC Transmission & Renewable Energy Systems (9 hours)

DC Transmission Systems: Line-Commutated Converters (LCC) and Voltage Source Converters (VSC). LCC and VSC based dc link, Real Power Flow control in a dc link. Comparison of ac and dc transmission. Solar PV systems: I-V and P-V characteristics of PV panels, power electronic interface of PV to the grid. Wind Energy Systems: Power curve of wind turbine. Fixed and variable speed turbines. Permanent Magnetic Synchronous Generators and Induction Generators. Power Electronics interfaces of wind generators to the grid.

Text/References:

1. J. Grainger and W. D. Stevenson, ―Power System Analysis‖, McGraw Hill Education, 1994.
2. O. I. Elgerd, ―Electric Energy Systems Theory‖, McGraw Hill Education, 1995.
3. A. R. Bergen and V. Vittal, ―Power System Analysis‖, Pearson Education Inc., 1999.
4. D. P. Kothari and I. J. Nagrath, ―Modern Power System Analysis‖, McGraw Hill Education, 2003.
5. B. M. Weedy, B. J. Cory, N. Jenkins, J. Ekanayake and G. Strbac, ―Electric Power Systems‖, Wiley, 2012.

PCC-EE15: Power Systems – I Laboratory (0:0:2 – 1 credit)

Hands-on experiments related to the course contents of EE14. Visits to power system installations (generation stations, EHV substations etc.) are suggested. Exposure to fault analysis and Electromagnetic transient program (EMTP) and Numerical Relays are suggested..

PCC-EST 320	ENERGY LAB IV

HSMC 305	**Project Management**	L	T	P	C
		2	1	0	3

Course Objectives:
1. To outline the need for Project Management
2. To highlight different techniques of activity planning
3. Project Planning & Management

Course Outcomes:
1. Evaluate and select the most desirable projects.
2. Apply appropriate approaches to plan a new project and develop project schedule.
3. Identify the important risks facing in a new project.

UNIT I: Introduction to Project Management and Project Selection (9)
Objectives of Project Management- Importance of Project Management- Types of Projects Project Management Life Cycle- Project Selection – Feasibility study: Types of feasibility Steps in feasibility study.

UNIT II: Project Planning and Implementation (9)
Project Scope- Estimation of Project cost – Cost of Capital – Project Representation and Preliminary Manipulations - Basic Scheduling Concepts - Resource Levelling – Resource Allocation.

UNIT III: Project Monitoring and Control (9)
Setting a base line- Project management Information System – Indices to monitor progress. Importance of Contracts in projects- Teamwork in Project Management - Attributes of a good project team – Formation of effective teams – stages of team formation.

UNIT IV: Project Closure (9)
Project evaluation- Project Auditing – Phases of project Audit- Project closure reports Checklist of closure, Risk mitigation, archiving of documents, Guidelines for closeout reports.

UNIT V: Special Topics in Project Management (9)
Computers, e-markets and their role in Project management- communication, Change management, Resource management, stakeholder management, Risk management, Leadership – Environmental Impact Assessment. Case studies in Project management.

Text Book

1. Berkun, Scott (2008), Making Things Happen: Mastering Project Management, O'Reilly Media: Cambridge, MA.
2. Campbell, Clark A. (2006), The One-Page Project Manager: Communicate and Manage
3. Any Project With a Single Sheet of Paper, Wiley: New York.
4. Cook, Curtis R. (2004), Just Enough Project Management, McGraw-Hill: Boston, MA.

Reference Books:

1. Crowe, Andy (2006), Alpha Project Managers: What the Top 2% Know that Everyone Else Does Not, Velociteach: Kennesaw, GA.
2. Khanna, R. B. (2011), Project Management, PHI Learning Private Limited, New Delhi.
3. Kendrick, Tom (2004), The Project Management Toolkit: 100 Tips and Techniques for Getting the Job Done Right, AMACOM Books: Boston, MA.
4. Pacelli, Lonnie (2004), The Project Management Advisor: 18 Major Project Screw-Ups, and how to Cut them off at the Pass, Prentice Hall: New York.
5. Rose, Kenneth H. (2005), Project Quality Management: Why, What and How, J. Ross Publishing: Ft. Lauderdale, FL.
6. Snead, G. Lynne (2002), The Project Management Scorecard: Measuring the Success of Project Management

Solutions, Butterworth-Heinemann: Oxford.

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PEC-EST-401	Electric Vehicle Technology	L	T	P	C
		3	1	0	4

Course objectives:

- To introduce the students to the emerging Electric Vehicle Technology
- To familiarize them on the various components of EV and its operation
- To develop understanding on the global trend and Indian scenarios of EV market including policy issues

Course Outcomes:

At the end of this course, students will demonstrate the ability to

- Understand the models to describe conventional and electric vehicles and their features.
- Understand the different possible ways of battery energy storage.
- Understand the different strategies related to battery management systems
- Gain knowledge on vehicle charging infrastructure and modes.

Unit I: Introduction to Electric Vehicles [7]

Conventional Vehicles - Basics – Fuel types – components of conventional vehicles - two stroke and four stroke engines, thermodynamics of otto and diesel cycles – various efficiencies, mechanical efficiency. Power transmission characteristics in vehicles, manual and automatic transmission-gears, clutches, breaks. Conventional vehicle vs Electric vehicle: Electric vehicle fundamental - History of electric vehicles.

Unit II: Electric Vehicles & Architectures **[**12]

Vechcile dynamics – various forces acting on the vehicles – rolling resistance, uphill drive, power requirements. Types of electric vehicles: battery electric vehicle (BEV) - Plug-in hybrid vehicles (PHEV)- Hybrid electric vehicles (HEV), Motors – basic principle of motor operation - types – AC and DC – Brush-type and brushless – EV motor characteristics - Tractive effort in normal driving – Induction motors – synchronous motors – motor slip.

Unit III: Energy for EV [17]

Energy Storage requirements for EV, battery parameters, types of energy storage devices (Lead-acid battery – lithium-ion battery & fuel cells): Nominal Voltage and Capacity, C-rate, Energy and Power, Cells in series & Parallel, Charging and discharging process, Challenges and advantages, Hybridization of energy storage devices, modelling of batteries, Comparison of different energy storage technologies for EV, Fuel cell and Hybrid fuel-energy storage system. Payload estimation of EVs.

Unit IV: Battery Management System and Drives [12]

Introduction to Battery Management System, Battery Pack topology, Voltage sensing, Temperature sensing, Sizing the battery - Effect of distance, load and force on battery life and BMS – need for BMS – Types of BMS - State-of-Charge and State-of-Health estimation – Topologies of BMS - Cell balancing – passive -active cell balancing - voltage balancing, capacity-energy balancing - cause of imbalance, circuits for balancing, Thermal management system - Thermal control – types of thermal BMS. Case studies. Electric drives and their types.

Unit V: Charging Technology and Govt. policy for EV [12]

Charging Technology, Future trends in EV, overcharge and Undercharge, Modes of charging: Wireless charging of EV - On-road charging of EV – Charging guns – national and international standards. Charging EVs from renewable, Electronic controllers and convertors. Battery swap technology - Government Policies: FAME 1 – FAME 2 and National electric vehicle policy. E-mobility: Indian and Global perspectives.

Text Books:

1. Electric Vehicle Battery Systems Sandeep Dhameja, October 2001, Pub Newnes, ISBN 0750699167
2. Rechargeable lithium-ion batteries: Trends and Trends and Progress in Electric Vehicle Technology, P. Elumalai & T. Maiyalagan, CRC Press, ISBN 9781138484092.

Reference Books:

1. Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2012. ISBN 978-1-119-94273-3
2. Plett, L. Gregory, "Battery Management Systems Volume 1", Artech House, 2015. ISBN 978-1-63081-023-8
3. Rui XIONG, Weixiang Shen "Advanced Battery Management Technologies for Electric Vehicles", John Wiley & Sons, 2019, ISBN 9781119481645.

PEC-EST-403	Organic Solar Photovoltaics	L	T	P	C
		3	0	0	3

Course objective:

- To give an overview of the new and emerging photovoltaic technologies
- To familirize with a range of topics including materials design and synthesis, materials characterisation, and device applications with an emphasis on organic semiconducting materials and photovoltaic devices.

Course Outcome:

- To evaluate how these materials can be implemented successfully in established and emerging organic electronic modules.
- Able to link molecular transport phenomena with macroscopic device response to analyze and design the next generation of organic electronic materials and devices.
- Demonstrate ability to plan synthetic strategies at an advanced level in order to synthesize organic optoelectronic materials.
- Able to propose different synthetic routes in order to enrich the properties of the material through rational understanding of structure-property relationships.

Unit I: Introduction to organic materials [9]

Introduction to organic materials for energy as a class of materials of great potential. Different classes of organic electronic materials, namely small molecule semiconductors, conjugated polymers, and carbon nanostructured materials and the main concepts. Organic optoelectronic devices, structure, principles and performances.

Unit II: Molecular, Thermal, Structural and Optical Characterization [9]

Molecular, Thermal, Structural and Optical Characterization methods to analyzedifferent material properties. Electronic Structure, Atomic and Molecular Orbitals, The Fermi Energy and The Density of States. Carrier Densities in Intrinsic Semiconductors. Charge Transport. Doping in Semiconducting Materials. Transport in Disordered Semiconductors.

Unit III: Organic Photovoltaic Devices [9]

Organic Polymer-based Solar cells, Plastic cells, perovskite solar cells, Field-Effect Transistors and Light Emitting Devices. Overview of Organic Photovoltaic Devices. Characterizing Device Parameters in OPVs. Nanostructural Impacts in OPV Devices. Interfacial Modifying Layers in OPV Devices. Emerging Trends in OPV Devices.

Unit IV: Optoelectronics [9]

Photovoltaic and Emerging Devices. Introduction to Organic Light-emitting Devices. Design Considerations for OLEDs. Introduction to Polymer Thermoelectric Devices. State-of-the-Art in Polymer Thermoelectrics.Determination of figure of merit and device characteriazation.

Unit V: Development of organic Materials [9]

Structure-property relationship in organic electronic materials. Tuning of the chemico-physical properties by synthesis and functionalization of the molecular structure. Key aspects in the development of organic-based devices; material design, structure and properties, interfaces, solid state aggregation and morphology of the active layer, charge transport, device architecture and long term stability.

Text books:

1. Organic Optoelectronics - Wenping Hu, Fenglian Bai, Xiong Gong, Xiaowei Zhan, Hongbing Fu, Thomas Bjornholm, Wiley, ISBN: 978-3-527-65345-4; 2013.

2. Solar Photovoltaics: Fundamentals, Technologies and Applications, C. S. Solanki, Prentice Hall of India, 2011.

Reference books:

1. Organic photovoltaics: Concepts and realization - C. Barbec, V. Dyakonov, J. Parisi, N. S. Sariciftci, Springer-Verlag 2003.
2. Advances in Carbon Nanomaterials: Science and Applications (1st ed.) - Tagmatarchis, N. (Ed.). (2012). Jenny Stanford Publishing.

PEC-EST-404	Additive Manufacturing for energy applications	L	T	P	C
		3	0	0	3

Objectives:

- The course is designed to impart knowledge and skills related to 3D printing technologies
- Understanding on material selection and appropriate 3D print technique to develop a product

Course Outcome

- After completion of this course, the students will be able to:
- Develop CAD models for 3D printing.
- Import and Export CAD data and generate .stl file.
- Select a specific material for the given application.
- Select a 3D printing process for an application.
- Produce a product using 3D Printing or Additive Manufacturing (AM).

Introduction to Additive Manufacturing (AM): **[9]**

Evolution of AM/3D printing; Comparison with subtractive and forming processes; Advantages of AM; Classification of AM processes; Key steps in AM.

Liquid State-based AM Processes: **[9]**

Stereo lithography – Process and working principle; Photopolymers; Photo polymerization, layering technology, Laser and Laser scanning; Micro-stereolithography; Equipment and specifications; Applications, advantages, disadvantages, examples; Solid ground curing: Process, Working principle; Equipment and specifications; Applications, advantages, disadvantages, examples.

Solid State-based AM Processes: **[9]**

Fused Deposition Modeling – Process, working principle and materials; Equipment and specifications; Laminated object manufacturing – Process and working principle; Equipment and specifications; Applications, advantages, disadvantages, examples; Other solid-state processes – Ultrasonic consolidation, Gluing, Thermal bonding; Demonstration of equipment.

Powder Based AM Processes: **[9]**

Powder Bed Fusion Processes – Working principle and materials; Powder fusion mechanism and powder handling; Various LBF processes (principle, materials, applications and examples) – Selective laser Sintering, Electron Beam Melting, Laser Engineered Net Shaping, Binder Jetting and Direct Metal Deposition; Comparison between LBF processes; Materials-process-structure-property relationships; relative advantages and limitations.

Applications of AM: **[9]**

Product development lifecycle applications – Rapid prototyping, concept models, visualization aids, replacement parts, tooling, jigs and fixtures, moulds and casting; Application sectors – aerospace, automobile, medical, jewelry, sports, electronics, food, architecture, construction and others.

Text /Reference Books:

1. Sabrie Soloman, 3D Printing & Design, Khanna Book Publishing Company, New Delhi, 2020.
2. Ian Gibson, David W Rosen, Brent Stucker, “Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping and Direct Digital Manufacturing”, Springer, 2015
3. Chua Chee Kai, Leong Kah Fai, “3D Printing and Additive Manufacturing: Principles & Applications,” World Scientific, 2015.
4. C.P Paul, A.N Junoop, “Additive Manufacturing: Principles, Technologies and Applications,” McGrawHill, 2021.

Online Resources:
1. https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. https://onlinecourses.nptel.ac.in/noc20_mg70/preview

Course Outcomes:
At the end of this course students will demonstrate the ability to
1. Understand the overall principle and various processes for additive manufacturing.
2. Select a particular additive manufacturing process based on the end application.
3. Plan the steps in fabricating a given part using additive manufacturing.

PEC-EST-405	Waste management to energy conversion	L	T	P	C
		3	0	0	3

Course objective
- To enable the students to impart the knowledge of waste & waste processing technology
- To facilitate the understanding of the environmental monitoring system
- To acquaint with the thermo-chemical conversion process for waste to energy
- To familiarize the environmental and health impacts-case studies
- To impart the knowledge of biofuels with bio-chemical conversion process for waste to energy

Course outcome
- After studying this course, students would be able to understand the municipal waste and management
- Acquire the knowledge for the waste treatment and disposal techniques
- Understanding of the thermochemical and biochemical waste to energy (WtE) techniques
- Realize various environmental effects due to various WtE conversions
- Experiencing the analyses of the case studies for WtE potential and challenges

Unit I: Introduction to waste & waste processing [9]
Definitions, sources, types municipal solid waste (MSW), biomedical waste (BMW) and composition of various types of wastes. Characterization of municipal solid waste, fundamental elements and factors effecting MSW composition, waste stream assessment, waste collection and transportation, transfer station, waste processing-size reduction, separation; waste management hierarchy, waste minimization and recycling of MSW; life cycle analysis (LCA), material recovery facilities (MRF), 6Rs of recycling, recycling of paper, glass, plastics, ferrous and non-ferrous metals.

Unit II: Waste Treatment and disposal [9]
Composting- basics, types, aerobic, anaerobic and vermin-composting, essential elements of composting. Landfills for waste, types, typical landfill process, methods and sitting consideration, layout and preliminary design of landfills. Sanitary and Bio-reactor landfills, composition, characteristics, generation, movement and control of landfill leachate and gases, environmental monitoring system for land fill gases.

Unit III: Thermo-chemical conversion process for waste to energy [9]
Thermo-chemical process: Incineration, gasification, pyrolysis and its types, plasma arc technology, Hydrothermal gasification, liquefaction and carbonization -environmental and health impacts of incineration, dioxins and its impact on health, pollution control devices, waste heat recovery, strategies for reducing environmental impacts. Gasification: syngas utilization *via* FT syntheses for fuels, plastic to bio-oil *via* pyrolysis.

Unit IV: Bio-chemical Conversion process for waste to energy [9]
Anaerobic digestion of sewage and municipal waste to biogas production, typical process, types of bio-digesters, and purification of bio-gas. Organic waste to biodiesel *via* transesterification, fermentation for bio-alcohols, bio-hydrogen and its processes. Bio-hydrogen processes: direct/indirect photolysis, photo fermentation, and microbial electrolysis-cell. Integration of biochemical conversion processes.

Unit V: Environmental and health impacts-case studies [9]

Integrating waste management system, present status of technologies for conversion of waste into energy, design of waste to energy plants for cities, small townships and villages. Environmental and health impacts of waste to energy conversion. Waste to energy- potentials and constraints in India, eco-technological alternatives for waste to energy conversions.

Text Books:

1. Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable omparisons, by Gary C. Young, ISBN:9780470539675, Publisher: John Wiley & Sons, Publication Date: June 2010.
2. Waste-to-Energy. Technologies and Project Implementation by Marc J. Rogoff And Francois Screve (Auth.) Publisher:William Andrew, 2011/2019.
3. Waste to Energy (WTE) Conversion Technology by Klinghoffer, N. B. (Hrsg.), Castaldi, M. J. (Hrsg.). ISBN 13:9780857090119 Woodhead Publishing Ltd, 2013.

Reference Books:

4. Recovering Energy from Waste Various Aspects Editors: Velma I. Grover and Vaneeta Grover, ISBN 978-1-57808-200-1; 2002.
5. Sustainable food waste-to-energy systems by Babbitt, Callie W., Trabold, Thomas, ISBN 13:9780128111581, Publisher:Academic Press, 2018.
6. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall, 2000.
7. Advances in Waste-to-Energy Technologies by Rajeev Pratap Singh (Editor), Vishal Prasad (Editor), BarkhaVaish (Editor), ISBN 10:1138390429, CRC Publishing, 2019.
8. Waste-to-Energy, Second Edition: Technologies and Project Implementation by Marc J. Rogoff, Francois Screve, Publisher:William Andrew, 2011.

PEC-EST 406	Solar energy for industrial process heat	L	T	P	C
		3	1	0	4

Course Objectives:

- To provide understanding about application of various low temperature solar thermal devices
- To study the importance of solar collectors for high temperature applications
- To give a detailed understanding on thermal energy storage and storage materials
- An extensive analysis on standard methods of testing of solar thermal collectors
- To gain knowledge on making economic analysis on solar thermal energy project

Course outcome:

- Will be exposed to knowledge of Industrial Process Heat Requirements
- Will be able to make Assessment of Solar Potential
- Will acquire knowledge on Design and Sizing of Solar Thermal Systems
- Will be able to carry out Techno-Economic Analysis of Solar Engineering Projects
- Will be exposed to Integration with Existing Infrastructure
- Will be exposed to Case Studies and Best Practices
- Will be able to gather knowledge on Emerging Technologies and Trends

Unit I: Introduction to solar energy [12]

Solar Spectrum, Solar Time and angles, day length, angle of incidence on tilted surface; Solar Radiation: Extra-terrestrial Radiation; Effect of earth atmosphere; Estimation of solar radiation on horizontal and tilted surfaces; Measurement of Solar radiation, Analysis of Indian solar radiation data and applications.

Unit II: Solar thermal collectors and its testing [12]

Flat Plate Collectors: Types of Flat Plate Collectors: Liquid Flat Plate Collectors, Air flat-plate Collectors; Evacuated tubular collectors; Solar Concentrating Collector Designs, Heliostats, Central receiver systems, parabolic trough systems; Solar furnaces; Testing protocols for low, medium and high temperature solar thermal collectors

Unit IV: Solar Heating & Cooling System [12]

Solar water heating systems; Liquid based systems for buildings; Solar air heating systems; Methods of modeling and design of Solar heating system; Photovoltaic-solar thermal hybrid collectors, Solar desalination, Cooling requirements of buildings; Vapour absorption refrigeration cycle; Water, ammonia & lithium bromide-water absorption refrigeration systems; Solar desiccant cooling.

Unit V: Solar energy for industrial process heat [12]
Solar thermal energy for industrial process heating, applications of solar flat plate water heater & air heater for industrial process heat; concentrating Solar collector systems; Basic concepts & parameters; industrial applications of concentrating collectors; Exercises in Industrial Applications; Utilization of solar thermal energy.

Unit V: E c o n o m i c analysis, Case Studies, Future Trends and Emerging Technologies [6]
Annualized cost method: Annualized cost, Life cycle savings, present worth of annual savings; Payback period, Case studies for Solar process heating in industries (e.g., food processing, textile, chemical, etc.), Successful implementation examples, Challenges and lessons learned, Advances in solar collector technology, Innovations in thermal energy storage, Integration with other renewable energy sources.

Text books
1. Duffie J. A. and Beckman W. A. Solar Engineering of Thermal Processes, John Wiley, 2013
2. Sharma, K.V. Renewable Energy Technologies for Industrial Applications. CRC Press, 2017.
3. S.P. Sukhatme, Solar Energy, Tata McGraw Hill Publishing Company Ltd. New Delhi, 3rd Edition , 2009.
4. A Sreekumar and G Raam Dheep, Solar Thermal Energy Including Laboratory Experiments, New Age International Publishers, New Delhi 2020.
5. Tyagi, H., Chakraborty, P. R., Powar, S., & Agarwal, A. K. (Eds.).. Solar Energy: Systems, Challenges, and Opportunities. Springer Nature, 2019.

Reference books:
1. G.N. Tiwari, Solar Energy – Fundamentals Design, Modelling and applications, Narosa Publishing House, New Delhi, 2002
2. Sukhatme, S. P. Solar Energy Principles of Thermal Collection and storage Tata McGraw Hill Publishing Company Ltd. New Delhi, 2005
3. Serrano, M. I. R.Concentrating solar thermal technologies. In Concentrating Solar Thermal Technologies (pp. 11-24). Springer, Cham, 2017.

Course Code	Course Title	L	T	P	Credits
PEC-EST 407	Biomethanation and Biomass gasification	3	0	0	3

Course Objective:
- The course aims to impart technology of gaseous biofuel production.
- To facilitate the understanding of the operation and maintenance of biogas plants based on anaerobic digestion and pyrolytic gasification.

Course Outcome:
- Understand the concept of anaerobic digestion and handling anaerobic microbes for generation of biogas.
- Design and install a small scale anaerobic digester
- Understand the optimum process conditions for biogas production
- Understand the biomass to gasification process
- Evaluate the gasification potential of biomass feedstock

Unit I. Biogas Types and Potential Resources: **[9]**
Classification of biogas: Biomethane, biohydrogen and Syngas. Properties and applications. Biomass feed-stock for biogas: Agricultural waste biomass, industrial process wastes, energy crops and forest produce.

Unit II. Anaerobic Digestion: **[9]**
Biochemistry of anaerobic digestion, reaction kinetics, process optimization. Digester types and classifications: Classification based on reaction kinetics, classification based on gas design. AD Plants: Small, medium and large-scale AD Plants, gas storage and applications.

Unit III. Biomass gassification: **[9]**

Thermo-chemical conversion of biomass - Biomass Pyrolysis and Gasification - Syngas production and characteristics. Classification of gassifiers - Environmental and technological challenges in biomass gasification.

Unit IV. Other sources of biogas: [6]
Biohydrogen from microbial resources, biohydrogen from Syngas, Hydrothermal gasification, other innovative gasification technologies.

Unit V. Biogass Upgradation and Applications: [12]
Biogas cleaning: Scrubbing, chemical based CO2 removal, membrane and other technologies. Upgradation of biogas - Catalytic hydrogenation - FT Sythesis. Syngas production plant over view - Syngass storage, distribution, and utilization. Transport application and electricity production - Challenges and issues. Entrepreneurial opportunities.

Text Books:

1. Hobson, P. N., & Wheatley, A. D. (1993). Anaerobic digestion: modern theory and practice.
2. Nijaguna, B. T. (2006). Biogas technology. New Age International.

References:

1. Horan, N., Yaser, A. Z., & Wid, N. (2018). Anaerobic Digestion Processes (pp. 978-981). Springer.
2. Lichtman, R. J. (1983). Biogas systems in India.
3. Chawla, O. P. (1986). Advances in biogas technology. Advances in biogas technology.9780444634535

Course Code	Course Title	L	T	P	Credits
PEC-EST408	Wind Resource Assessment and Siting	3	0	0	3

Course Objective
1. To understand wind energy potential and methods to evaluate wind resources
2. To study different wind measurement methods for collection and analysis of wind data
3. To describe and discuss the modelling of physical parameters in different wind energy calculation methods.
4. To Analyse and account for limitations, possibilities and sensitivity in calculation methods and wind measurement methods

Course Outcome
1. Able to find and evaluate information about wind resources
2. Able to identify and theoretically describe meteorological wind phenomena, account for and evaluate different wind measurement methods for collection and analysis of wind data
3. Able to describe and discuss the modelling of physical parameters in different wind energy calculation methods.
4. Able to analyse and account for limitations, possibilities and sensitivity in calculation methods and wind measurement methods

Unit-I: Introduction & Guiding Principles of a Wind Resource Assessment Program [9]
Approaches And Objectives, Measurement Plan, Monitoring Strategy, Quality Assurance Plan, Monitoring Duration, and Data Recovery.

Unit-II: Siting of Monitoring Systems and Measurement Parameters [9]
Use Of Wind Data Sources, Topographic Indicators, Field Surveys and Site Ranking, Tower Placement, Land Leasing and Permitting, Basic Parameters, Optional Parameters, Recorded Parameters and Sampling Intervals, and Supplemental Parameters to Classify Wind Energy Sites.

Unit-III- Monitoring Station Instrumentation and Installation [9]
Basic Sensors, Optional Sensors, Data Loggers, Data Storage Devices, Data Transfer Equipment, Power Supplies, Towers, Sensor Support Hardware, Wiring, Grounding, Lightning Protection, Measurement System Accuracy, and Reliability. Equipment Procurement, Equipment Acceptance Testing and Field Preparation, Installation Team, Safety, Determination of True North, Tower Installation, Sensor and Equipment Installation, Site Commissioning, Documentation

Unit-IV- Station Operation and Maintenance [9]
Site Inspections, Operation and Maintenance Procedures, Documentation, Equipment Functional Checks, Spare Parts Inventory

Unit-V- Data Collection, Handling, Validation Processing & Reporting [9]
Raw Data Storage, Data Retrieval, Data Retrieval Frequency, Data Protection and Storage, Documentation, Data Validation Methods, Data Processing and Reporting, and Quality Assurance Reporting. Cost and labor estimates, staffing recommendations.

Textbooks
1. Steve Parker, "Wind power", Gareth Stevens Publishing, 2004.
2. Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.
3. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994.
4. Matthew Huaiquan Zhang Wind Resource Assessment and Micro-siting: Science and Engineering, Wiley, 2015.

Reference Books:
1. Joshua Earnest and Tore Wizelius, "Wind Power Plants and Project Development", PHI Learning Pvt. Ltd., New Delhi, 2011.
2. J. F. Manwell, J. G. McGowan and A. L. Rogers, "Wind Energy Explained – Theory, Design and Application", Wiley, 2009.
3. Johnson G. L., "Wind Energy Systems", Prentice Hall, 1994 (published by the author online).
4. Spera D. A., "Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering", ASME Press, New York, 2009.
5. Voker Quashning, "Understanding Renewable Energy Systems", Earthscan, Second edition, 2016.
6. Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, "Wind Energy Handbook" JOHN WILEY & SONS, LTD , Second Edition,2011.

PEC-EST 409	Hydrogen and Fuel Cell Technology	L	T	P	C
		3	1	0	4

Outcome: Understand fundamental concept and working of various fuel cells, their relative advantages /disadvantages and hydrogen generation/storage technologies. This course provides the comprehensive view about various hydrogen production methods and fuel cell technologies. This course will serve as a guide for hydrogen related technologies and advancement

Unit- I Fundamentals [12]
Hydrogen – Basics: Hydrogen as a source of energy, physical and chemical properties, salient characteristics, types of hydrogen, hydrogen economy and transistion, safety and environmental impacts. Production of hydrogen: fossil fuel methods, electrolysis, catalytic methods, thermo-chemical methods, solar energy methods and biological hydrogen production,

Unit –II Hydrogen Storage and Applications [12]
Hydrogen storage options, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, carbon-based materials for hydrogen storage. Overview of hydrogen utilization, hydrogen as an alternative fuel, and hydrogen transportation.

Unit-III Fuel Cells [12]
History, principle, working, thermodynamics and kinetics of fuel cell process, types of fuel cells; AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, microbial fuel cells – relative merits and demerits, performance evaluation of fuel cell.

Unit-IV Fuel cell components and performance [12]
Fuel cell components, electrodes, electrolytes, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates. Single cell and fuel cell stack. Fuel cell operating conditions: pressure, temperature, flow rates, and humidity.

Unit -V Applications of fuel cells [12]
Fuel cell usage for domestic power systems, large scale power generation, automobile, space application, economic and environmental analysis on usage of hydrogen and fuel cell. Future trends in fuel cells, portable fuel cells, laptops, mobiles, submarines. Fuel cycle analysis – application to fuel cell and other competing technologies like battery powered vehicles, SI engine fueled by natural gas and hydrogen and hybrid electric vehicle.

Text Books:

1. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.
2. . AgataGodula-Jopek, Hydrogen Production by Electrolysis, Wiley-VCH, Germany, 2015
3. Michael Hirscher, "Handbook of Hydrogen Storage", Wiley-VCH, 2010.
4. Viswanathan.B and Aulice Scibion (2008), Fuel Cells: Principles and applications, CRC Press
5. Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz (2016), Fuel Cell Fundamentals, John Wiley & Sons. Print ISBN:9781119113805

Reference Books:

1. Dincer, C Zamfirescu, Sustainable Hydrogen Production, Elsevier, 2017.
2. Dincer, H Ishaq, Renewable Hydrogen Production, Elsevier, 2021.
3. Global Hydrogen Review 2021, IEA (2021), Paris, https://www.iea.org/reports/global-hydrogen-review-2021
4. Sorenson B, Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorenson, Academic Press (2005).
5. Hordeski MF, Hydrogen and Fuel Cells: Advances in Transportation and Power, The Fairmont Press, Inc. (2009).
6. Busby RL, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Books (2005).

PEC-EST410	Bioprocess Engineering	L	T	P	C
		3	0	0	3

Course Objectives:

- To outline the need for bioprocess in Energy engineering
- To highlight different bioprocess in bioenergy
- To acquaint with the cellular mechanisms and enzyme kinetics
- To impart the knowledge of designing of reactors for bioprocess applications

Course Outcome:

- After studying this subject, students would be able to measure the extent of biochemical growth types of biochemical interactions for living processes.
- Ability to analyze the microbial growth kinetics
- The student can design a fermenter for the bioprocessing of different products.
- The student can scale up the bioprocess for large scale production
- The students can monitor the bioprocess for higher production efficiency

Unit I: Engineering Biology [9]

Overview of bioprocess engineering, Biological systems, Cellular components and cell growth, Bioenergetics and cellular metabolism, Metabolic pathways, Autotrophic metabolism, Anaerobic metabolism, Metabolism of hydrocarbons, Biosynthesis.

Unit II: Enzyme Kinetics [9]

Enzymes and its function, Enzyme synthesis, Mechanism of enzymatic action, Enzyme kinetics, Single enzyme kinetics, Michaelis–Menten kinetics, Model of complex enzyme kinetics, Immobilized enzyme systems, Enzymatic processes.

Unit III: Cellular Growth [9]

Building blocks of cellular components, Cellular growth and models, Growth curves, Kinetic of cell growth, Batch growth kinetics, Continuous growth kinetics, Determination of growth parameters, Stoichiometry of microbial growth, Yield coefficients for cell mass

Unit IV: Reactor Design [9]

Principles of bioprocess, Batch, fed-batch, and continuous processes Chemostat systems, Operation and performance of the process systems, Types of bioreactors in bioprocesse, Instrumentation and control of bioreactors, Reactor design considerations, Scale-up and scale-down of bioprocesses, Immobilized cell system, Passive and active immobilization, Solid-state fermentation

Unit V: Bioprocess Applications and Product Recovery [9]
Anaerobic bioprocessing, Cellulosic ethanol production, Biological production of 2-butanol, Lactic acid production, Aerobic fermentation, Renewable chemicals production, Product separation process, Cell disruption and mechanical separation, Filtration, Centrifugation, Coagulation, Flocculation, Separation of soluble products, Biosafety and Bioethics

Text Books and References:

1. Bailey, J. E., & Ollis, D. F. (2018). Biochemical engineering fundamentals. McGraw-Hill.
2. Shuler, M. L., & Kargi, F., (2006). Bioprocess Engineering Basic Concept Pearson Education, Inc.
3. Cornish-Bowden, A. (2013). Fundamentals of enzyme kinetics. John Wiley & Sons.
4. Liu, S. (2020). Bioprocess engineering: kinetics, sustainability, and reactor design. Elsevier.
5. Doble, M., Kruthiventi, A. K., & Gaikar, V. G. (2004). Biotransformation and bioprocesses. CRC Press.

Reference book:

1. Bioprocess Engineering, by Shijie Liu, 2020, Elsevier.
2. Current Developments in Biotechnology and Bioengineering: Synthetic Biology, Cell Engineering and Bioprocessing Technologies, Sudhir P. Singh, Ashok Pandey, Guocheng Du, Sudesh Kumar, 2019, Elsevier.

PEC-EST 411	Design of Heat-exchanger Equipment	L	T	P	C
		3	0	0	3

Course Objectives
- To understand the principles of heat transfer and fluid mechanics as applied to heat exchanger design.
- To familiarize students with different types of heat exchangers and their applications.
- To develop skills in the design, analysis, and optimization of heat exchanger equipment for various engineering applications.
- To provide hands-on experience with software tools used for heat exchanger design and simulation.

Course outcome:
- Students will develop a thorough understanding of the fundamental principles of heat transfer and fluid mechanics.
- Students will be familiar with various types of heat exchangers.
- Students will gain the ability to size and select appropriate heat exchangers based on specific design requirements.
- Students will develop skills in the design, analysis, and optimization of heat exchanger equipment.
- Students will develop problem-solving and critical thinking skills by applying heat exchanger design principles to real-world engineering problems.

Unit 1: Different classification and basic design methodologies for heat exchanger: [9]
Classification of heat exchanger, selection of heat exchanger, overall heat transfer coefficient, LMTD method for heat exchanger analysis for parallel, counter, multi-pass and cross flow heat exchanger, e-NTU method for heat exchanger analysis, fouling, cleanliness factor, percent over surface, techniques to control fouling, additives, rating and sizing problems, heat exchanger design methodology.

Unit II: Fouling of heat exchangers: [9]
Basic consideration, effect of fouling on heat transfer and pressure drop, cost of fouling, design of heat exchangers subject to fouling, fouling resistance, cleanliness factor, techniques to control fouling

Unit III: Design of double pipe and compact heat exchangers: [12]
Thermal and hydraulic design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, total pressure drop, Heat transfer enhancement, plate fin heat exchanger, tube fin heat exchanger, heat transfer and pressure drop

Unit IV: Design of Shell & tube heat exchangers: [9]
Basic components, basic design procedure of heat exchanger, TEMA code, J-factors, conventional design methods, Bell-Delaware method.

Unit V: Heat Transfer Enhancement and Performance Evaluation: [6]
Enhancement of heat transfer, Performance evaluation of Heat Transfer Enhancement technique. Introduction to pinch analysis.

Text books

1. Kuppan Thulukkanam, Heat Exchanger Design Handbook, CRC Press, 2013.
2. Robert W. Serth, Thomas Lestina, Process Heat Transfer: Principles, Applications and Rules of Thumb, Wiley, 2014.
3. Donald Q Kern, Process Heat transfer by, McGraw Hill, 2001
4. Heat Exchanger Selection, Rating and Thermal Design by Sadik, Kakac, CRC Press, 2020.

Reference Books:

1. Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill, 1984
2. Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press, 2017.
3. Heat Exchanger Design Hand Book by Schunder E.U., Hemisphere Pub., 2011.

PEC-EST 412	Carbon Footprint & CO_2 Sequestration	L	T	P	C
		3	0	0	3

Course Objective:
- To learn the concept of global CO_2 generation and fixation in the globe.
- Familiarize the international laws, convention and regulation on carbon sequestration
- Develop basic understanding on biomass synthesis, available energy potential, its exploitation, current scenario in India.
- Develop basic understanding on available technological options for CO2 sequestration

Unit I: Climate change and International agreements [8]
The green-house effect. The United Nations Framework Convention on Climate Change (UNFCCC). The Intergovernmental Panel on climate change (IPCC), the Kyoto Protocol, the Clean Development Mechanism (CDM). Afforestation and Reforestation projects, Reduced Emissions from Deforestation and Degradation (REDD). CDM projects, finance, project development. Conservation of natural carbon sinks. National inventory management system in India (NIMS)

Unit II: Primary productivity: mechanisms and assessment [10]
Photosynthesis, absorption and yield. C3, C4 and CAM pathways. Laboratory measurement of primary productivity: cell, plant, ecosystem. Direct field measurements of biomass and primary productivity: allometric models, harvest methods for forests, grasslands and ocean. Indirect measurements of biomass and primary productivity: remote sensing and other methods. The CDM methodologies for measurement of stocks and fluxes.

Unit III: Biogeochemistry [9]
Role of soil in the carbon balance: decomposition and sequestration in soils. The carbon cycle: plant, soil and atmosphere. Impact of soil degradation. Conditions for the formation of fossil stocks of carbon. Carbon balance of ecosystems: forests, grasslands and oceans. Impact on the global carbon balance. Soil Organic Carbon (SOC) and biodiversity and climate change. SOC global stock – hot spots and bright spots. Measurement, reporting and verification of SOC. SOC for sustainable development.

Unit IV: Remote sensing and spatial analysis [10]
Sensors. Reflectance of vegetation. Measuring biomass with remotely sensed data. Measuring primary productivity with remotely sensed data. High resolution satellites, use and limitations to measure biomass and primary productivity. Low resolution satellites use and limitations to measure biomass and primary productivity. Regional and global assessments of biomass and primary productivity. Introduction to

Geographic Information Systems (GIS). Land-use and land-use changes assessment. The Clean Development Mechanism (CDM) methodologies for measurement of stocks and fluxes at the landscape level.

Unit V: Carbon Sequestration Technologies [8]
Post, Pre and Oxy combustion capture – Sequestration in geological formation: Oil-Gas, Deep sea and unmineable coal seams. CCS programmes, issues and challenges. Clean Technology Scenario and CCS. CCS an international policy strategy and legal perspective.

Text Books:
1. Bhatta, B. 2009. Remote sensing and GIS. Oxford UniversityPress.
2. Monteith, J. L., and M. H. Unsworth. 1990. Principles of environmental physics, Second edition. EdwardArnold.

References:
1. Neteler, M., and H. Mitasova. 2008. Open Source GIS. A GRASS GIS approach, Third edition.Springer.
2. Pachauri, S. and L. Jiang, 2008. The household energy transition in India and China. Interim Report, International Institute for Applied SystemsAnalysis.
3. Walker, B. and W. Steffen (eds.) 1996. Global change and terrestrial.

PEC-EST 413	Power Electronics and Drives	L	T	P	Credits
		3	0	0	3

Course Objective:
- Understand the operation, characteristics, and applications of power switching devices such as diodes, thyristors, MOSFETs, and IGBTs, including their I-V characteristics and gate drive circuits.
- Explore the principles and operation of DC-DC buck converters and analyze their power circuits and waveforms at steady state.
- Investigate the operation and characteristics of DC-DC boost converters
- Gain proficiency in the analysis and operation of single-phase and three-phase voltage source inverters
- Learn modulation techniques such as square wave, bipolar sinusoidal, and unipolar sinusoidal modulation, as well as modulation index and output voltage control.

Course Outcomes:
At the end of this course students will demonstrate the ability to
- Understand the differences between signal level and power level devices.
- Analyse controlled rectifier circuits.
- Analyse the operation of DC-DC choppers.
- Analyse the operation of voltage source inverters.

Module 1: Power switching devices (8 Hours)
Diode, Thyristor, MOSFET, IGBT: I-V Characteristics; Firing circuit for thyristor; Voltage and current commutation of a thyristor; Gate drive circuits for MOSFET and IGBT.

Module 2: Thyristor rectifiers (7 Hours)
Single-phase half-wave and full-wave rectifiers, Single-phase full-bridge thyristor rectifier with R-load and highly inductive load; Three-phase full-bridge thyristor rectifier with R-load and highly inductive load; Input current wave shape and power factor.

Module 3: DC-DC buck converter (5 Hours)
Elementary chopper with an active switch and diode, concepts of duty ratio and average voltage, power circuit of a buck converter, analysis and waveforms at steady state, duty ratio control of output voltage.

Module 4: DC-DC boost converter (5 Hours)
Power circuit of a boost converter, analysis and waveforms at steady state, relation between duty ratio and average output voltage.

Module 5: Single-phase voltage source inverter (10 Hours)
Power circuit of single-phase voltage source inverter, switch states and instantaneous output voltage, square wave operation of the inverter, concept of average voltage over a switching cycle, bipolar sinusoidal modulation and unipolar sinusoidal modulation, modulation index and output voltage

Module 6: Three-phase voltage source inverter (8 Hours)
Power circuit of a three-phase voltage source inverter, switch states, instantaneous output voltages, average output voltages over a sub-cycle, three-phase sinusoidal modulation

Text Books
1. Erwin Kreyszig, Advanced Engineering Mathematics, 9th Edition, John Wiley & Sons.
2. Ramana B.V., Higher Engineering Mathematics, Tata McGraw Hill New Delhi,2010.
3. Probability and statistics for data science,D.C Agarwal, Pradeep K Joshi, Shree Sai publishers, First edition

Reference Books:
1. NB.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 44th Edition.
2. R. J. Beerends ,H. G. Ter Morsche ,J. C. Van Den Berg, E. M. Van De Vrie, Fourier and Laplace Transforms, Cambridge University Press.
3. Sastry S.S, Introductory Methods of Numerical Analysis, PHI.

PEC-EST 414	Green Buildings and Sustainable Development	L	T	P	C
		3	0	0	3

Course Objective:
To impart knowledge of the principles and practices of the green buildings
To know the importance of sustainable use of natural resources and energy
To understand the principles of effective energy and resources management in buildings
To bring awareness of the basic criteria in the green building rating systems
To understand the methodologies to reduce, recycle and reuse towards sustainability

Course Outcome: At the end of the course, the student will be able to
- Understand the concepts and factors influencing green building concepts, systems and energy management.
- Define sustainability and a green building, along with its features and benefits.
- Able to appreciate impact of indoor environmental quality on occupant well-being and comfort.
- Identify and compare existing energy codes, green building codes and green rating systems.
- Study about the fundamentals of energy and energy production systems pertaining to Residential, Commercial, Institutional and Public Buildings.
- Explain the energy efficiency terms and methods used in green building practices. Use low embodied energy industrial and building materials and cost effective building technologies.

Unit I: Introduction [9]
Conservation of Energy, Energy Utilization in Buildings, Sustainable construction, -Study of climate and its influence in building design for energy requirement, Principles of energy conscious design of buildings, typical features of green buildings, benefits of green buildings towards sustainable development, Environment and Resource concerned of building, Implementation strategies related to integrative design Strategies.

Unit II: Implications of Building Technologies Embodied Energy of Buildings [9]
Primary and Secondary Energy, Embodied Energy, Role of Materials, Emission and pollution, Resources for Building Materials, Life Cycle Assessment, Life Cycle Costing, Key considerations regarding sustainable materials, High-Performance Building Energy Design Strategy and Goal Settings Methods to reduce embodied energy in building materials, Energy efficiency and conservation through green concepts including natural light, fresh air, and integrated system.

Unit III: Comforts in Building [9]
Thermal comfort in Buildings – Issues, Passive Cooling concepts, Heat transfer, Characteristic of Building Materials and Building Techniques, Properties of Atmospheric air, Psychometric properties of Air, Chart,

Analyzing Air-conditioning Processes; Heating, Cooling, Dehumidification and Humidification, Evaporative Cooling, Adiabatic mixing of two moist air streams, Cooling towers, energy efficient appliances for heating and air conditioning systems.

Unit IV: Alternative Building Materials [9]

Fibers- metal and synthetic - Properties and applications. Fiber reinforced plastics, Matrix materials, and roof-cool paints. Fibers organic and synthetic - Properties and applications. Building materials from agro and industrial wastes, construction and demolition wastes and mine wastes.

Unit V: Green Composites for buildings and ratings [9]

Concepts of Green Composites. Water utilization in Buildings, Low Energy approaches to Water Management. Urban Environment and Green Buildings. Green Cover and Built Environment. Rating systems for energy efficient buildings in India and other countries. Green building rating systems and certification such as LEED, GRIHA, ASOOCHAM GEM, BEE and ECBC.

Text/Reference Books:

1. K.S.Jagadish, B. U. Venkataramareddy, K. S. Nanjundarao. Alternative Building Materials andTechnologies. New Age International, 2007.
2. Low Energy Cooling for Sustainable Buildings. John Wiley and Sons Ltd, 2009.
3. C. Givoni, Man, Climate and Architecture Elsevier, 1969.
4. T. A. Markus and E. N. Morris Buildings Climate and Energy. Pitman, London, 1980. Arvind Kishan et al (Ed.) 29 | P a g e
5. Sustainable Building Design Manual. Vol 1 and 2, Teri, New Delhi, 2004. Hill, 2001.
6. Osman Attmann Green Architecture Advanced Technologies and Materials. McGraw Hill, 2010.
7. Michael F. Ashby Materials and the Environment, Elsevier, 2009. 9. Jerry Yudelson Green Building Through Integrated Design. McGraw Hill, 2009.

PEC-EST 415	Advanced Techniques for Material Characterization	L	T	P	C
		3	0	0	3

Course objectives:

- To introduce the students to various analytical instrument techniques for materials characterization,
- To impart knowledge on various chromatographic, spectroscopic, microscopic and surface studies including electrochemical techniques.
- To be in a position to appreciate functional groups, metal and non-metal bond identification, distinguish amorphous and crystalline materials and understand the topography of the materials.

Course outcome:

- Understand the principles underlying different materials characterization techniques.
- Describe the instrumentation and experimental setup for each technique.
- Analyse and interpret data obtained from materials characterization experiments.
- Apply appropriate techniques to solve real-world materials analysis challenges.

Unit I: Introduction to Materials Characterizations [9]

Relevance of advanced characterizations to materials development, scientific understanding of phenomena in materials technology. Measuring physical and chemical properties of materials. Importance of atomic and molecular structures and crystal structures of materials. Structure and property relations – grain size and physical and chemical properties -nano size effects – metals, semiconductors and insulators and polymers characterizations.

Unit II: Chromatographic and Spectroscopic Techniques [9]

Introduction to chromatographic techniques-TLC, Column, Gas Chromatography principles, Instrumentation, GC column, detectors and stationary phase and applications, hyphenated techniques (GC-MS). Liquid chromatography LC/HPLC, column efficiency in LC, Detectors, Instrumentation, Partition/Adsorption /Ion exchange chromatography and applications in material analysis. UV-visible and infrared spectroscopy, Raman spectroscopy, Nuclear Magnetic Resonance (NMR) and ESR Spectroscopies, Principles, instrumentation, and their applications in material analysis.

Unit III: Microscopic Techniques [9]

Optical microscopy- Fluorescence microscopy and confocal microscopy, Basics of electron microscopy Scanning Electron microscopy (SEM) and Transmission Electron Microscopy (TEM)'s working principles and instrumentation, Imaging, and microanalysis using SEM and TEM. TEM High-resolution imaging and diffraction techniques-indexing lattice fringes and selected area diffraction patterns (SAED) and its indexing. Atomic force microscope (AFM) – tunnelling current-contact and non-contact modes – applications to magnetic and biomaterials.

Unit IV: Diffraction Techniques [9]

Crystal systems – lattices – miller indices. X-ray diffraction (XRD) principles – Braggs law - phase identification and phase quantification, lattice parameter determination and peak broadening and crystallite size estimation, nanomaterials characterization – temperature dependent studies. Electron and neutron diffractions – principles and applications.

Unit V: Surface analysis techniques: [9]

Introduction to particle size characterization, Zeta potential measurement – Particle size analysis, specific surface area by BET analysis, Photoconductivity. X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES), Surface composition, and chemical state analysis.

List of textbooks:

1. Encyclopedia of Materials Characterization Editors: C.R. Brundle, C.A.Evens, Jr,S. Wilson, Butterworth-Heinmann, Boston (1992)
2. Materials Characterization Techniques Sam Zhang, Lin Li, Ashok Kumar; CRC press, (2008)

Reference Books:

1. Transmission Electron Microscopy; D.B. Williams and C.B. Carter, Plenum Press (2004)
2. Modern ESCA The Principles and Practice of X-Ray Photoelectron Spectroscopy, Terry L.Barr, CRC press,(1994)
3. Scanning Electron Microscopy and X-ray Microanalysis by Joseph Goldstein, Dale E. Newbury, David C. Joy, and Charles E.; Springer Science (2003)

PEC-EST 416	Battery Energy Storage	L	T	P	C
		3	1	0	4

Course objectives:

- To introduce the students to various electrochemical energy storage technologies
- To specifically impart knowledsge on lead-acid batteries, lithium-ion including solid-state batteries, supercapacitors
- To expose them on development in flexible and solid-state and hybrid energy storage systems.

Course Outcome: The outcomes of the course are

- Enrich knowledge on basics of energy conversion & storage
- Gain know-how battery and battery types and its operation of various batteries
- Gain knowledge on fabrication technology of lead-acid battery and lithium-ion battery

- Aware about the hybrid energy storage and of renewable energy using battery

Unit I: Introduction [12]

Basics of electrochemical energy conversion and storage - electrochemical cells, electrolytic cells - electro motive force, free energy changes and emf, number of electrons involved in a cell reactions, thermodynamic calculations, electrochemical series-equilibrium potential, Nernst equation-Battery types – primary and secondary batteries and examples - theoretical voltage, capacity, energy & specific energy, power & specific power.

Unit II: SLI and VRLA battery technology [12]

Principle, construction, components, merits and demerits of lead acid, nickel-cadmium, nickel- metal hydride. Advantages and disadvantages of lead acid batteries, electrochemical reactions, physical and chemical properties of active materials, characteristics and properties of sulphuric acid, constructional features, materials and manufacturing methods, SLI (Automotive) batteries, charge and discharge properties of lead acid batteries, sealed lead acid or maintenance free batteries fabrication technology and testing. Lead acid battery for PV and automotive applications.

Unit III: Lithium-ion battery and Solid-state Batteries [12]

Advanced anodes and cathodes – theoretical capacity – merits and demerits - Nanomaterials for anodes: carbon nanotubes, graphene, Sn, Al, Si, SnO_2, NiO and LTO. Nanomaterials for cathodes: $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, and doped cathodes. Fabrication of nanostructured $LiCoO_2$, MNC, NCA and NMCA, $LiMn_2O_4$, $LiFePO_4$, Si, Sn and CNTs. Battery fabrication technology and testing, batteries for electric vehicles, hybrid vehicles and solar photovoltaic applications.

Unit IV: Supercapacitors [12]

Introduction to supercapacitors, types of supercapacitors, Ragone plot, similarities and differences between supercapacitors and batteries, electrode interface & double layer capacitors-redox capacitors-construction and performance evaluation, materials for supercapacitors and technology development — solid-state and flexible supercapacitors - supercapattery - typical examples.

Unit V: Hybrid Energy storage and Post-LIB [12]

Concept of hybrid energy systems, development of battery and supercapacitors systems – Batteries and Fuel cells power systems – Recent developments and application areas. Metal-air batters, Metal-sulphur and metal-CO_2 batteries- Principles, components, challenges, merits and de-merits.

Text Books

1. Electrochemical Power Sources*:* Primary and Secondary Batteries, M. *Barak,* Institution of Engineering and Technology, U.K 1980 reprint 1997**.**
2. Handbook of Batteries, David Linden, Thomas Reddy, Mcgraw-hill, 2002.

References

1. A.J. Bard & L.R. Faulkner, Electrochemical Methods Fundamentals and Applications, John Wiley & Sons. 2nd Edition, 2001.
2. B.E. Conway, Electrochemical supercapacitors: scientific fundamentals and technological applications, Kluwer Academic / Plenum publishers, New York, 1999.
3, T.R. Crompton, Batteries reference book, Newners, 3rd Edition, 2002.

PEC-EST 417	**Artificial Intelligence and Machine learning for Energy Engineering**	L	T	P	C
		2	0	2	3

Course Objective:

- To provide students with a comprehensive understanding of Artificial Intelligence and Machine Learning techniques as applied to energy engineering.
- By the end of the course, students should be able to apply these techniques to analyze energy-related data, make informed decisions, and develop predictive models.

Course Outcome:

- Understand the fundamental concepts of Artificial Intelligence and Machine Learning:
- Define Artificial Intelligence and its various applications in energy engineering.
- Explain the significance of the Turing Test and its relevance in evaluating AI systems.
- Utilize Python libraries such as NumPy, Pandas, and Scikit-learn for machine learning tasks.
- Preprocess and clean energy-related data effectively:
- Implement data preprocessing techniques to handle missing values and outliers.
- Normalize and standardize data for improved model performance.
- Reduce data dimensionality and visualize insights:
- Apply data reduction techniques such as PCA and LDA for dimensionality reduction.
- Create effective data visualizations using Python libraries to communicate insights.
- Utilize clustering techniques for energy data analysis:
- Implement clustering algorithms like k-means and SOM for energy data segmentation.
- Interpret clustering results to derive meaningful insights for energy engineering applications.
- Develop and train Artificial Neural Network models:
- Understand the architecture and functioning of Artificial Neural Networks.
- Implement backpropagation algorithm for training neural networks and address issues like overfitting and underfitting.
- Apply Artificial Neural Networks in energy engineering tasks:
- Develop ANN models for tasks such as radiation prediction and power prediction.
- Evaluate and interpret ANN models for their effectiveness in energy-related applications

Unit 1: Fundamentals of Artificial Intelligence and Machine Learning [9]

Definition and scope of Artificial Intelligence, Historical background and evolution of AI,Various branches and applications of AI in energy engineering, Explanation of the Turing Test and its significance in AI, Critiques and limitations of the Turing Test, Modern approaches to evaluating AI systems, Overview of Python programming language for data analysis and machine learning, Introduction to essential libraries such as NumPy, Pandas, and Scikit-learnHands-on exercises on basic data manipulation and visualization using Python libraries

Unit 2: Data Preprocessing Techniques

Importance and goals of data preprocessing in machine learning,Steps involved in data preprocessing pipeline,Different Data Cleaning Techniques:Handling missing data: imputation methods, removal strategies, Outlier detection and treatment techniques,Normalization and Standardization:Explanation of normalization and standardization techniques, Application of normalization and standardization in preparing data for modelling, Comparative analysis of the effects of normalization and standardization on model performance

Unit 3: Data Reduction Techniques and Data Visualization

Data Reduction Techniques: Principle Component Analysis (PCA) for dimensionality reduction, Linear Discriminant Analysis (LDA) for feature extraction,Application scenarios and limitations of data reduction techniques,Data Visualization Techniques:, Introduction to data visualization tools and libraries (e.g., Matplotlib, Seaborn),Types of visualizations: scatter plots, histograms, heatmaps, etc.,Effective communication of insights through data visualization

Unit 4: Clustering Techniques

Introduction to Clustering:Explanation of clustering and its applications in energy engineering,Types of clustering algorithms: centroid-based, density-based, hierarchical, etc., K-means Algorithm:Detailed explanation of the K-means clustering algorithm, Implementation of K-means algorithm using Python, Self-Organizing Maps (SOM): Understanding the concept and architecture of Self-Organizing Maps, Practical application of SOM in energy data analysisEnergy Data Analysis for Clustering:Real-world case studies demonstrating the use of clustering in energy data analysis,Interpretation of clustering results and their implications in energy engineering

Unit 5: Artificial Neural Network (ANN) Architecture and Applications

Introduction to Artificial Neural Networks: Basic structure and functioning of artificial neurons,Types of neural network architectures: feedforward, recurrent, convolutional, etc. Learning, Overfitting, and Underfitting:Understanding the concepts of model learning, overfitting, and underfitting,Techniques to prevent overfitting and underfitting in neural networks, Backpropagation Algorithm:Explanation of the backpropagation algorithm for training neural networks,Optimization methods: gradient descent, stochastic gradient descent, etc.Applications of ANN in Energy Engineering: Use cases of ANN in radiation prediction, power prediction, energy consumption forecasting, etc.Challenges and considerations in implementing ANN models for energy-related tasks

Reference

1. Python Machine Learning, Authors: Sebastian Raschka and Vahid Mirjalili, Publisher: Packt Publishing,ISBN-13: 978-1789955750,Edition: 3rd Edition
2. Title: Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow,Author: Aurélien Géron, Publisher: O'Reilly Media, ISBN-13: 978-1492032649,Edition: 2nd Edition
3. Pattern Recognition and Machine Learning, Author: Christopher M. Bishop,Publisher: Springer, ISBN-13: 978-0387310732,Edition: 1st Edition

Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking, Authors: Foster Provost and Tom Fawcett, Publisher: O'Reilly Media, ISBN-13: 978-1449361327, Edition: 1st Edition, Title: Deep Learning, Authors: Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Publisher: MIT Press,ISBN-13: 978-0262035613,Edition: 1st Edition

PEC-EST 418	Thermal Energy Storage	L	T	P	C
		3	0	0	3

Course Objectives

- Students will develop a comprehensive understanding of thermal energy storage (TES) systems.
- Students will gain a solid foundation in heat transfer and thermodynamics principles relevant to thermal energy storage.
- Students will learn about different types of thermal energy storage systems, including sensible heat storage, latent heat storage, and thermochemical storage.
- Students will develop skills in the design, analysis, and optimization of thermal energy storage systems.
- Students will learn how to integrate thermal energy storage systems into various energy systems.
- Students will explore different materials and technologies used for thermal energy storage.

Course Outcome

- Students will be able to identify and classify different types of thermal energy storage systems.
- Students will gain the skills to analyze the thermal performance of energy storage systems.
- Students will learn to evaluate the performance, efficiency, and economic feasibility of various thermal energy storage technologies.
- Students will understand the role of thermal energy storage in energy systems.
- Students will develop critical thinking skills and problem-solving abilities by applying thermal energy storage principles to real-world engineering problems.

Unit I: Introduction to Thermal Energy Storage [10]

Overview of energy storage concepts, Importance of thermal energy storage in various industries, Heat transfer mechanisms in Thermal energy storage (conduction, convection, and radiation).

Unit II: Types of Thermal Energy Storage [10]
Sensible heat storage-materials and design, Latent heat storage-Phase Change Materials (PCMs), Suitability to judge materials for latent heat storage, thermos-physical, chemical and economic properties of PCMs, Thermochemical energy storage, comparison of different types of thermal energy storage,

Unit III: Materials for Thermal Energy Storage and Thermal storage Technologies [8]
Phase change materials (PCMs), High-temperature storage materials, Selection criteria for TES materials, Water-based thermal energy storage, Molten salt storage, Ice storage, Underground thermal energy storage (UTES), Main means of accumulation, Importance of thermal stratification, Cold TES; Seasonal TES - Characteristics of heat storage materials; Performance characteristics, testing, safety, standards and system sizing.

Unit IV: System Design and Integration [16]
Design considerations for TES systems, Heat exchanger design for thermal energy storage, heat exchanger charging-discharging analysis with PCM, encapsulation techniques, Integration with renewable energy sources.

Unit V: Applications of Thermal Energy Storage [6]
Heating, ventilation, and air conditioning (HVAC), Solar thermal power plants, Industrial processes and applications, Cost analysis of thermal energy storage systems.

Text Books:

1. Ibrahim Dincer and Marc A. Rosen, Thermal Energy Storage and Applications, John Wiley & Sons Ltd., 2021.
2. Bruce R. Munson, David P. DeWitt, Howard N. Shapiro, and Michael J. Moran, Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics, and Heat Transfer, John Wiley & Sons Inc; 1st edition (30 January 2003) 2003
3. Kalogirou, Therma Energy Storage for Sustainable Energy Consumption: Fundamentals, Case Studies, and Design, Academic Press, 2014.

Reference Books:

1. Luisa F. Cabeza, Thermal Energy Storage Technologies for Sustainability: Systems, Design, Assessment, and Applications, Springer, 2014.
2. Andrzej Rejman and Stanislaw Sieniutycz, Heat Transfer and Thermal Storage, CRC Press, 2017

PEC-EST 419	Computational Fluid Dynamics for Energy Engineering	L	T	P	C
		3	0	2	4

Course Objective
- To Understand the fundamentals of Computational models for Thermal and Fluid systems
- To develop skills in computational fluid dynamics to address engineering problems.
- To understand the basic structure and capabilities of current commercial CFD codes.
- To apply CFD codes in the design of fluid systems and components.

Course Outcome
- At the end of the course students should be able to, describe the physical significance of each term in the governing equations for CFD.
- Effectively use a commercial CFD package to solve practical CFD problems.
- Quantify and analyze the numerical error in solution of the CFD, PDE's.
- Formulate explicit and implicit algorithms for solving the Navier Stokes Equations
- Create and demonstrate verification strategies for evaluating CFD application in Energy Engineering.

UNIT - I **Governing Equations and Boundary Conditions [9]**
Basics of computational fluid dynamics – Governing equations of fluid dynamics – Continuity, Momentum and Energy equations – Chemical species transport – Physical boundary conditions – Time-averaged equations for Turbulent Flow – Turbulent–Kinetic Energy Equations – Mathematical behaviour of PDEs on CFD – Elliptic, Parabolic and Hyperbolic equations.

UNIT -II Finite Difference & Finite Volume Methods for Diffusion [9]

Derivation of finite difference equations – Simple Methods – General Methods for first and second order accuracy – Finite volume formulation for steady state One, Two and Three -dimensional diffusion problems – Parabolic equations – Explicit and Implicit schemes – Example problems on elliptic and parabolic equations – Use of Finite Difference and Finite Volume methods.

UNIT - III Finite Volume Method for Convection Diffusion [9]

Steady one-dimensional convection and diffusion – Central, upwind differencing schemes properties of discretization schemes – Conservativeness, Boundedness, Transportiveness, Hybrid, Power-law, QUICK Schemes.

UNIT -IV Turbulence Modelling [9]

Important features of turbulent flow, Vorticity transport equation, Statistical representation of turbulent flows: Homogeneous turbulence and isotropic turbulence, General Properties of turbulent quantities, Reynolds average Navier stokes (RANS) equation, Closure problem in turbulence: Necessity of turbulence modelling, Different types of turbulence model: Eddy viscosity models, Mixing length model, Turbulent kinetic energy and dissipation, The κ-ε model, Advantages and disadvantages of κ -ε model, More two-equation models: RNG κ-ε model and κ-ω model, Reynolds stress model (RSM),Large eddy Simulation (LES),Direct numerical simulation (DNS).

UNIT - V Application of CFD in WIND, PV and Battery/Fuel Cells Energy Systems [9]

Application of CFD in Wind Energy, Different load configurations (Aerodynamic load, gravity loads, centrifugal loads, wind Shear), Co-efficient of pressure, Kinetic Energy of wind, momentum in the wind, Power, Coefficient of Power. Application of CFD in Photo Voltaic Energy System. Application of CFD in Battery/Fuel Cells.

Text Books:

1. Computational Fluid Flow and Heat Transfer, K. Muralidhar, T. Sundararajan (Narosa Publication)
2. Computational Fluid Dynamics by Chung T. J., Cambridge University Press

Reference Books:

1. Computational Fluid Dynamics by Tapan K. Sengupta, University Press
2. Numerical Computation of Internal and External Flows by Hirch C., Elesvier
3. Numerical Heat Transfer and Fluid Flow by S. V. Patankar
4. Essential Computational Fluid Dynamics by Zikanov. O., Wiley
5. Computer Simulation of Flow and Heat Transfer by P. S. Ghoshdastidar (4th Ed, Tata McGraw-Hill)

Course Code	Small and Microhydropower Systems	L	T	P	C
PEC-EST 420		3	0	0	3

Course Objective

1. To understand the Significance of Small and Micro-Hydropower technologies
2. To Understand Construction Principles and Components of Small and Micro Hydropower plants

To Understand the Electrical & Electronics components and transmission system of Small and Micro Hydropower plants

Course Outcome:

1. After completing the syllabus, students can:
2. Learn the essential components of a small and Micro Hydropower System,
3. How to design a Small HP System, able to select the suitable system components.

Able to know how to transmit power and distribute it efficiently.

UNIT - I Introduction to Small and Micro-Hydropower Technology (MHP) [9]

Introduction to small and MHP system design, Planning concepts, Evaluation of small and MHP requirements, Power from water, Classification of hydropower and end users, System components of Mini and Micro Hydropower, Introduction of Hydropower plant in India, Micro Hydropower plant in India, Policy of India

Government and concerned authorities, Potential Hydropower plant projects identified in India, Water management.

UNIT - II Layout design of civil components of Small and MHP system [9]
Overview of civil components of MHP system, Intake, and weir. Headrace canal, Spillway, Settling basins, Fore-bay, Penstock, Anchor blocks, Support piers, Expansion joints, Powerhouse.

UNIT - III Design and Selection of mechanical components of Small and MHP system [9]
Selection of turbines and its components, Selection of turbine based on load demand, Valves, Plant efficiency, Power output calculation, Turbine sizing.
Selection of electro-mechanical equipment:
Introduction of different belts: Vee belt, tooth belt, flat belt , Selection of belt, Pulley: Introduction of pulleys, Coupling: Introduction of different couplings, Selection of couplings, Gearbox, Safety measures of MHP equipment, *De-silting basin, Fore-bay structure, Water convey pipeline, Valves, Turbines, Belt and coup*ling

UNIT IV Selection of electrical components of the Small and MHP system [9]
Generator – type and size (a) Synchronous generator, (b) Induction generator; Selection of generator type; Determination of size of the generator; Speed governing system-Conventional oil pressure mechanical governor, electronic governor
Selection of Transformer: Introduction of the transformer, Construction details of the transformer, Selection of transformer rating and specification, Operation, and maintenance of transformer, and Safety measures.

UNIT V Selection of Transmission and Distribution Lines [9]
Selection of transmission voltage, Selection of underground or overhead lines, Sizing of overhead transmission line conductor, Installation of transmission and distribution lines, Grid connection of Small and MHP plant.

Text Books:

1. Adam Harvey with Andy Brown, Priyantha Hettiarachi and Allen Inversin: Micro Hydro Design Manual, A Guide to Small Scale Water Power Schemes (ITDG Publication).
2. D.P. Kothari, K.C. Singal and Rakesh Ranjan: Renewable Energy Sources and Emerging Technologies, Printice Hall of India Ltd.
3. Small hydroelectric engineering practice- Bryan Leyland, CRC Press

Reference Books:

1. Win Hulsher and Peter Frankel, "The Power Guide, Intermediate Technology Publication.
2. "Manuals on MHP for Installation and Commissioning, Maintenance and Repair, Operation and Management", ICIMOD. Hydropower Engineering- C.C. Warnik, Prentice Hall.

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Energy Laboratory –I: PCC-EST 210
Electrical, Thermal & Fluid Engineering Lab

Suggested Topics for Laboratory Experiments:

Electtrical Lab

1. To perform and analyze the Internal & External Characteristics of the excited DC Shunt Generator, Series Generator, and Compound Generator and obtain the critical field resistance of the machine from magnetizing Characteristics.
2. To conduct a direct load test on a D.C. compound generator with a) Shunt field alone and b) Cumulative and differential compounding for short and long shunt connections.
3. To perform and analyze Speed-Torque characteristics of DC Series Motor and DC Shunt Motor.
4. To determine the efficiency and losses of two similar shunt machines by regenerative method. (Hopkinson's Test.)
5. To perform field tests on identical sets of Two D.C. series machines.
6. To determine the various losses in a D.C. machine and the separation of its core losses.
7. To determine the efficiency of Swinburne's test on a DC shunt motor.
8. To perform Speed control of the DC Shunt Motor using a) Armature control and b) field control methods.
9. To perform direct load test on a D.C. shunt motor and plot variation of (a) Input current (b) Speed (c) Torque (d) Efficiency versus output power.
10. To conduct open and short circuit tests on a three-phase transformer and determine the equivalent circuit parameters with line and Phase voltage quantity.
11. To separate hysteresis and eddy current losses of a single-phase transformer at rated voltage and frequency by conducting no load tests at different frequencies, keeping V/f constant.
12. To operate two single-phase transformers of different KVA ratings in parallel and plot the variation of currents shared by each transformer versus load current.
13. To conduct the Sumpner test on two identical single-phase transformers and determine their efficiency at various loads.
14. To make Scott connection of two single-phase transformers and to verify the three-phase to two-phase conversion.
15. To perform and analyze different types of transformers vector group connections.

Fluid Engineering

Calibration of Pitot-static tube for gas (air) flow, orifice meter and ventury meter for liquid (water) flow through pipe Laminar and turbulent flow through pipes, pressure drop, heat transfer coefficient Flow over a cylinder – study of wake, drag coefficient and heat transfer coefficient Flow through converging and diverging nozzles

Theremal Lab

Heat transfer by radiation and natural convection Drying of material by hot air Shell and tube heat exchangers – LMTD, pressure drop, heat transfer coefficient Plate heat exchangers – LMTD, pressure drop, heat transfer coefficient Pump and turbine efficiencies CoP of refrigeration cycles – VCR and VAR Efficiency and BHP of SI and CI engines Efficiency of Rankine cycle and Stirling cycle.

Conduct of Experiments & Evaluation:

A minimum of 10 experiments shall be offered in the laboratory and evaluated for the grade.

Energy Lab -II PCC-EST 220
Design, Modeling, and Simulation of Energy Systems

Suggested Topics for Laboratory Experiments:

Introduction to CAD - Engineering Drawings:

1. Introduction to engineering graphics,
2. Orthographic projections,
3. Projections of regular solids,
4. Development of surfaces,
5. Isometric projections

I**ntroduction to 3-D Modelling Design and Assembly of Various Engineering Components**

1. Design and modelling of 3-D Assembly of Bolt and Nut
2. Design and modelling of 3-D Assembly of Protected Type Flange Coupling
3. Design and modelling of 3-D Assembly of Universal Coupling
4. Design and modelling of 3-D Assembly of Plumber Block
5. Design and modelling of 3-D Assembly of Swivel Bearing

Introduction to Stress Analysis on Engineering Components

1. Stress analysis of a plate with a circular hole
2. Stress analysis of rectangular L bracket
3. Stress analysis of the cantilever beam
4. Stress analysis of an axisymmetric component
5. Thermal Analysis – 1D problems with conduction and convection boundary conditions
6. Thermal stress analysis of a 2D component
7. Conductive heat transfer analysis of a 2D component
8. Convective heat transfer analysis of a 2D component
9. Stress analysis of a truss

1. Fluid flow Analysis – Potential distribution in 2-D & 3-D bodies
2. Introduction to any one of the suitable software employed in modeling and simulation of aerodynamic problems.
3. Solution for the following equations using finite difference method(code development).
    i) One-dimensional wave equations using explicit method of lax
    ii) One-dimensional heat conduction equation using explicit method
4. Generation of the following grids(code development).
    i) Algebraic Grid
    ii) Elliptic Grids.
5. Numerical simulation of flow problems using commercial software packages: i) Flow over an airfoil. ii) Supersonic flow over a wedge. iii) Flat plate boundary layer. iv) Laminar flow through pipe. v) Flow past a cylinder.

Computational Modelling and Simulation of Electrical System:

1. Electrical Energy Planning & Management Of Autonomous System – (MATLAB-Simulink)
2. Closed Loop Position & Velocity Control Of A Dc Brush Servomotor– (MATLAB-Simulink)
3. Tuning of P, PI, PID controller using simulation software– (MATLAB-Simulink)
4. Various Types of Stepper Motor Control – (MATLAB-Simulink)
5. Various Types Of Dc Motor -Characteristics And Modelling – (MATLAB-Simulink)

Conduct of Experiments & Evaluation:

A minimum of 10 experiments shall be offered in the laboratory and evaluated for the grade.

Energy Laboratory-III PCC-EST 310
IC Engine, Combustion and Bioenergy Lab.

Suggested Topics for Laboratory Experiments:

The laboratory exercise will mainly aim at introducing the determination of fuel properties relevant to their combustion and design of combustion equipments. This will include the properties like calorific value, proximate analysis, viscosity, surface tension, density, flash point, carbon residue (for liquid fuels) and determination of Flame velocity for gaseous fuels. The basic understanding of IC engines, their parts and its working will be shown. The testing and performance evaluation of engine will also be included

1. To determine the physical properties of biomass (density, calorific value, moisture content
2. To determine the physical properties of biomass (ash content, ultimate & proximate analysis)
3. Synthesis of biodiesel from oil by transesterification
4. Analytical characterization of biodiesel
5. Saccherificartion of lignocellulosic biomass
6. Ethanolic fermentation and bioethanol distillation
7. Charecterization of biodiesel (viscosity, pour point, flashpoint, fire point, heat value)
8. Analysis of flu gas, scrubbing and other CO2 sequestration methods
9. Processing of dry biomass for briquette and its analysis.
10. To study the biomass cultivation and growth curve analysis
11. Extraction and analysis of lipids from microalgae/oil bearing seeds
12. Extraction and analysis of carbohydrates and pigments from microalgae biomass
13. Culture, growth, harvest microalgae biomass and its analysis
14. To study the production process of biofuels
15. Performance testing of biofuels in IC engine
16. Demonstration of transport using biodiesel and bioethanol

Conduct of Experiments & Evaluation:

A minimum of 10 experiments shall be offered in the laboratory and evaluated for the grade.

Energy Laboratory-IV PCC-EST 320
Solar & Wind Energy Lab

Suggested Topics for Laboratory Experiments:

1. Measurement of global solar irradiance by using pyranometer
2. Study I-V Characteristics of Solar module
3. Effect of Solar Irradiance on the I-V and P-V Characteristics of a given Solar Module
4. To Study the Effect of Solar Module Inclination on the I-V and P-V Characteristics of given Module
5. Shade Effect on Efficiency of a given Solar Module
6. Study of Solar Module I-V Characteristics with Series and Parallel Connection
7. Thermal efficiency of FPC-based solar water heater
8. Thermal performance of solar air heater under forced condition
9. Thermal performance of greenhouse dryer
10. Thermal performance of solar box cooker without load
11. MPPT algorithm and Charge controller testing
12. MPPT algorithm testing for an stand-alone system
13. Synchronization process for single phase solar Grid tied PV system
14. Evaluation of Cut in Speed of the Wind turbine
15. Evaluation of the tip speed ratio (tsr) at different wind speed.
16. To plot turbine power versus wind speed curve.
17. Experimental study on analyzing the working of wind turbine (VI characteristics)
18. Experimental study on analyzing the working of wind turbine (Wind Velocity and Generator power)
19. Experimental study on analyzing the working of wind turbine (Yawing)
20. Experimental study on the performance of Wind turbine with Augmentations

Conduct of Experiments & Evaluation:

A minimum of 10 experiments shall be offered in the laboratory and evaluated for the grade.

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