Curriculum

M.Tech
Green Technology

July, 2025

School of
Engineering and Technology

Department of
Electrical & Electronics Engineering
Education

Deemed to be University under Distinct Category

NATIONAL INSTITUTE OF TECHNICAL TEACHERS' TRAINING AND RESEARCH (NITTTR), BHOPAL
(Deemed to be University under Distinct Category)
Ministry of Education, Government of India
Shamla Hills, Bhopal – 462 002
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National Institute of Technical Teachers' Training & Research (NITTTR), Bhopal
(Deemed to be University under Distinct Category)
Ministry of Education, Government of India
Shamla Hills, Bhopal (M.P.) 462 002
http://www.nitttrbpl.ac.in

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Preface

National Institute of Technical Teachers' Training and Research (NITTTR), Bhopal is a unique premier institution under the MoE, GOI for improving the quality of the higher education system in India, especially the technical education system of the country. It was established in 1965 as the Regional Training Institute (RTI) for the western region. Later in 2003, it was upgraded as NITTTR, and recently in 2024, NITTTR was granted the status of a Deemed University under Distinct Category.

It is to mention here with great pride and immense pleasure that NITTTR Bhopal has launched 05 M. Tech. programmes in engineering, one MBA programme,2 MSc programmes. 09 PG Diploma and 03 diploma programmes from 2025-26. Two batches have already been passed out in the Diploma in Semiconductor Packaging (OSAT/ATMP). The institute has also developed the centre of excellence in Siemens with 11 High-Tech Laboratories, a Centre of Excellence for OSAT/ATMP and a Centre for Experiential learning (CEL) for providing hands-on experience to the learners. The PhD programme in Schools of engineering, sciences, management and creative education &liberal arts has already been launched.

The learner-centric outcome-based curricula have been developed for all 08 PG programmes. These curricula with multidisciplinary approach are aligned to the philosophy of NEP:2020 and NCrF, with provision of ME&ME, flexibility and holistic development, catering to nurture intellectual, emotional, psychological, social, moral and physical wellbeing of the learners to be good human being and ensuring success in profession of their choice in industry/research/academic/start-ups.

NEP recommends integrating vocational/technical education with general education and strengthening industry-academia collaboration in HEIs. Experiential learning is integrated in the curriculum to be practiced by the learners through hands-on experience at all high-tech labs and centres of excellence at the institute. Project/ problem based learner centric flexible learning environment is propagated for life-long learning, even from their workplace.

By formally embedding unique features and OBE principles into our M. Tech, MSc. and MBA programmes, NITTTR is committed to nurturing competent, responsible and forward-thinking, futuristic educators, technologists & researchers. This initiative complements our broader mission of fostering and integrating pedagogical excellence into engineering, science and management streams for quality-driven education.

The effective implementation of these curricula using advanced pedagogical methods and assessment reforms will provide high-quality, learner-centric education that will meet the expectations of industry, academia and research.

20/8/25

Prof. (Dr.) Chandra Charu Tripathi,
Project Director
NITTTR, Bhopal

2. Introduction:

Global trend in power sector is looking forward sustainable energy solutions. Governments of India and power industries are shifting power generation from conventional power generation to renewable energy. To promote ecologically sustainable growth in solar and wind energy, Government of India initiated research and development for achieving self-reliance in the power sector supplementing the core conventional resources.

As per study conducted by jointly conducted by the Council on Energy, Environment and Water (CEEW), NRDC India (Natural Resources Defense Council India), and Skill Council for Green Jobs (SCGJ), India's renewable energy sector continues to grow steadily and create employment opportunities. Earlier studies showcased the potential to employ 1million people in the sector as India marches towards its 2030 ambitions. The study also pointed to a huge shortage of workers trained in upstream manufacturing segments such as making poly-silicon, ingots, wafers and cells. This segment is the focus of the recently launched ₹19,500 crore ($2.43 billion) production-linked incentive (PLI) scheme, which targets 65 GW of domestic manufacturing capacity. The bulk of the current jobs are in assembling solar modules. India aims to build 140 GW of wind capacity by 2030, could power about 100 million homes - part of its wider goal to install 500 GW of renewable energy by the end of the decade's. Another initiative is the National Green Hydrogen Mission, which aims to accelerate the deployment of Green Hydrogen as a clean energy source, will support the development of supply chains that can efficiently transport and distribute hydrogen. The Green Energy Technology program is designed to cater post graduates in aligned with India's mission.

The Master of Technology in Green Technology is a professional degree for engineers to excel and drive innovation in the field of clean energy. This master's program is developed for giving the skills and confidence for the takers to build career in new directions. The Green Technology programme offers technical and business strategic skills for the students to lead in organizations. The courses are planned by considering the entire industry value chain, from energy generation to energy use and management. It covers a wide range of related topics such as renewable energy technologies, smart grid, energy storage, hydrogen fuel cell, dynamics of energy transitions and the impacts of global climate change. It also covers topics on cyber security, artificial intelligence, energy policy and the importance of energy efficiency.

In the present competitive scenario for the technical education sector in India, an educational administration and management skills are the prime requirement of technical teachers for effective governance. To cater the need, teaching pedagogy courses are included in programme.

This programme provides solid foundation in green energy business strategy and innovation, operations and logistics, project management and organizational leadership and teaching pedagogy. In this programme, two streams of courses are introduced; Energy Management System and Electric Vehicle Technology and learners can choose a stream on their own interest.

The programme consists of 4 offline spells and 2 online spells, totaling 80 credits. There is provision for learner to exit the course after completing second offline spell followed by one additional exit course to enhance his/her skillsin the area of Green Technology. The curriculum includes different courses to develop professional specific skills in the technology domain and in pedagogy as well in each spell including the Capstone project. Students have the option to choose courses from the list of Professional Elective Courses to develop professional skills related to the area of Electric Vehicle or Energy Management. Similarly, Skill Enhancement Courses is offered to develop their specialization in the given area.

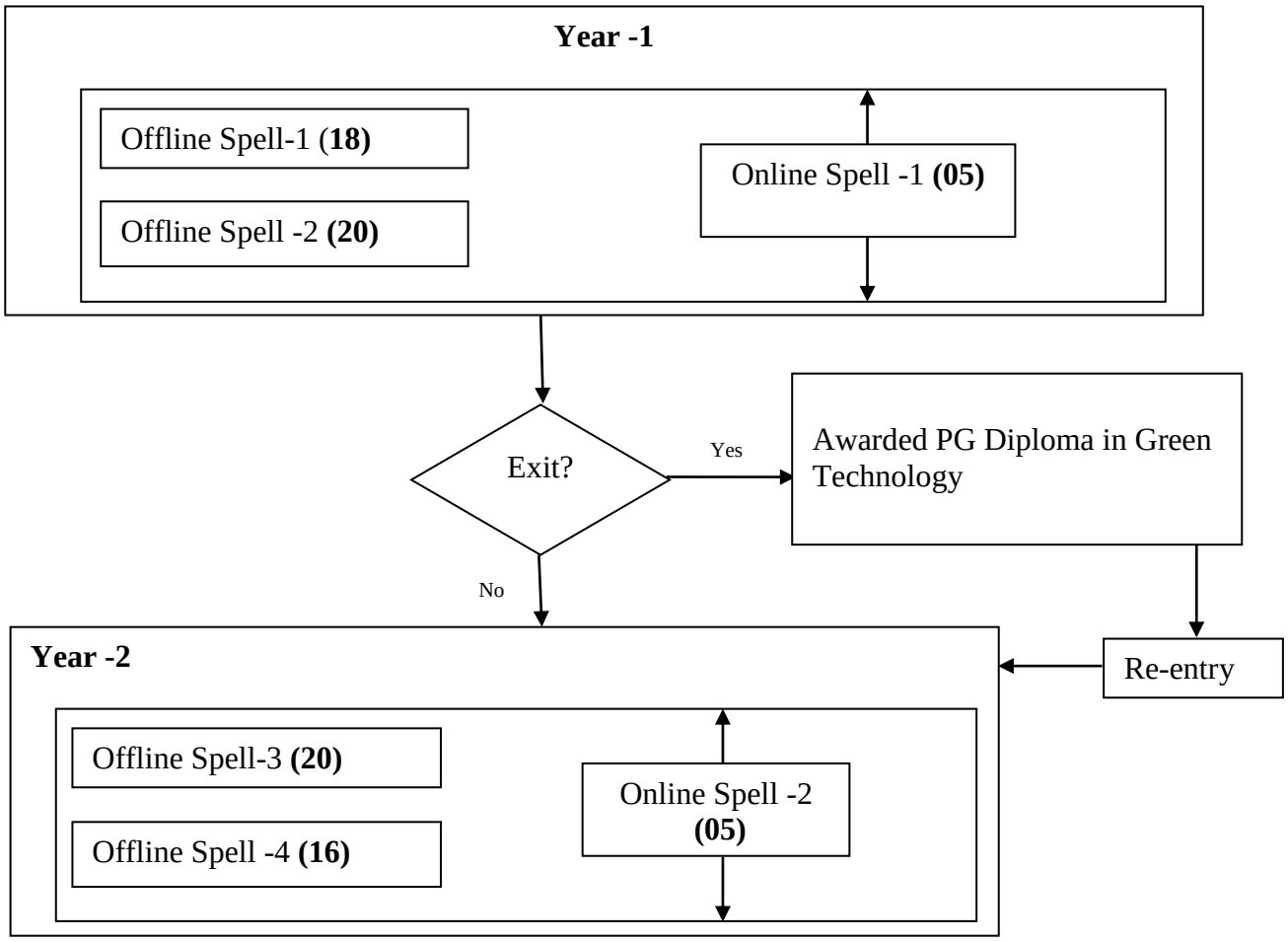
3. Approach for Scientific Design & Development of Curriculum:

The curriculum is designed after identifying the current job title of the industry where pass-out students will be absorbed. Later, different job skills required for the professionals are identified. These job skills are further mapped with the courses to be offered. Course outcomes for all the courses are also identified based on the job skills required for the professionals.

4. Unique Features of the Curriculum:

- The programme is aligned with the philosophy and requirements of NEP and NHEQF.
- Outcome-Based, learner centric curriculum with comprehensive and balanced mix of different category of courses as mentioned in Table-1.
- The duration of M.Tech. Programme is two academic years, (4 offline spells and 2 online spells running in parallel with offline spells). The online spell-1 will run parallelly with offline spell 1 and 2. The online spell-2 will run parallelly with offline spell 3 and 4. The representation of offering of programmeis mentioned in Figure 1. Each offline spell is of 15 weeks duration. This includes one week end-term examination and 5 weeks of mandatory classroom/lab based study. The total credit and marks are mentioned in Table-2
- The provision for Recognition of Prior Learning is also included.
- Dynamic curriculum with option of inclusion of diversified courses as per the changing needs of the industry.
- Holistic and multidisciplinary educational programme
- Inter-disciplinary research based project, emphasis on project management and finance, creativity and innovation, concern for professional ethics, environment and society etc.
- Credit-based courses with an option of Multi- Entry and Exit and projects in community engagement, environmental education, and Bhartiya Knowledge System.
- Recognition of identified SWAYAM / NPTEL courses.

Figure -1 Representation of Offering of Programme



5. Vision & Mission Statements of the Institute:

Vision: To be the world class leader for integrated development of technical education and training systems catering to the changing needs while achieving highest level of client satisfaction, quality, professional values and contributing to technological, economic and social development of the country.

Mission: NITTTR Bhopal will act as a centre of excellence to: Intensify teacher education for improving quality and performance of technical institutions. Make the technical education a vibrant learning system for producing competent manpower to steer technological and economic development. Provide a wide spectrum of client driven services and products through various modes. Strengthen networking and synergic partnership with technical institutions; industries, field agencies, and premier national and international organizations. Promote creativity, innovations, research and development, professional management practices, concept of learning organization, benchmarking and economics of education amongst client systems. Enthuse the spirit of professionalism, values and work ethics, networking and partnership with industry and other organizations and technical institutions.

6. Vision & Mission Statements of the Department:

Vision: Continue to innovate processes and products to usher in developments in electrical/electronic engineering education, keeping excellence in focus and deliver quality services to match the needs of the technical education system, industry and society.

Mission:

- Offer long-term and short-term programmemes related to electrical and electronics engineering and technical education for quality improvement through blended and other modes.
- Undertake researches in emerging areas of electrical and electronics engineering to enhance employability of the graduates.
- Undertake researches to develop, review and modify curricula to match the needs of electrical & electronics engineering and allied programmemes to enhance employability of the graduates.
- Undertake Outcome-Based Curriculum Development in electrical & electronics and allied disciplines.
- Develop different types of learning resources to fulfil the needs of electrical and electronics engineering and engineering education.
- Undertake consultancy and extension services to external agencies with a view to help society related to electrical and electronics engineering education.
- Network with industries, national and international institutions, R & D, community and service organisations for synergic partnership.

7. Programme Educational Objectives (PEOs):

PEO 1: Have successful professional careers in educational institutes.

PEO 2: Have successful technical/professional careers in Green Technology, research & other organizations.

PEO 3: Pursue higher studies and continue their professional development.

PEO 4: Manage Green Energy solutions using state-of-the-art technologies.

PEO 5: Be a successful entrepreneur providing services in Green Technology and allied areas.

8. Programme Outcomes (POs): -As per NBA

PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.

PO-2 An ability to write and present a substantial technical report/document**.**

PO-3 Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO-4 Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance.

9. Employment Potential:

Sample Employment and self-employment avenues are mentioned below-

9.1. Employment Avenues:

- Academician
- Scientist
- Wind Turbine Engineer
- Solar System Designer
- Energy Manager
- Energy Engineer
- Sustainability Engineer
- Green Energy Consultant
- Sustainable Energy Analyst
- Bio-fuel Engineer

9.2. Self-Employment Avenues:

- Solar Energy Engineer
- Eco-Friendly Products Manufacturing
- Energy Efficiency Consultant
- Green Building Services
- Green Energy Consultant
- Renewable Energy Equipment engineer
- EV (Chargers/ Vehicles) Entrepreneurs

10. Features of M. Tech. Programme in Green Technology:

- Holistic and multidisciplinary educational programme open to all engineering and science graduates
- Inter-disciplinary research-based project, creativity and innovation, concern for professional ethics, environment and society etc.
- Integration of renewable energy emerging technology such as Solar PV, Wind Energy, Ocean Energy, Bio Mass and Electric Vehicle.
- Recognition of identified SWAYAM / NPTEL courses

Programme Structure (PS) with Teaching & Learning and Assessment Scheme:

1.	**Title of Programme**	:	M. Tech. in Green Technology
2.	**Board of Studies**	:	Green Technology
3.	**Duration of Programme**	:	Two Years
4.	**Entry Qualification**	:	B. Tech./ B.E.
5.	**Total Marks**	:	3840
6.	**Total Credits**	:	85
7.	**Total Number of Courses**	:	22

Summary of Credits and Marks

S. No	Spell	Credits	Total Marks
Year -1			
1.	Offline Spell - 1	20	850
2.	Offline Spell –2	20	830
3.	Online Spell – 1 (PD& NEP)	05	250
Total		**45**	**1930**
Year-2			
4.	Offline Spell - 3	19	860
5.	Offline Spell - 4	16	800
6.	Online Spell – 2 (PD & NEP)	05	250
Total		**40**	**1910**
Grand Total		**85**	**3840**

Category wise Courses

S. No.	Course Category	Abbreviations	Number of Courses	Total Credits
1.	Programme Core Courses	PCC	08	31
2.	Programme Elective Courses	PEC	-	-
3.	Stream Specific Diversified Courses (if applicable)	SSC	03	11
4.	Open Elective Courses (Common Basket)	OEC	01	03
5.	Project, Dissertation	PD	03	29
6.	Pedagogy Courses	PC	04	08
7.	NEP Courses	NEP	03	03
Total			**22**	**85**

Green Technology- GTECH

Teaching & Learning and Assessment Scheme (Year – 1)

Offline Spell – 1

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH01	PCC	**Solar Photovoltaic System**	45	15	45	15	120	04	30	70	20	-	20	30	170
GTECH02	PCC	**Biomass Conversion Technologies**	45	15	45	15	120	04	30	70	20	-	20	30	170
GTECH03	PCC	**Hydrogen Generation Technologies**	45	15	45	15	120	04	30	70	20	-	20	30	170
GTECH04	PCC	**Soft Computing**	45	15	-	30	90	03	30	70	20	-	-	-	120
CSEB05	PCC	**Basics of Artificial Intelligence and Machine Learning**	30	15	45	30	120	04	30	70	20	-	20	30	170
NEP01-05	NEP*	**NEP Courses**	15	-	-	15	30	01	25	-	25	-	-	-	50
Total			**225**	**75**	**180**	**120**	**600**	**20**	**175**	**350**	**125**	**-**	**80**	**120**	**850**

Legends:

Course Category: Programme Core Courses (PCC), Programme Elective Courses (PEC), Stream Specific Diversified Courses (SSC), Open Elective Courses (OEC), Project (PD), Dissertation (PD), Pedagogy Courses (PC), NEP Courses (NEP)

***Basket** of **NEP Courses:** Sports, Yoga & Meditation (NEP01)/ Open Educational Resources (NEP02)/ Professional Ethics (NEP03)/ Financial Literacy (NEP04)/ Engineering Economics (NEP05)

Offline Spell – 2

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)							Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)			
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)		
GTECH05	PCC	**Wind Power Technology**	45	15	45	15	120	04	30	70	20	-	20	30		170
GTECH06	PCC	**Modeling and Simulation of Green Energy Systems**	45	15	45	15	120	04	30	70	20	-	20	30		170
GTECH07-08	SSC	**Stream Specific Diversified Course-1**	45	15	45	15	120	04	30	70	20	-	20	30		170
GTECH09-10	SSC	**Stream Specific Diversified Course-2**	45	15	-	30	90	03	30	70	20	-	-	-		120
PD01	PD	**Project**	-	-	45	105	150	05	-	-	200	-	-	-		200
Total			**180**	**60**	**180**	**180**	**600**	**20**	**120**	**280**	**280**	**-**	**60**	**90**		**830**

Legends:

Course Category: Programme Core Courses (PCC), Programme Elective Courses (PEC), Stream Specific Diversified Courses (SSC), Open Elective Courses (OEC), Project (PD), Dissertation (PD), Pedagogy Courses (PC), NEP Courses (NEP)

Stream Specific Diversified Course – 1: Electric Vehicle Technology (GTECH07)/ Energy Conservation and Audit (GTECH08)
Stream Specific Diversified Course – 2: Energy Storage Systems (GTECH09)/ Energy Economics and Policy (GTECH10)

* All the Stream Specific Diversified Courses (SSC) have to be chosen from any one basket only. (Out of the 2/3/4 basket identified) Each basket will have 2 to 3 courses.

Online Spell –1

The online spell -1 will be offered parallelly with offline spell -1 and offline spell -2

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PC01	PC	**Research Methodology**	30	-	-	30	60	02	30	50	20	-	-	-	100
PC02	PC	**Curriculum & Assessment**	30	-	-	30	60	02	20	30	50	-	-	-	100
NEP06	NEP	**Indian Knowledge System (IKS)**	15	-	-	15	30	01	25	-	25	-	-	-	50
Total			**75**	**-**	**-**	**75**	**150**	**05**	**75**	**80**	**95**	**-**	**-**	**-**	**250**

Legends:

Course Category: Programme Core Courses (PCC), Programme Elective Courses (PEC), Stream Specific Diversified Courses (SSC), Open Elective Courses (OEC), Project (PD), Dissertation (PD), Pedagogy Courses (PC), NEP Courses (NEP)

Year – 2

Offline Spell – 3

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		Total Marks (TA+TWA+LA)
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH11	PCC	**Industrial Automation**	45	15	45	15	120	04	30	70	20	-	20	30	170
GTECH12-13	SSC3	**Stream Specific Diversified Course-3**	45	15	45	15	120	04	30	70	20	-	20	30	170
GTECH14-20	OEC	**Open Elective Course**	45	15	-	30	90	03	30	70	20	-	-	-	120
PD02	PD	**Dissertation Part -I**	-	-	90	150	240	08	-	-	300	100	-	-	400
Total			**135**	**45**	**180**	**210**	**570**	**19**	**90**	**210**	**360**	**100**	**40**	**60**	**860**

Legends:

Course Category: Programme Core Courses (PCC), Programme Elective Courses (PEC), Stream Specific Diversified Courses (SSC), Open Elective Courses (OEC), Project (PD), Dissertation (PD), Pedagogy Courses (PC), NEP Courses (NEP)

Stream Specific Diversified Course-3: Power Converters for Renewable Energy (GTECH12)/ Energy Efficiency in Utilities (GTECH13)
* All the Stream Specific Diversified Courses (SSC) have to be chosen from any one basket only. (Out of the 2/3/4 basket identified) Each basket will have 2 to 3 courses.

Open Elective Course (Offering through MOOC): Smart Grid System (GTECH14)/ Solar Thermal Energy System (GTECH15)/ Ocean and Geothermal Energy (GTECH16)/ Hydropower System (GTECH17)/ Green Building and Sustainable Development (GTECH18)/ Nanotechnology for Solar Energy Systems (GTECH19)/ Climate Change and Carbon Sequestration (GTECH20)

Note: Learners may also opt Open Elective Course offered by other PG programmes as well as from any category of the courses of the same spell/ MOOC courses.

Offline Spell - 4

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PD03	PD	**Dissertation Part - II**	-	-	105	375	480	16	-	-	500	300	-	-	800
Total			**-**	**-**	**105**	**375**	**480**	**16**	**-**	**-**	**500**	**300**	**-**	**-**	**800**

Legends:

Course Category: Programme Core Courses (PCC), Programme Elective Courses (PEC), Stream Specific Diversified Courses (SSC), Open Elective Courses (OEC), Project (PD), Dissertation (PD), Pedagogy Courses (PC), NEP Courses (NEP)

Online Spell –2

The online spell -2 will be offered parallelly with offline spell -3 and offline spell -4 in Second Year

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)							
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		Total Marks (TA+TWA+LA)
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PC03	PC	**MOOC Creation**	30	-	-	30	60	02	20	30	50	-	-	-	100
PC04	PC	**Learner Centric Instructional Methods**	30	-	-	30	60	02	30	50	20	-	-	-	100
NEP07	NEP	**Intellectual Property Rights (IPR)**	15	-	-	15	30	01	25	-	25	-	-	-	50
Total			**75**	**-**	**-**	**75**	**150**	**05**	**75**	**80**	**95**	**-**	**-**	**-**	**250**

Legends:

Course Category: Programme Core Courses (PCC), Programme Elective Courses (PEC), Stream Specific Diversified Courses (SSC), Open Elective Courses (OEC), Project (PD), Dissertation (PD), Pedagogy Courses (PC), NEP Courses (NEP)

Course Curriculum Detailing- Offline Spell -1

S. No.	Course Codes	Course Titles	Page No.
1.	GTECH01	Solar Photovoltaic System	2
2.	GTECH02	Biomass Conversion Technologies	11
3.	GTECH03	Hydrogen Generation Technologies	24
4.	GTECH04	Soft Computing	34
5.	CSEB05	Basics of Artificial Intelligence and Machine Learning	40
6.	NEP01-05	NEP Course	51

A)	**Course Title:** Solar Photovoltaic System
B)	**Course Code:** GTECH01
C)	**Pre- requisite (s):** Basics of Electrical and Electronics

Deemed to be University under Distinct Category

D) **Rationale:** Solar photovoltaic (PV) energy systems are made up of different components. The type of component in the system depends on the type of system and the purpose. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants. PV systems can operate by themselves as off-grid PV systems and integrated with utility grid or grid-tied PV systems. Electricity generated by solar photovoltaic panels is inexhaustible and does not pollute, and thus contributes to sustainable development as well as favouring local employment. This course deals with solar PV system, solar energy integration with grid and energy storage system. This course will be beneficial to electrical & mechanical engineers, energy & environment professionals, architects & structural engineers and other professionals looking to enter solar industry, or interact with solar projects in current line of work.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH01.CO1	Select a suitable location for a solar panel using the solar radiation map and measuring instruments
GTECH01.CO2	Interpret the I-V and P-V characteristics of the solar PV system
GTECH01.CO3	Develop an MPPT algorithm for maximum power extraction in a standalone PV system
GTECH01.CO4	Model the grid-connected PV system and protection schemes
GTECH01.CO5	Select an energy storage system and a charge controller for a solar PV System

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH01.CO1	3	2	3	2
GTECH01.CO2	3	3	2	3
GTECH01.CO3	2	-	2	3
GTECH01.CO4	1	-	2	3
GTECH01.CO5	2	2	3	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH01	PCC	Solar Photovoltaic System	45	15	45	15	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected toperform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	RelevantCO Number(s)
TSO 1a. Explain the History of Solar Energy *TSO 1b.* Explain solar Geometry *TSO 1c.* Explain Explain the History of Solar Energy *TSO 1d.* the Properties of Sunlight *TSO 1e.* Explain solar Radiation and atmospheric effects *TSO 1f.* Identify the given measuring instruments used for solar energy *TSO 1g.* Explain solar radiation map *TSO 1h.* Explain the solar physics and characteristics *TSO 1i.* Describe the effect of light on solar cell junctions	**Unit 1.0 Introduction to Solar Energy** 1.1 History of Solar Energy 1.2 Solar Geometry 1.3 Properties of Sunlight 1.4 Solar Radiation and Atmospheric Effects 1.5 Measuring Instruments for Solar Energy 1.6 Solar Radiation Map 1.7 Solar cell physics and characteristics 1.8 Dark and illuminated junctions of a solar cell	**CO1**
TSO 2a. Draw PV cell architecture *TSO 2b.* Classify the different types of solar cells based on the fabrication *TSO 2c.* Explain the characteristics of the PV cell, module, array, and thermal *TSO 2d.* Use diodes as bypass diodes as well as blocking diodes *TSO 2e.* Inference of solar irradiance and temperature effects on solar cells under Standard Test Conditions (STC) against Normal Operating Cell Temperature (NOCT) conditions *TSO 2f.* Use AI models to predict the actual output power under NOCT based on STC parameters and environmental data.	**Unit 2.0 Solar Cell Physics and Characteristics** 2.1 PV cell architecture 2.2 Types of solar cell: crystalline Si substrates, thin film deposition, amorphous Si, dye sensitized cell, CIGS, Cd-Te etc., 2.3 Characteristics of PV cell- PV Module and Array 2.4 Bypass and blocking diodes 2.5 Irradiance and temperature effects under 2.6 Standard Test Conditions (STC) against Normal Operating Cell Temperature (NOCT) conditions 2.7 Prediction of STC against NOCT using ML	**CO2**
TSO 3a. Examine the balancing of solar *TSO 3b.* PVsystem components and their design *TSO 3c.* Develop an algorithm to extractmaximum power from a given solar PV panel *TSO 3d.* Infer the effect of shading on solar panel performance *TSO 3e.* Build stand stand-alone PV System *TSO 3f.* Develop a Stand-Alone PV System with AC/DC Load *TSO 3g.* Design an Electronic Control Circuit and an Inverter for a Solar PV panel *TSO 3h.* Use real-time data and reinforcement learning to adjust tilt and azimuth dynamically.	**Unit 3.0 Solar PV Components** 3.1 Balance of system components and their design 3.2 Maximum Power Point Tracking (MPPT) Algorithms 3.3 Effect of shading on solar panel performance 3.4 Stand-Alone PV System 3.5 Stand-Alone PV System with AC/DC Load 3.6 Electronic Control Circuit and Inverter 3.7 Tilt angle calculation and Sun Tracking 3.8 AI-based tracking systems with real-time data and reinforcement learning	**CO3**
TSO 4a. Model grid grid-connected PV system using software	**Unit 4.0 Solar Energy Integration and Protection**	**CO4**

Major Theory Session Outcomes (TSOs)	Units	RelevantCO Number(s)
TSO 4b. Install solar PV Systems in grid-connected mode *TSO 4c.* Select a suitable inverter for solar PV panel interconnect to the grid *TSO 4d.* Design the size of the cable and the grounding system *TSO 4e.* Analyze the cost of installation and payback period *TSO 4f.* Estimate the generation cost of a solar PV system *TSO 4g.* Explain environmental and safety issues *TSO 4h.* Select a suitable site using the assessment *TSO 4i.* Develop ML models on past irradiance and weather data to predict future solar resource at the site *TSO 4j.* Explain Surge Protection for PV Panel of Inverter on the DC/AC Side *TSO 4k.* Make use of IEEE Standards for PV Protection *TSO 4l.* Summarize the General Safety Precautions of PV modules	4.1 Grid-Connected PV System 4.2 Installation of SPV Systems 4.3 Inverter selection 4.4 Cable sizing and grounding 4.5 Cost analysis and payback calculations 4.6 Concept of feed-in tariffs 4.7 Environmental and safety issues 4.8 Site Location and Site Assessment 4.9 Solar Resource Forecasting using ML 4.10 Surge Protection for PV Panel of Inverter—DC/AC Side 4.11 IEEE Standards for PV Protection 4.12 General Safety Precautions	
TSO 5a. List the selection criteria for batteries *TSO 5b.* Design charge controllers for battery-powered powered by Solar PV panels *TSO 5c.* Compare various batteries on their characteristics and performance *TSO 5d.* Analyze the effect of Depth of Discharge (DoD) on Cost of Stored Energy (COS) *TSO 5e.* Develop ML models to predict the cost of storage at various DoD levels *TSO 5f.* Explain the operation, maintenance, and safe disposal of Batteries *TSO 5g.* Describe the characteristics of a super capacitor	**Unit 5.0: Energy Storage for Solar PV System** 5.1 System Design and Selection Criteria for Batteries 5.2 Charge controllers for battery powered by Solar PV panel 5.3 Comparison of various batteries on their characteristics and performance 5.4 Effect of Depth of Discharge (DoD) on Cost of Stored Energy (COS) 5.5 AI/ML model for DoD vs COS 5.6 Operation, Maintenance, and Safe Disposal of Batteries 5.7 Super Capacitors-characteristics	**CO5**

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1 Obtain the I-V and P-V characteristics of solar cell under dark and illuminated conditions *LSO 1.2* Analyze the performance of solar cell under dark and illuminated conditions	1.	a) Dark and Illuminated Current-Voltage Characteristics of Solar Cell b) Measure the voltage and current of the solar panel under dark condition c) Measure the voltage and current of the solar panel under an illuminated condition	CO-1

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
		d) Analyze the performance of solar cell under dark and illuminated conditions.	
LSO 2.1 Measure differential spectral responses of a solar cells *LSO 2.2* Measure differential spectral responses of a solar cells under bias light conditions	2.	Spectral Response Measurement a) Develop a setup for spectral responses b) Measure differential spectral responses of a solar cells c) Measure differential spectral responses of a solar cells under bias light conditions	CO1
LSO 3.1 Obtain the I-V and P-V characteristics of series combination of PV modules *LSO 3.2* Obtain the I-V and P-V characteristics of parallel combination of PV modules	3.	V and P-V characteristics PV modules a) Obtain I-V and P-V characteristics of series combination of PV modules b) Obtain I-V and P-V characteristics of parallel combination of PV modules	CO1
LSO 4.1 Analyze the performance of two solar cells connected in series *LSO 4.2* Analyze the performance of two solar cells connected in parallel	4.	Measurement of Current-Voltage Characteristics of Two Solar Cells a) Current-Voltage Characteristics of Two Solar Cells in series b) Current-Voltage Characteristics of Two Solar Cells in parallel	CO2
LSO 5.1 Obtain the connection of Solar PV module with bypass diode and blocking diode *LSO 5.2* Analyze the use of bypass diode and blocking diode in Solar PV module	5.	Use of bypass diode and blocking diode in Solar PV module a) Connect Solar PV module with bypass diode b) Connect Solar PV module with blocking diode	CO2
LSO 6.1 Examine the characteristics of crystalline silicon Solar cell on light intensity *LSO 6.2* Examine the characteristics of crystalline silicon Solar cell on temperature	6.	Dependence of Current-Voltage Characteristics of Crystalline Silicon Solar Cell a) Obtain Current-Voltage Characteristics of Crystalline Silicon Solar Cell by varying light intensity b) Obtain Current-Voltage Characteristics of Crystalline Silicon Solar Cell by varying temperature	CO2
LSO 7.1 Develop MATLAB Simulation model for Solar PV system to implement Maximum Power Point Tracking (MPPT) algorithm *LSO 7.2* Determine the maximum voltage, maximum current and maximum power at which the maximum power point	7.	Develop a simulation model to verify Maximum Power Point Tracking (MPPT) algorithm a) Develop a simulation model of solar PV panel b) Write a program for Maximum Power Point Tracking (MPPT) algorithm c) Obtain power from a simulation model using MPPT algorithm	CO2
LSO 8.1 Determine the Maximum Power Point manually by varying the resistive load across the PV panel *LSO 8.2* Obtain the P-V characteristics of PV module	8.	Develop a simulation model standalone PV system a) Develop a simulation model of solar PV panel for DC/AC load b) Determine the Maximum Power Point	CO3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 9.1 Determine the Maximum Power Point manually by varying the duty cycle of DC-DC converter *LSO 9.2* Obtain the P-V characteristics of PV module for different duty cycles	9.	Maximum Power Point tracking manually by varying the duty cycle of the DC-DC converter on a standalone PV system for DC/AC load a) Develop a simulation model of solar PV panel b) Write a program for Maximum Power Point Tracking (MPPT) algorithm c) Determine the Maximum Power Point	CO3
LSO 10.1 Determine the PV module output power without shadow *LSO 10.2* Determine the effect of shading on PV module output power *LSO 10.3* Compare the effect of shadow on output power of shadow model	10.	Shading effect on PV module output power	CO3
LSO 11.1 Obtain a 3 Phase ON/OFF Grid Inverter powered by Solar PV module by Using Open Loop Mode on Solar Boost Converter Side *LSO 11.2* Obtain a 3 Phase ON/OFF Grid Inverter powered by Solar PV module by Using Closed Loop Mode on Solar Boost Converter Side	11.	Solar-Based 3 Phase ON/OFF Grid Inverter by Using Open/closed Loop Mode on Solar Boost Converter Side	CO4
LSO 12.1 Develop PV Module and integrate with Distribution system using software *LSO 12.2* Analyse the impact of integrate PV module on distribution grid using software	12.	Solar PV power impact on distribution grid as distributed energy source using software	CO4
LSO 13.1 Model a solar form using solar PV panel/Module *LSO 13.2* Obtain the characteristics for series and parallel combination of solar panel	13.	Design and analyze the solar farms using software	CO4
LSO 14.1 Model Solar PV module and integrate with transmission grid using software *LSO 14.2* Integrate and Analyse the Solar PV module impact on transmission grid using software	14.	Analysis of Solar PV integration impact on transmission grid using software	CO4
LSO 15.1 Obtain charging and characteristics of battery *LSO 15.2* Obtain discharging characteristics of battery	15.	Develop simulation model to observe Charging and discharging characteristics of battery	CO5

K) Suggested Research Based Problems:

i. Design a rooftop solar PV panel for a given specification of load in the building
   - Lamps: 40W X 5 numbers
   - Fans: 60WX5 Numbers
   - Select other type of load with their ratings

ii. Prepare a project proposal to implement "a solar PV System on rooftop of your home". Proposal should address the following with respective to your home/apartment/flat:
iii. Total electrical load of the house with detailed specifications of all components/gadgets.
iv. Power consumption curve for 24 hours.
v. Electricity bill calculation per month.
vi. Detailed block diagram to setup Solar PV system on rooftop of your house.
vii. Estimating the size and specifications of RES system and accessories with justification.
viii. Simulations can accelerate the testing and development process by allowing multiple scenarios to be tested quickly and simultaneously. Simulations allow for the testing of systems and scenarios without the risk of real-world consequences. Simulation tools aid in designing solar PV systems by allowing engineers to test different configurations and components before actual deployment. Models allow for the analysis of the efficiency of different PV panel types and configurations, helping to identify the most effective solutions.

ix. Develop simulation model of the following:

- Rooftop Solar PV panel and DC-AC converter connected to load
- Energy storage device to store excess energy

x. Perform the following with the developed simulation model:

- Analyze the power flow from Solar PV panel to load
- Analyze the power flow from Solar PV panel to energy storage
- Analyze the power flow from Solar PV panel by interconnecting with Grid

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- Fabrication of PV cell
- Solar window
- Solar tree

c. Self-Learning:

- Floating Solar PV module
- Solar-blind Photo detectors

d. Industrial visit

- Nearby Solar PV pool integrated with grid and prepare report on
- Solar power generated from one panel per day

- Solar power generated from Solar PV pool per day
- Average annual power generated from the solar PV pool
- Type Solar PV module used in the pool with justification
- Issues related to integration Solar PV with grid

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit -1.0 Introduction to Solar Energy	14
CO2	Unit -2.0 Solar Cell Physics and Characteristics	14
CO3	Unit -3.0 Solar Pv Components	14
CO4	Unit -4.0 Solar Energy Integration and Protection	14
CO5	Unit -5.0 Energy Storage for Solar PV System	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	Solar PV Panel	75 W	1-6
2.	Solar-Based3-Phase ON/OFF Grid Inverter	10 A,24 V	11
3.	Maximum Power Point tracking manually by varying the duty cycle of the DC-DC converter on a standalone PV system for DC/AC load	10 A,24 V	9
4.	MATLAB Software	Simulink tool box, Simscape tool box	6-8, 10-15

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition withISBN
1.	Solar Photovoltaics: Fundamentals, Technologies and Applications	Chetan singhsolanki	PHI Learning Pvt. Ltd., May 2016
2.	Grid Integration of Solar Photovoltaic Systems	Majid Jamil, M. Rizwan, D. P. Kothari	CRC Press, Taylor & Francis Group 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742, 2018
3.	Designing indoor solar products	Julian F. Randall	John Wiley & Sons, Ltd, ISBN-13 978-0-470-01661-9 (HB),2005
4.	Solar Electric Power Generation - Photovoltaic Energy Systems	Stefan C.W. Krauter	Springer-Verlag Berlin Heidelberg 2006
5.	Solar Photovoltaics: Fundamentals, Technologies and Applications	Chetan singhsolanki	PHI Learning Pvt. Ltd., May 2016

b) Online Educational Resources (OER):

1) http://cos-h.cc/education/
2) https://archive.nptel.ac.in/courses/115/107/115107116/
3) https://onlinecourses.nptel.ac.in/noc20_ph14/preview
4) https://archive.nptel.ac.in/courses/115/103/115103123/
5) https://onlinecourses.nptel.ac.in/noc22_ee71/preview
6) https://onlinecourses.nptel.ac.in/noc21_ph25/preview
7) https://www.youtube.com/watch?v=IJF0t1wS3DY
8) https://www.youtube.com/watch?v=OR60-_EJvDQ
9) https://www.youtube.com/watch?v=DtkUY17SWFo
10) https://www.youtube.com/watch?v=HQ4SfbeGg5s

Q) Course Curriculum Developer

S. No.	Name and Designation	E-mail Address
1.	Prof. K. Manickavasagam	kmanickavasagam@nitttrbpl.ac.in

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A)	**Course Title:** Biomass Conversion Technologies	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH02	
C)	**Pre- requisite (s):** Chemistry, Basic civil engineering, Basic Electrical Engineering, Renewable Energy, Mathematics	

D) **Rationale:** India has significant agricultural and forest resources and biomass represents a crucial sustainable energy pathway that aligns with both traditional practices and modern technological advancements. This course introduces students to the fundamentals of biomass as a renewable energy source and various technologies for its conversion to useful energy forms. The course also integrates AI & ML applications for optimization and monitoring of biomass conversion systems while emphasizing environmental sustainability, economic viability, and societal impact particularly in the Indian context. On successful completion of the course, the students would be able to contribute towards providing biomass based sustainable energy solutions to the client and society.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH02.CO1	Analyze various biomass resources and their characteristics for energy conversion.
GTECH02.CO2	Optimize different biomass conversion technologies to extract energy from biomass.
GTECH02.CO3	Use thermo chemical conversion technology for production of value-added bio-products, biogas, bio-power.
GTECH02.CO4	Use Bio chemical conversion technology for production of bio fuel for environmental sustainability
GTECH02.CO5	Generate power for captive use using biomass cogeneration systems.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH02.CO1	3	2	3	2
GTECH02.CO2	3	2	3	3
GTECH02.CO3	3	2	3	3
GTECH02.CO4	3	2	3	3
GTECH02.CO5	3	2	3	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH02	PCC	Biomass Conversion Technologies	45	15	45	15	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Analyze the characteristics of different types of biomass resources *TSO 1b.* Analyze regional biomass distribution and estimated potential in Indian context *TSO 1c.* Design sustainable biomass collection systems *TSO 1d.* Apply ML algorithms for yield prediction and resource assessment *TSO 1e.* Evaluate ethical implications of biomass sourcing	**Unit-1.0 Biomass Resources** 1.1 Biomass classification and characterization 1.2 Assessment methods for biomass potential 1.3 Biomass availability in India 1.4 Physicochemical properties 1.5 Sustainable harvesting methodologies 1.6 Traditional biomass utilization 1.7 AI/ML for biomass resource mapping 1.8 Ethical considerations of biomass sourcing	**CO1**
TSO 2a. Analyze the types of biomass conversion technologies and also its environmental implications. *TSO 2b.* Analyze suitable thermo chemical processes for specific biomass types *TSO 2c.* Evaluate biochemical conversion paths for different feed stocks *TSO 2d.* Describe three steps in Thermo chemical conversion technology *TSO 2e.* Describe two forms of biochemical conversion *TSO 2f.* Describe the working of a given type of gasifier and their outputs with the help of a neat diagram. *TSO 2g.* Apply AI algorithms for biomass conversion process optimization	**Unit-2.0 Biomass Conversion Technologies** 2.1 Types of biomass conversion technologies-Densification of biomass, Combustion and incineration, Thermo-chemical conversion and Bio-chemical conversion 2.2 Thermo chemical conversion -Pyrolysis, liquefaction and Gasification; 2.3 Biochemical conversion - Anaerobic digestion, Ethanol Fermentation 2.4 Bio mass Gasifiers - Electricity generation by biomass gasifier and its economics, Case studies 2.5 Design and types -Fixed bed type - updraft, down draft and Fluidized bed Gasifier 2.6 Process optimization using AI/ML 2.7 Environmental impact assessment 2.8 Inclusive design approaches	**CO2**
TSO 3a. Describe the anaerobic digestion technology of producing Biogas detailing out the three steps involved. *TSO 3b.* Describe briefly the factors affecting the quality and quantity of the bio gas produced. *TSO 3c.* Classify biogas plants based on feed method. *TSO 3d.* Describe the working of a given type of biogas plant with the help of a neat labeled sketch. *TSO 3e.* Implement AI-based monitoring for process control for Biogas plants.	**Unit-3.0 Biogas Plants** 3.1 Bio gas production- Anaerobic digestion, steps of anaerobic digestion – Hydrolysis, Acid formation and Methane formation 3.2 Classification of biogas plants based on feed method - Batch plants, Continuous plants and Semi-continuous plants 3.3 Biogas plant types-Floating drum type (Khadi Village Industries Commission-KVIC) and Fixed Dome type (Deena bandhu - DBP), Community Night-soil	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
	based plant and its working, latest trends 3.4 Biogas plant site selection criteria, 3.5 Design for cold climates increasing bio gas production in winters 3.6 Economics of biogas plant with their environmental and social impacts 3.7 Benefits of Bio gas plant 3.8 Monitoring systems with AI integration 3.9 Case studies and numerical	
TSO 4a. Enlist the feedstock categories from which ethanol is produced. *TSO 4b.* Describe the process of production of Ethanol from Biomass with the help of block diagram *TSO 4c.* Prepare a table indicating the characteristics such as Flash point, Density, Viscosity, Octane number and heating value of four types of biodiesels *TSO 4d.* Describe the production process of Biodiesel from Jatropha. *TSO 4e.* Explain the environmental benefits of using Biomass energy	**Unit-4.0 Bio Fuels** 4.1 Ethanol feedstock categories-Sugar, Starches and Celluloses, i. Biochemical conversion and its forms-Anaerobic Fermentation ii. Ethanol Fermentation 4.2 Ethanol production process from Biomass 4.3 Properties of Ethanol as fuel 4.4 Properties of Biodiesel and Petro diesel 4.5 Production of Biodiesel from Jatropha 4.6 Characteristics of four biodiesels – Biodiesel (Jatropha), Biodiesel (Sunflower), Biodiesel (Soya bean), and Biodiesel (Peanut) 4.7 Energy crops plantation, Environmental impacts and benefits	**CO4**
TSO 5a. Explain the principle of Combined Heat and Power (CHP) generation *TSO 5b.* Design appropriate cogeneration systems for specific applications for optimizing the performance. *TSO 5c.* Design integration strategies with conventional energy systems *TSO 5d.* Describe how the power is generated from different types of waste with the help of a Block diagram *TSO 5e.* Implement intelligent control for system optimization *TSO 5f.* Evaluate social and economic implications of implementations	**Unit-5.0 Biomass Cogeneration** 5.1 Principles of CHP, System configurations and Performance analysis, Integration with existing energy systems 5.2 Urban waste and its types – Municipal Solid Waste (MSW), Municipal Liquid Waste and urban Industrial waste 5.3 Power generation from MSW, from landfill gas, from sewage waste, from distillery waste, from pulp and paper mill black liquor waste (block diagram) 5.4 AI-based control strategies 5.5 Socioeconomic impact assessment 5.6 Biomass cogeneration – case study	**CO5**

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)		S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1	Determine key properties of different biomass samples such as (moisture content, calorific value, composition)	1.	Biomass characterization and analysis	CO1
LSO 2.1	Evaluate the performance of a small-scale Biomass Gasifier with solid and loose biomass.	2.	Performance evaluation of a small-scale Biomass Gasifier with solid and loose biomass.	CO2
LSO 3.1 *LSO 3.2*	Determine the calorific value of a solid and liquid Biomass Sample using Bomb calorimeter. Operating skill of Bomb Calorimeter	3.	Calorific Value of a solid and liquid Biomass Sample using Bomb calorimeter	CO3
LSO 3.3	Evaluate the performance of of a given type of Biogas plant	4.	Performance evaluation of a given type of Biogas plant	CO3
LSO 4.1	Characterize the liquid biomass (Viscosity, density, flash/fire point, cloud point) and s compare with diesel	5.	Characterization of liquid biomass (Viscosity, density, flash/fire point, cloud point) and its comparison with diesel	CO4
LSO 4.2	Produce bio-diesel from different feed stocks and determine its physical properties	6.	Biodiesel production from different feed stocks and quality testing	CO4
LSO 4.3	Produce Bio-ethanol from different feed stocks and determine its physical properties	7.	Bio-ethanol production from different feed stocks and quality testing	CO4
LSO 5.1	Evaluate the performance of a given small scale Bio mass Cogeneration system	8.	Performance evaluation of a given small scale Bio mass Cogeneration system	CO5
LSO 5.2	Develop predictive models for Biomass conversion efficiency	9.	AI/ML for predictive modeling	CO2, CO5
LSO 5.3	Simulate Model conversion processes using simulation software	10.	Model conversion processes using simulation software	CO2, CO5

K) Suggested Research Based Problems:

i. Comparative analysis of traditional and modern biomass gasification techniques with focus on efficiency and emissions
ii. Optimization of bio gasifier operations using genetic algorithms and reinforcement learning
iii. Design of smart biomass supply chain management system integrating traditional knowledge with modern logistics
iv. Machine learning approaches for predicting biogas composition from heterogeneous organic waste inputs
v. Development of compassionate AI framework for equitable biomass energy distribution in rural communities
vi. Advanced control systems for biomass cogeneration incorporating predictive analytics and fuzzy logic

vii. Integration of IoT and AI for real-time biomass quality assessment and process adaptation
viii. Social impact assessment methodologies for bioenergy projects incorporating traditional value systems
ix. Design of resilient community-scale bioenergy systems for disaster-prone regions
x. Development of AI-driven predictive maintenance system for biogas plants using sensor fusion and deep learning approaches

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Analyze the effect on production of producer gas and other outputs in the following conditions?
  (a) If fixed carbon is high
  (b) If Ash melting point is low
  (c) If moisture content is high
  (d) If volatile matter is high in feed material
- Does ethanol require more energy to produce than it delivers as a fuel? – prepare a report on this topic.
- Differentiate between Batch plants, Continuous plants and Semi-continuous plants.
- Carry out an internet survey to analyze the Indian energy scenario of Bio mass and cogeneration.
- Prepare a report on current status of alternative transportation fuels derived from biomass.
- Prepare a report on the renewable energy approaches to meet rural energy needs of India.

b. Seminar Topics:

- Impact of biomass energy global warming
- Is biomass energy a carbon-neutral source of energy?
- Electricity created with biomass
- Key Design Features of cook stoves
- Energy crops
- Cogeneration and captive power plant

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1.0 Biomass Resources	12
CO2	Unit 2.0 Biomass conversion Technologies	14
CO3	Unit 3.0 Biogas Plants	14
CO4	Unit 4.0 Biofuels	15
CO5	Unit 5.0 Biomass Cogeneration	15
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	Bio energy trainer	To generate electricity using Bio energy and to run different loads	1
2.	Flue gas analyser	Portable, digital, Range& Other Details - • O2 measurement = 0 to 21 vol. • CO measurement (with H2 compensation) = 0 to 8,000 ppm, • Ambient CO measurement (internal/flue gas probe) = 0 to 2,000 ppm, • Pressure measurement = -100 to +200 hPa, • Efficiency testing (Eta) = 0 to 120 % • Probe Length 700mm, 1000Deg C, • Carryings case for Instrument, Probe, with necessary filters	1
3.	Digital Bomb Calorimeter with safety device	For Determination Of Heat Combustion Of Organic Matter And Calorific Value And Sulphur Content Of Coal, Solid And Liquid Fuels. Material - Stainless Steel Suitable for Laboratory Work • Bomb calorimeter comprises of the	3

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		following: • The Bomb: A thick-walled, stainless steel vessel designed to withstand high pressures during combustion. • Water Bath: The bomb is submerged in a known mass of water inside an insulated container. • Insulated Jacket: A jacket that surrounds the water bath to minimize heat loss during the experiment. • Thermometer: A device to accurately measure the temperature change of the water. • Ignition System: A means of igniting the sample, often using an electrical energy source. • Sample Holder: A container for holding the biomass sample within the bomb. • Oxygen: A supply of oxygen is introduced into the bomb to support combustion. **2. Associated Equipment:** • Analytical Balance: For accurately weighing the biomass sample and water. • Grinder (if needed): To reduce the size of solid biomass samples. • Pressure Gauge**:** To monitor the oxygen pressure within the bomb.	
4.	Rotational viscometers	These use rotating cylinders or cones to measure the shear stress and rate of deformation, providing more detailed information about the liquid's viscosity behavior.	5
5.	Densitometer	These measure the mass per unit volume of the liquid, providing a more precise measurement of density.	5
6.	Abels Flash Point Apparatus	TypeHR-AFP-5A (Manual Model) Measuring RangeHT-AFP1: 30°C to +110°C HT-AFP2: -30°C to +110°C Sample Cooling /Heating Cooling-By Cooling Coil in the Bath Heating-By Water immersion Heater Display Voltage Variac-For Control Heating StrringManual Temprature SensorPT-100 in Stainless Steel sheath Flash Detector Thermometer ASTM 11C Ignition Source Gas ignition with automatic ligthing or electric ignition. Interchageable	5

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		Gas Supply (When gas ignition is used) LP gas or natural gas(Max. pressure:10kPa) Power Supply:100/120VAC or220/240VAC,50/60Hz Power Consumption 250VA Max Electric Consumption 30Wh for 1 test (about 30 min), 11.34gCO2 (@ 0.378kgCO2/1kWh)	
7.	Cloud Point Apparatus:	This equipment cools the liquid slowly and measures the temperature at which the liquid begins to cloud or precipitate solids. This is often important for understanding the behavior of fuels at low temperatures.	5
8.	BIOMASS GASIFIER	**2 KW CAPACITY**, for lighting applications, small motors, charging etc., Fuel type CHARCOL/COOCONUT SHELL/ WOOD/RICE HUSK ALONG WITH WOOD CUTTING MACHINE. - Power rating: 1 kg/hr - Gasifier type: Open top, down draught fixed bed Fuel consumption-1-1.5 kg/kwh Gasification efficiency- 70-75% Gas Calorific value- 4.5-5.5 MJ/Nm^3 Cooling cleaning-Cyclone separator, Scrubbing and filters Start up time-10-15 minutes Operation moade: manual Area required- 5'X5' Material – Mild steel with heat-resistant paint and insulation Emission standards: should meet local pollution norms (With filtration) - Engine Make: HONDA or reputed - The cost should include installation, commissioning, Training and Annual Maintenance charges	**2**
9.	Floating Drum type Bio gas Plant (KVIC Model)	Plastic floating drum for bio gas, 2 Cubic meter per day. Daily feed requirement @ 50 Kg It is a biogas production system where a plastic dome, acting as a gasholder, floats on a digester containing slurry. This type of plant is suitable for small-scale biogas generation, typically for household or community use. **Key features** Capacity:2 cubic meters of biogas storage Feed stock-Cow dung, foodwaste, organic kitchen waste, poultry litter Daily feed:10-15 kg of organic waste Gas yield-4-5% of feeding Retention time- 28-32 days Construction material- Steel/FRP for drum model	**4**

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		Gas composition- Methane-55-65%, CO2-30-40%, trace H2S and water vapor Slurry output -8-20 litres /day (can be used as organic fertilizer) Gas pressure-5-9mbar(variable) Gas storage1.5-2 m^3 in builtin drum Usage: Cooking, lighting (biogas lamps) Dimensions- Varies -1.5 m diameterX1.8 m height Life span 10 years (with maintenance) The cost should include preliminary survey, installation, commissioning, Training and Annual Maintenance charges	
10.	True RMS Multimeter	True RMS multimeter, including batteries and 1 set of measuring cables • Voltage range = 0.1 mV to 1000 V AC/DC • Current Range = 0.1 µA to 10 A AC/DC • Resistance Range = 0.01 to 60 MΩ • Frequency Range = 0.1 Hz to 60 MHz • Capacitance = 0,001 nF to 60 mF • Temperature = -20 to +500°C • Display = 6,000 counts • CAT III & CAT IV • Protection Class = IP64 • Standard = EN 61326-1, EN 61010-2-033, DIN EN 61140 • Authorisation = CSA, CE • Basic Accuracy = 0.1% • Must have dial option for ease of operation • Measurement parameter detection and selection via the socket assignment • True RMS • Measurement of Diode & continuity testing should be possible with this Instrument • Carryings case, test leads & Battery must be provided with the Instrument • Weight must be less than 340g Note: With NABL Calibration certificate	All
11.	Cable-grab Clamp meter	• Voltage Range = 1 mV to 1000 V AC mV to 1000 V DC • Current Range = 0.01 to 600A AC/DC • µA measuring Range = 0.1 to 600 µA AC/DC • Resistance Range = 0.01 Ω to 60 MΩ • Frequency Range = 0.01 Hz to 9.999 kHz • Capacitance Range = 0.001 nF ... 60 mF • Temperature Measuring Range = -20 to +500 °C • Display = 6,000 counts • CAT III & CAT IV • Protection Class = IP64 • Measurement Category = CAT IV 600 V & CAT III 1000 V • Standard = EN 61326-1, EN 61140	All

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		• Approvals = CSA/ETL, CE • Accuracy = 0.1% • Dimension = 243 x 96 x 43 mm (L x W x H) • Must have Logging Option • Must have Onsite report generation & APP connectivity • Must be possible to measure Inrush Current • Must be possible to power factor • Must have retractable pincer arm easy to operate • Large two-line display • Must have Backlight • Carryings case, test leads & Battery must be provided with the Instrument • Must be possible to measure Micro & milli voltage measurement • True RMS Note: With NABL Calibration Certificate	
12.	Portable Infrared Thermometer	• IR Range = -30 to +400 °C • Contact type Measurement = -50 to +500 °C • Accuracy for Infrared = ±1.5 °C or ±1.5% of m.v. (+0.1 to +400 °C) • Accuracy for Contact = ±0.5 °C +0.5% of m.v • Response time must be less than 0.5s • D:S = 12:1 • Must have alarm Facility • Must have contact & non-contact measurement in single Instrument • Must have max, min & Hold Function • Must have Dual Laser • Must be adjustable Emissivity • Spectral Range = 8 to 14 µm • Battery life mini = 13hrs in continuous operation • Weight = less than 200g Note: With NABL Calibration Certificate	1,5
13.	Humidity / Temperature Meter	**Relative Humidity Range -** • Measuring range 0 to 100 %RH • Accuracy ±1 digit 2.5 %RH (5 to 95 %RH) • Resolution 0.1 %RH • Protection – IP 20 **Temperature NTC -** • Measuring range -20 to +60 °C • Accuracy ±1 digit ±0.5 °C • Resolution 0.1 °C • Must have Onsite report generation & APP connectivity • Report generation facility • Battery life Mini – 100hrs • Must have printer option in Instrument • Carryings case &Battery must be provided	1,5

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		with the Instrument **Features** • Audible alarm sounds if a limit value is exceeded • Measure Temp, Humidity, dewpoint and wet bulb temperature • Timed and point mean value calculation Note : With NABL Certificate for Humidity	

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition withISBN
1.	Bioenergy: Principles and Applications	Yebo Li and Samir K. Khanal	Wiley-Blackwell, ISBN-10 : 9781118568316, ISBN-13 : 978-1118568316
2.	Introduction to Biomass Energy Conversions	Sergio Capareda	CRC Press Inc; 1st edition (9 July 2013) ISBN-10: 1466513330 ISBN-13: 978-1466513334
3.	CIGR Handbook of Agricultural Engineering Vol V Energy and Biomass Engineering	Osamu Kitani, Thomas Jungbluth, Robert M Peart, AbdellahRamdani	American Society of Agricultural Engineering, ISBN-10: 0929355970 ISBN-13: 978-0929355979
4.	Understanding Clean Energy and Fuels from Biomass	H S Mukunda	Wiley (1 January 2011) ISBN-10: 9788126529698 ISBN-13: 978-8126529698
5.	Biomass Combustion Science, Technology and Engineering	Lasse Rosendahl	Woodhead Publishing Ltd; Reprint edition (30 October 2018) ISBN-10: 0081015682 ISBN-13: 978-0081015681
6.	Biomass Energy Systems	Venkata Ramana P and Srinivas S. N	Tata Energy Research Institute, (January 1, 1997), ISBN-10: 8185419256 ISBN-13: 978-8185419251
7.	Biogas Systems: Principles and Applications	Mital K.M	New Age International publishers (P) Ltd. January 1996, ISBN-10: 8122409474 ISBN-13: 978-8122409475
8.	Biogas Technology	Nijaguna, B. T	New Age International publishers (P) Ltd, First Edition (1 January 2002) ISBN-10: 8122413803 ISBN-13: 978-8122413809
9.	Non-Conventional Energy Resources	Sobh Nath Singh	Pearson Education,1st edition (1 January 2014), ISBN-10: 9332526451 ISBN-13: 978-9332526457
10.	Biomass Gasification and Pyrolysis Practical Design and Theory	PrabirBasu	Elsevier Inc1st Edition - June 9, 2010 eBook ISBN: 9780080961620
11.	Compassionate Artificial Intelligence	Amit Ray	Inner Light Publishers ISBN-10 : 9382123466 ISBN-13 : 978-9382123460

b) Online Educational Resources (OER):

1) Ministry of New and Renewable Energy (MNRE) – https://mnre.gov.in/bio-energy/current-status
2) National Institute of Rural Development - Biogas Portal - https://nirdpr.org.in/nird_docs/sb/doc/Biogas%20Technology.pdf
3) International Renewable Energy Agency (IRENA) - https://www.irena.org/publications/2019/Jan/Solid-Biomass-Supply-for-Heat-and-Power
4) Bio-Energy Council of India - https://bioenergycouncilofindia.com/
5) AI for Earth by Microsoft – https://www.microsoft.com/en-us/ai/ai-for-earthhttp://cos-h.cc/education/
6) "Biomass to Biofuel" by IIT Kharagpur on NPTEL - https://onlinecourses.nptel.ac.in/noc25_ch92/preview
7) Engineering Aspects of Biofuels and Biomass Conversion Technologies,By Prof. Ejaz Ahmad,IIT(ISM) Dhanbad - https://onlinecourses.nptel.ac.in/noc25_ch92/preview
8) Waste to Energy ConversionBy Prof. P. Mondal , IIT Roorkee - https://onlinecourses.nptel.ac.in/noc25_ch46/preview
9) MOOC course on “Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems”, By Prof. R. Anandalakshmi, Prof. Vaibhav Vasant Goud, IIT Guwahati- https://onlinecourses.nptel.ac.in/noc21_ch11/preview
10) "Ethics of AI" by University of Helsinki - https://ethics-of-ai.mooc.fi/

Q) Course Curriculum Development Team

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A)	**Course Title:** Hydrogen Generation Technologies	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH03	
C)	**Pre- Requisite Course (S):** Renewable Energy Technologies, MATLAB, Basic Electrical Engineering	

D) **Rationale:** This course will cover all aspects of hydrogen generation by utilization of fossil fuels (grey and blue hydrogen) and renewable energy sources (green hydrogen). Beyond production, the entire hydrogen energy value chain including storage, distribution, and household/industrial applications is covered. Safety issues associated with hydrogen use will be addressed alongside environmental and social impacts. Artificial intelligence is integrated throughout the curriculum as it plays an increasingly critical role in optimizing hydrogen production processes, predictive maintenance of electrolyzers, real-time monitoring of hydrogen infrastructure, and development of novel catalysts through machine learning. Students will gain hands-on experience with AI tools that are transforming efficiency, safety, and cost-effectiveness across the hydrogen economy. The course will conduct technical and economic comparisons of different production methods, providing comprehensive knowledge of hydrogen as an energy carrier. Students will understand hydrogen's critical role in various sectors for decarbonization, current limitations, and future scenarios.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry-expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH03.CO1	Analyze various hydrogen generation methods and their role in sustainable energy systems.
GTECH03.CO2	Evaluate renewable energy generation and storage systems.
GTECH03.CO3	Evaluate hydrogen production technologies incorporating recent advances including AI applications.
GTECH03.CO4	Assess various hydrogen storage and distribution techniques.
GTECH03.CO5	Evaluate hydrogen-fuel cell performances

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH03.CO1	2	2	2	2
GTECH03.CO2	3	2	2	2
GTECH03.CO3	3	3	3	3
GTECH03.CO4	2	3	3	3
GTECH03.CO5	3	2	3	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH03	PCC	Hydrogen Generation Technologies	45	15	45	15	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Analyze conventional energy generation sources *TSO 1b.* Evaluate the environmental, social and economic impacts of fossil fuel. *TSO 1c.* Describe the concept of Net zero and carbon neutrality *TSO 1d.* Critique the properties of hydrogen which make it suitable to be used as a fuel. *TSO 1e.* Compare the types of energy sources. *TSO 1f.* Describe Grey, blue and green hydrogen *TSO 1g.* Explain the architecture of hydrogen production systems	**Unit 1:.0 Hydrogen Generation** 1.1 Types of sources of energy: fossil fuels (hydrocarbons) and renewable energy sources 1.2 Conventional Energy generation: Fossil Fuel – Coal, Petroleum and Natural Gas 1.3 Impact of hydrocarbon-based energy production: environmental, social and economic 1.4 Greenhouse gases 1.5 Concepts of carbon neutral/ net zero 1.6 Hydrogen production: need of the hour 1.7 Properties of hydrogen 1.8 Electrolysis of water to produce H2 and O2 gases. 1.9 Molar Volume of hydrogen gas. 1.10 Grey, blue and green hydrogen 1.11 Components of a hydrogen production system.	**CO1**
TSO 2a. Explain the operating principles of solar photovoltaic (PV), wind turbines, and hydroelectric power systems. *TSO 2b.* Compare the efficiencies, characteristics, and deployment scales of solar, wind, and hydro technologies. *TSO 2c.* Assess the long-term environmental and socioeconomic implications of renewable energy technologies *TSO 2d.* Classify various energy storage technologies *TSO 2e.* Explain the working principles, advantages, and limitations of different storage systems. *TSO 2f.* Discuss the role of storage in stabilizing variable renewable energy sources. *TSO 2g.* Describe AI-based strategies for forecasting performance in energy generation systems	**Unit 2.0: Energy Generation and Storage Systems** 2.1 Renewable Energy Technologies: Solar photovoltaics, wind, hydroelectric, hybrid systems 2.2 Raw materials, components and concepts of each system 2.3 Environmental, social, and economic impacts of using renewable energy 2.4 Energy Storage systems 2.5 Energy Storage systems in different energy generation systems 2.6 AI-based strategies for forecasting performance in energy generation systems	**CO2**
TSO 3a. Analyze the principles of hydrogen production via steam-methane reforming and partial oxidation. *TSO 3b.* Evaluate methanol reforming processes for hydrogen generation. *TSO 3c.* Assess the potential and limitations of biomass-based hydrogen production. *TSO 3d.* Analyses of Hydrogen Production from	**Unit 3.0: Hydrogen Production Technologies** 3.1 From natural gas: steam-methane reformation and partial oxidation 3.2 Methanol 3.3 Biomass 3.4 Steam splitting, 3.5 Electrolysis: electrode based and PEM	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
Solar-assisted Electrolysis *TSO 3e.* Compare electrode-based and PEM electrolysis *TSO 3f.* Describe AI-driven techniques for process monitoring of various hydrogen production methods.	3.6 Hydrogen Generation from Electrolysis: Alkaline Electrolyzer 3.7 Hydrogen Production from Solar-assisted Electrolysis 3.8 Environmental Impact of Different Hydrogen Production Techniques 3.9 AI-driven techniques for process monitoring of various hydrogen production methods.	
TSO 4a. Describe the importance of Storage and distribution techniques for hydrogen *TSO 4b.* Analyze the principles governing gaseous, liquid, and solid-state hydrogen storage systems. *TSO 4c.* Analyse the techno-economic trade-offs between different hydrogen storage methods. *TSO 4d.* Describe simulation-based risk management protocols for hydrogen distribution networks by leveraging AI.	**Unit 4.0: Storage and Distribution Techniques** 4.1 Storage and distribution techniques for hydrogen 4.2 Gaseous storage (compressed tanks, underground storage), 4.3 Liquid storage (combining hydrogen with other chemicals like CO2 sequestration), 4.4 Solid-state storage (absorbers), 4.5 Risks associated with the use of hydrogen (at generation, storage and distribution stage) 4.6 Risk management protocols for hydrogen distribution networks by leveraging AI.	**CO4**
TSO 5a. Analyze the suitability of hydrogen technologies for household energy applications. *TSO 5b.* Describe the effectiveness of industrial-scale hydrogen applications. *TSO 5c.* Assess the major limitations hindering large-scale hydrogen deployment. *TSO 5d.* Compare various hydrogen production technologies. *TSO 5e.* Analyze performance parameters of a hydrogen fuel cell system	**Unit 5.0: Applications of Hydrogen as an Energy Carrier** 5.1 Applications of hydrogen at household level (HHO/oxyhydrogen oven for cooking, home heating, regenerative fuel cell for lighting) 5.2 At industrial level (fuel cell for cars/large trucks, manufacture of ammonia), 5.3 Current limitations for application of hydrogen generation at a large scale (at generation/storage stages) 5.4 Economical comparison between different hydrogen production methods. 5.5 Performance parameters of a hydrogen fuel cell system	**CO5**

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1 Analyze the electrochemical principles behind alkaline electrolysis.	1.	Performance assessment (Specific Energy Consumption (SEC), Hydrogen Production	CO1, & CO3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.2 Measure the key parameters such as voltage, current, and hydrogen production rate. *LSO 1.3* Evaluate the performance of an alkaline electrolyzer.		Rate & Electrolyzer Efficiency) of Hydrogen Generation from electrolysis using Alkaline Electrolyzer	
LSO 2.1 Analyze the electrochemical principles of PEM electrolysis. *LSO 2.2* Measure the key parameters such as voltage, current, efficiency, and hydrogen production rate. *LSO 2.3* Evaluate the performance of a PEM electrolyzerfrom key parameters	2.	Performance assessment of (Specific Energy Consumption (SEC), Hydrogen Production Rate & Electrolyzer Efficiency) of hydrogen production using Proton Exchange Membrane (PEM) Electrolyzer	CO1& CO3
LSO 3.1 Analyze the relationship between the volume of hydrogen gas and the number of moles. *LSO 3.2* Apply the concepts of gas laws to calculate the molar volume of hydrogen gas. *LSO 3.3* Evaluate the molar volume of hydrogen gas.	3.	Determination of Molar Volume of hydrogen gas.	CO1 &CO3
LSO 4.1 Analyze the working principles of integrating photovoltaic (PV) systems with electrolysis units. *LSO 4.2* Create a dynamic simulation model (e.g., using MATLAB/Simulink) to replicate the behavior of a solar-powered electrolysis system. *LSO 4.3* Assess electrical parameters from the PV system and link them to the performance of the electrolyzer.	4.	Development of simulation modelof the solar-assisted electrolysis system and assess the performance compare it with real time results	CO1 &CO3
LSO 5.1. Analyze the operational principles of hydrogen fuel cells. *LSO 5.2.* Evaluate the efficiency and power output of a hydrogen fuel cell system under various load conditions.	5.	Evaluate the performance (Fuel Cell Efficiency (%), Specific Power Output, Hydrogen Utilization (%))of a hydrogen fuel cell system.	CO5
LSO 6.1 Analyze the working principles of solid-state hydrogen storage. *LSO 6.2* Evaluate the hydrogen storage capacity, kinetics of solid-state storage materials through under controlled pressure and temperature conditions.	6.	Evaluate the performance of Solid-State Hydrogen Storage Systems: (Gravimetric Capacity – wt% H_2 stored, Volumetric Capacity – kg H_2/m^3, Absorption/Desorption Kinetics)	CO4
LSO 7.1 Analyze the principles underlying biomass gasification *LSO 7.2* Evaluate the performance parameters of hydrogen production from Biomass	7.	Performance assessment (Hydrogen Yield, Gas Composition, Cold Gas Efficiency (CGE), Carbon Conversion Efficiency (CCE), Specific Energy Consumption (SEC)) of Hydrogen Production from Biomass: Gasification Process	CO1 &CO3
LSO 8.1 Analyze the catalytic steam reforming reaction of methanol for hydrogen production *LSO 8.2* Evaluate the performance parameters	8.	Performance assessment (Hydrogen Yield, Gas Composition, Cold Gas Efficiency (CGE), Specific Energy Consumption (SEC) etc. of Hydrogen Generation via Methanol	CO1 & CO3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
(Hydrogen Yield, Gas Composition, Cold Gas Efficiency (CGE), Specific Energy Consumption (SEC) etc. of Hydrogen Generation via Methanol Reforming		Reforming	
LSO 9.1 Simulate the voltage-current (V-I) and power-voltage (P-V) characteristics of a Proton Exchange Membrane Fuel Cell (PEMFC) under varying loads. *LSO 9.2* Evaluate polarization	9.	Simulation of PEM Fuel Cell and evaluate the characteristics and performance parameters	CO5
LSO 10.1 Model a PEM fuel cell connected to a DC bus. *LSO 10.2* Simulate power sharing between the battery and fuel cell. *LSO 10.3* Evaluate SoC behavior and fuel utilization rate.	10.	Modeling of a Hybrid Energy System: Hydrogen Fuel Cell + Battery and Evaluate SoC behavior and fuel utilization rate.	CO5

K) Suggested Research Based Problems:

i. Integrate machine learning with thermodynamic and electrochemical models to optimize efficiency, cost, and environmental impact.

ii. Analyze the techno-economic, environmental, and social aspects of implementing green hydrogen technologies in various Indian regions.

iii. Create a real-time simulation platform to monitor, control, and predict performance of hydrogen systems.

iv. Synthesize and test novel non-platinum group catalysts (e.g., transition metal oxides or graphene composites).

v. Explore biological or thermochemical methods for converting organic matter to hydrogen.

vi. Investigate novel nanomaterials for safe, compact, and reversible hydrogen storage.

vii. Evaluate the infrastructure needs, cost modeling, and policy support required for hydrogen fueling stations.

viii. Model hybrid energy systems combining PV/wind with hydrogen production and storage to power isolated grids.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Prepare a detailed report comparing efficiency, cost, CO_2 emissions, scalability, and AI potential in each method.
- Create a conceptual design (with a block diagram and basic calculations) for a solar-wind-hydrogen hybrid microgrid for a rural community.
- Write a critical summary of the National Green Hydrogen Mission and propose policy amendments for rural hydrogen adoption.
- Research and prepare a presentation/report on at least two AI-based case studies in hydrogen energy (e.g., electrolyzer optimization, fuel cell diagnostics).
- Draft a risk mitigation plan including risk identification, classification, and control measures with a sample safety checklist.

b. Seminar Topics:

- Present how AI/ML can be utilized to optimize various stages of hydrogen production (electrolysis, reforming) and storage (e.g., material science for storage).
- Evaluate the feasibility and scalability of integrating renewable energy sources (solar, wind) with hydrogen production via electrolysis.
- Explore the challenges and economic aspects of building a hydrogen refueling infrastructure for hydrogen-powered vehicles.
- Provide a comparative LCA of hydrogen production methods, focusing on environmental and economic impacts, including the assessment of carbon footprint.
- Investigate how hydrogen can address the seasonal storage challenges of renewable energy systems, including long-duration storage and grid balancing.
- Analyze the role of governmental and global policies in fostering the hydrogen economy, including subsidies, incentives, and regulatory challenges.
- Discuss the current and future applications of hydrogen fuel cells in industrial sectors, including transportation (e.g., trucks, buses), heavy industry, and backup power systems.

c. Self-Learning:

- Use software tools like HOMER, MATLAB Simulink, or Aspen Plus to model hydrogen production processes (e.g., electrolysis, reforming) and optimize system design.
- Coursera, edX, or MIT OpenCourseWare.
- Critically analyze recent research papers on topics such as green hydrogen production, AI applications in hydrogen systems, fuel cell technology, and hydrogen storage.
- Set up a small-scale experiment at home to produce hydrogen via electrolysis of water. Alternatively, use virtual labs to explore experimental setups.
- Visit to a nearby institution/ industry where a working hydrogen generation plant is operational.

d. Suggested Problems/Micro Projects: Problems/Micro projects may be designed for the attainment of identified COs/combination of COs

- Optimize the efficiency of hydrogen generation through water electrolysis using AI algorithms.
- Conduct a life cycle assessment (LCA) of at least three hydrogen production methods (e.g., SMR, electrolysis, biomass).
- Design a compact HHO-based hydrogen cooker and simulate its thermal efficiency.
- Design a lab-scale solar-assisted PEM electrolyzer for sustainable hydrogen production.
- Develop a checklist/toolkit for evaluating safety hazards in hydrogen storage facilities.
- Compare the cost, ROI, and scalability of green (renewable) hydrogen vs. grey hydrogen.
- Apply sensor data to predict faults in a hydrogen fuel cell using ML algorithms.
- Propose a modular setup using biomass or solar-based hydrogen production for remote villages.
- Develop a model using experimental/simulated data to predict H_2 yield from methanol under different conditions.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1:.0 Hydrogen Generation	10
CO2	Unit 2.0: Energy Generation and Storage Systems	10
CO3	Unit 3.0: Hydrogen Production Technologies	20
CO4	Unit 4.0: Storage and Distribution Techniques	20
CO5	Unit 5.0: Applications of Hydrogen as an Energy Carrier	10
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number	Remarks
1.	Alkaline Electrolyzer Setup	Electrolyzer cell stack, KOH electrolyte tank, DC power supply (0–60V), flow meter, safety valves, pressure sensor	1	Standard lab-scale alkaline electrolyzer
2.	PEM Electrolyzer System	PEM cell stack, DI water feed, DC power supply (adjustable up to 60V), humidifier, temperature/pressure controls	2	Lab-grade PEM setup
3.	Gas Collection Apparatus	Graduated cylinder/burette, water trough, sealed gas delivery tubing	3	For molar volume measurement
4.	Basic Electrolysis Kit	Transparent water electrolysis cell, platinum/graphite electrodes, gas collection tubes, 0–30V DC power supply	4	For H_2 and O_2 generation
5.	Solar PV Panel with Electrolyzer Interface	50–100W solar panel, DC-DC converter, solar charge controller, integrated electrolysis cell	5	For renewable hydrogen production
6.	Hydrogen Fuel Cell Test System	PEM fuel cell (10–100W), hydrogen input, voltage/current sensors, DC load bank, digital display	6	Includes stack, load, and control
7.	Solid-State Hydrogen Storage Unit	Metal hydride storage container, temperature sensor, pressure gauge, hydrogen supply interface	7	For adsorption /desorption performance study
8.	Biomass Gasifier Reactor	Bench-scale downdraft or fluidized-bed reactor, biomass feeder, thermocouples, gas sampling ports, gas analyzer	8	For hydrogen-rich syngas production
9.	Methanol Reforming Setup	Catalyst reformer unit, methanol tank, electric heater, thermocouples, gas analyzer (H_2, CO_2, CO detection), condensate separator	9	Safety interlocks included

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	The Hydrogen Revolution: a blueprint for the future of clean energy	Marco Alverà	Hodder Studio, 18 August 2022, ISBN-10: 1529360315 ISBN-13: 978-1529360318
2.	Hydrogen: A renewable energy perspective	International Renewable Energy Agency (IRENA)	IRENA, 9 January 2020, e-book
3.	A Solar-Hydrogen Economy: Driving the Green Hydrogen Industrial Revolution (Strategies for Sustainable Development Series)	John Mathews	Anthem Press, 15 November 2022 ISBN-10: 1839986425, ISBN-13: 978-1839986420
4.	Hydrogen Technology: Mobile and Portable Applications (Green Energy	Aline Léon	Springer-verlag, 21 July 2008 ISBN-10: 9783540790273

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
	and Technology)		ISBN-13: 978-3540790273
5.	Green hydrogen cost reduction: Scaling up renewables to meet the 1.5C climate goal	International Renewable Energy Agency (IRENA)	IRENA, 13 September 2023 e-book

b) Online Educational Resources (OER):

1) À NPTEL: Energy Resources and Technology
2) MIT OCW: Electrochemical Energy Systems
3) Coursera: Hydrogen Economy (EIT InnoEnergy)
4) edX: Solar Energy (TU Delft)
5) NPTEL: Fuel Cell Technology
6) Fuel Cell Store Tutorials (fuelcellstore.com)
7) YouTube: NPTEL videos on Biomass Gasification
8) Ministry of New and Renewable Energy (MNRE) - https://mnre.gov.in/bio-energy/current-status
9) National Institute of Rural Development - Biogas Portal – https://nirdpr.org.in/nird_docs/sb/doc/Biogas%20Technology.pdf
10) International Renewable Energy Agency (IRENA) - https://www.irena.org/publications/2019/Jan/Solid- Biomass-Supply-for-Heat-and-Power
11) Bio-Energy Council of India - https://bioenergycouncilofindia.com/
12) AI for Earth by Microsoft - https://www.microsoft.com/en-us/ai/ai-for-earth http://cos-h.cc/education/
13) "Biomass to Biofuel" by IIT Kharagpur on NPTEL - https://onlinecourses.nptel.ac.in/noc25_ch92/preview
14) Engineering Aspects of Biofuels and Biomass Conversion Technologies, By Prof. Ejaz Ahmad, IIT(ISM) Dhanbad - https://onlinecourses.nptel.ac.in/noc25_ch92/preview
15) Waste to Energy ConversionBy Prof. P. Mondal, IIT Roorkee - https://onlinecourses.nptel.ac.in/noc25_ch46/preview
16) MOOC course on “Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems”, By Prof. R. Anandalakshmi, Prof. Vaibhav Vasant Goud, IIT Guwahati- https://onlinecourses.nptel.ac.in/noc21_ch11/preview
17) "Ethics of AI" by University of Helsinki - https://ethics-of-ai.mooc.fi/

Q) Course Curriculum Developer

S. No.	Name	E-mail Address
1.	Prof. Pallavee Bhatnagar	pbhatnagar@nitttrbpl.ac.in

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A)	**Course Title:** Soft Computing	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH04	
C)	**Pre- Requisite Course (S):** Basics of Set Theory	

D) Rationale: Soft computing is an alternative computing methodology based on a consortium of Neural Network, and Fuzzy Logic. It offers the superiority of humanlike problem solving in Al-oriented applications where a fast-approximate solution to a vaguely formulated problem is the prime concern. The case study of a machine vision problem amply demonstrates the power of soft computing in perceptual tasks. As the knowledge-based approach used by traditional AI approaches saturation, Al-oriented problem solving will increasingly rely on soft computing. The course provides the perceptual and Al-oriented tasks in a heterogeneous distributed environment, while numeric intensive tasks.

E) Course Outcomes (COs): After the completion of the course, teachers are expected to ensure the accomplishment of following industry-expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH04.CO1	Explain the concepts of Fuzzy logic, neural networks, and their importance in control systems
GTECH04.CO2	Select suitable membership functions of Fuzzy logic controllers and learning schemes of neural network
GTECH04.CO3	Identify an appropriate control law of a fuzzy logic controller for a given application
GTECH04.CO4	Develop an artificial neural network for a given application
GTECH04.CO5	Develop hybrid fuzzy neural controller for a given application

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH04.CO1	3	2	3	2
GTECH04.CO2	3	2	3	3
GTECH04.CO3	3	2	3	3
GTECH04.CO4	3	2	3	3
GTECH04.CO5	3	2	3	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH04	PCC	Soft Computing	45	15	-	30	90	03	30	70	20	-	-	-	120

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the concept of Fuzzy Sets and Related concepts *TSO 1b.* Identify suitable membership function *TSO 1c.* Develop rule base *TSO 1d.* Design the structure of fuzzy model using Mamdani Fuzzy Systems *TSO 1e.* Compare Mamdani Fuzzy Systems with Takagi- Sugeno Fuzzy Systems	**Unit-1.0 Fuzzy Sets and Fuzzy Systems** 1.1 Introduction; Fuzzy Sets and Related concepts 1.2 Membership function 1.3 Fuzzy Relations and Fuzzy If- then rules 1.4 Fuzzy Reasoning Challenges 1.5 Fuzzy Model and Fuzzy Systems: Mamdani Fuzzy Systems 1.6 Takagi- Sugeno Fuzzy Systems	**CO1**
TSO 2a. Construct fuzzylogic controller *TSO 2b.* Evaluate fuzzy rules for a given application *TSO 2c.* Develop fuzzy model using Mamdani Type *TSO 2d.* Develop fuzzy model using Takagi-Sugeno Model *TSO 2e.* Evaluate time response, steady state error and stability of the fuzzy logic controllers	**Unit-2.0 Introduction to Fuzzy Logic Control** 2.1 Structure of fuzzy logic control 2.2 Generating fuzzy rules 2.3 Mamdani Type fuzzy logic controller 2.4 Takagi- Sugeno Model Based fuzzy logic control 2.5 Time response 2.6 Steady state error and stability of the fuzzy logic controller	**CO2**
TSO 3a. Explain the concept of neural networks *TSO 3b.* Explain Learning capability and Delta rule *TSO 3c.* Develop Back propagation algorithm *TSO 3d.* Construct a neural network using training and testing *TSO 3e.* Make use of trained neural network in applications *TSO 3f.* List the issues in practical training of neural network	**Unit-3.0 Introduction to Neural Networks** 3.1 Structure of artificial neurons 3.2 Learning capability and Delta rule 3.3 Back propagation algorithm 3.4 Training a neural network 3.5 Testing a neural network 3.6 Implementing neural networks 3.7 Practical issues in training	**CO1, CO3**
TSO 4a. Explain the concept of Neural Control *TSO 4b.* List the requirement of Neural Control *TSO 4c.* Explain the concept of Inverse dynamics *TSO 4d.* Apply neural network in Temperature Control applications *TSO 4e.* Identify T-S Fuzzy Modelling	**Unit-4.0 Design of Neural Control** 4.1 Neural Control 4.2 Requirement of Neural Control 4.3 Inverse dynamics 4.4 Neural networks in direct neural control Example: Temperature Control 4.5 T-S Fuzzy Modelling and Identification	**CO2, CO4**
TSO 5a. Explain Fuzzy concepts in neural networks *TSO 5b.* Explain Principles of fuzzy-neural systems and neural-fuzzy systems *TSO 5c.* Develop fuzzy rules for hybrid controller	**Unit 5.0: Hybrid Fuzzy-Neural Control** 5.1 Fuzzy concepts in neural networks 5.2 Principles of fuzzy-neural systems 5.3 Principles of neural-fuzzy systems	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 5d. Apply Fuzzy Logic Controller in a given system *TSO 5e.* Apply Neural Network Control in a given system *TSO 5f.* Apply Hybrid Fuzzy-Neural Controller in a given system	5.4 Generating fuzzy rules 5.5 Applications of Fuzzy Logic Controller 5.6 Applications of Neural Network Control 5.7 Applications of Hybrid Fuzzy-Neural Controller	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems:

i. Design a Fuzzy Logic Controller for a chosen application using simulation by performing the following:
ii. Select suitable membership function for the Fuzzy Logic Controller Justify the following:
    - Number of membership function
    - Type of membership function
    - Type of rule base chosen
iii. Fuzzy controllers are becoming alternative to the classical controllers as it enables the use of engineering expertise. Design a fuzzy controller and hybrid of fuzzy logic and conventional controller for the system chosen and compare the performances of the system with the designed controllers.
iv. In this context, prepare a project proposal to implement "Design fuzzy logic controller and hybrid controller for a chosen application using simulation". Proposal should address the following:
v. Choose a suitable fuzzification and defuzzification method and show its calculation
vi. Integrate the Fuzzy Controller, hybrid controller in the chosen system
vii. Compare and analyze the performance characteristics of the controllers
viii. Select better controller based on the performance
ix. A neural network controller can be used to maintain the water temperature at a desired set point despite fluctuations in water flow and input water temperature in a water heater system.
x. Components:
    - Sensor: Measures the current water temperature.
    - Actuator: Controls the heating element
xi. Develop simulation model of the following:
    - Identify suitable inputs and outputs for training the neural network
    - Design neural network controller for water heater system
xii. Perform the following with the developed simulation model:
    - Train the neural network controller for temperature control
    - Test the trained network

xiii. Analyze the performance of water heater system

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- Deep learning algorithm
- Fuzzy Logic in Artificial Intelligence

c. Self-Learning:

- Application of Fuzzy PID Control
- Application of Fuzzy Sliding Mode Control
- Application of Adaptive Fuzzy Control
- Industrial visit

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit -1.0 Fuzzy Sets and Fuzzy Systems	14
CO2	Unit -2.0 Introduction to Fuzzy Logic Control	14
CO3	Unit -3.0 Introduction to Neural Networks	14
CO4	Unit-4.0 Design of Neural Control	14
CO5	Unit -5.0: Hybrid Fuzzy-Neural Control	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Fuzzy System Engineering	Nadia Nedjah, Luiza de Macedo Mourelle	Springer, Year: 2010, ISBN: 9783642064609,3642064604
2.	Artificial intelligence and soft computing: behavioral and cognitive modeling of the human brain	Amit Konar	CRC Press, Year: 2000 ISBN: 9780849313851,0849313856
3.	Principles of Soft Computing	S. N. Sivanandam, S. N. Deepa	Wiley, 3rd edition, 2018
4.	Soft Computing in Green and Renewable Energy Systems	Kasthuri rangan Gopalakrishnan, Siddhartha Kumar Khaitan, SoterisKalogirou	Springer-Verlag Berlin and Heidelberg GmbH & Co. K, 2016 ISBN: 978-366252000

b) Online Educational Resources (OER):

1) URL:https://www.youtube.com/watch?v=rI7GRfhcQbkhttps://onlinecourses.nptel.ac.in/noc22_cs54/preview
2) URL:https://cse.iitkgp.ac.in/~dsamanta/courses/sca/index.html
3) URL:https://drmcet.digimat.in/nptel/courses/video/106105173/L01.html
4) URL:https://onlinecourses.nptel.ac.in/noc22_ee21/preview
5) URL:https://onlinecourses.nptel.ac.in/noc21_ge07/preview
6) URL:http://acl.digimat.in/nptel/courses/video/108104157/108104157.html
7) URL:https://archive.nptel.ac.in/noc/courses/noc21/SEM1/noc21-ee49/
8) URL:https://www.youtube.com/watch?v=8LdZMqcFEHs&list=PLYwpaL_SFmcCPUl8mAnb4g1oExKd0n4Gw
9) URL:https://www.youtube.com/watch?v=K9gjuXjJeEM&list=PLJ5C_6qdAvBFqAYS0P9INAogIMklG8E-9
10) URL:https://www.youtube.com/watch?v=Nn5YbbcuXdY&list=PLuAADu3OvBt5-e5yXuIqBi1pttqw3RBeg
11) URL:https://www.youtube.com/watch?v=Nn5YbbcuXdY&list=PLuAADu3OvBt5-e5yXuIqBi1pttqw3RBeg
12) URL:https://www.youtube.com/watch?v=MSw2XuhDnOw&list=PL4gu8xQu0_5JK6KmQi-Qx5hI3W13RJbDY
13) URL:https://www.youtube.com/watch?v=uULW7fOlP48&list=PL4pCSxxlsHoFE9ywcpd2iOI8lJ_zX8o9f
14) URL:https://www.youtube.com/watch?v=h4zkfgLKxPM&list=PLTwXRHDoo-A-lZIEmP2cI95YIU4P3nNbM

Q) Course Curriculum Developer

S. No.	Name	E-mail Address
1.	Prof. K. Manickavasagam	kmanickavasagam@nitttrbpl.ac.in

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A)	**Course Title:** Basics of Artificial Intelligence and Machine Learning	Deemed to be University under Distinct Category
B)	**Course Code:** CSEB05	
C)	**Pre- requisite (s):**	

D) **Rationale:** Artificial Intelligence and Machine Learning are no longer confined to computer science; they are transformative technologies impacting every engineering discipline. From optimizing civil infrastructure designs, predicting material failures in mechanical systems, enhancing power grid efficiency in electrical engineering, to developing intelligent control systems, AI/ML offers unparalleled tools for problem-solving, efficiency, and innovation.

Therefore, this course is important for all disciplines. This course will equip learners with foundational knowledge in data-driven decision-making, predictive analytics, and automation. Regardless of their specialization, the comprehension of AI/ML will enable them to leverage these technologies to create smarter products, optimize processes, interpret vast datasets, and remain competitive in a rapidly evolving AI-driven industrial landscape.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
CSEB05.CO1	Develop Python programs for solving mathematical problems.
CSEB05.CO2	Manipulate Sequence data types in Python
CSEB05.CO3	Analyse the data using Python Libraries, modules, and Packages
CSEB05.CO4	Apply various Machine learning paradigms.
CSEB05.CO5	Evaluate the performance of the prediction model after creating it.
CSEB05.CO6	Analyse data using various tools for AI & ML Applications.

F) Suggested Course Articulation Matrix (CAM): (To be prepared by the curriculum development committee of the respective programme)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		Total Marks (TA+TWA+LA)
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
CSEB05	PCC	Basics of Artificial Intelligence and Machine Learning	30	15	45	30	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Differentiate between Procedure-Oriented and Object-Oriented Programming approaches with examples. *TSO 1b.* Explain the concept of Lvalue and Rvalue *TSO 1c.* Write Python program using various data types and operators *TSO 1d.* Write Python program using decision-making statements. *TSO 1e.* Write Python Program using loop structure to solve iterative problems.	**Unit-1.0 Basics of Python Programming** 1.1 Procedure oriented vs. Object-Oriented approach of programming 1.2 Python character set, Python tokens, variables, concept of Lvalue and Rvalue, use of comments. 1.3 Data types: number (integer, floating point, complex), Boolean, sequence (string, list, tuple), none, mapping (dictionary), mutable and immutable data types 1.4 Operators: arithmetic operators, relational operators, logical operators, assignment operator, augmented assignment operators. Expressions, statements, type conversion &	**CO1**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
	input/output: precedence of operators, expressions, and evaluation of expressions. 1.5 Conditional statements: simple if statement, if-else statement, if-elif-else statement 1.6 Iterative statements: while loop, for loop, range function, break and continue statements, nested loops	
TSO 2a. Explain the procedure to perform the various operations on a string using string operators and methods. *TSO 2b.* Explain the procedure to perform various operations on a List using list operators and methods *TSO 2c.* Explain the procedure to perform various operations on tuples using tuple operators and methods *TSO 2d.* Explain the procedure to perform various operations on a set using set methods *TSO 2e.* Explain the procedure to perform various operations on a dictionary using dictionary methods. *TSO 2f.* Explain the procedure to create and use user-defined functions to implement a modular programming approach. *TSO 2g.* Explain the working of the scopes of variables.	**Unit 2.0: Sequence data types, Functions.** 2.1 String: indexing, string operations (concatenation, repetition, membership & slicing), traversing a string using loops, and built-in functions. 2.2 Lists: introduction, indexing, list operations: concatenation, repetition, membership & slicing, traversing a list, built-in list functions, linear search on a list of numbers, and counting the frequency of elements in a list 2.3 Tuples: Creating, initializing, accessing elements, tuple assignment, performing operations on tuples, tuple methods and built-in functions, nested tuples 2.4 Set: Creating sets, traversing, adding, removing data in a set, performing set operations like join, Union, intersection, difference 2.5 Dictionary: accessing items in a dictionary using keys, mutability of dictionary: adding a new item, modifying an existing item, built-in dictionary functions. 2.6 Functions: types of function (built-in functions, functions defined in module, user-defined functions), creating user user-defined function, arguments and parameters, default parameters, positional parameters, Lambda functions, returning value, scope of a variable: global scope, local scope	**CO2**
TSO 3a. Write simple Python programs with an object-oriented approach *TSO 3b.* Explain the workflow to use the constructors and destructors appropriately in a Python program *TSO 3c.* Write the program to implement the given	**Unit-3.0 OOPS, Data Analysis using Modules and Packages** 3.1 Object-oriented programming concepts and approach, Abstraction, encapsulation, class,	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
type of inheritance in Python. *TSO 3d.* Explain the procedure to implement the concept of Polymorphism in Python *TSO 3e.* Write Python programs for exception handling in Python *TSO 3f.* Differentiate between different modes of file opening. *TSO 3g.* Explain the procedure to perform read, write, and Append operations in files *TSO 3h.* Explain the procedure to import and use Python modules, libraries, and Packages. *TSO 3i.* Write the procedure to apply the Pandas data structure for data analysis *TSO 3j.* Illustrate the process of using Pandas to perform various operations and functions on series. *TSO 3k.* Explain the procedure to perform the various operations in a Data Frame's columns and rows *TSO 3l.* Write a program to read and write on CSV, XLS, and Text data files *TSO 3m.* Write the procedure to use the various data cleaning operations and prepare data.	object, class method vs static method in Python, class and static variable, constructor and destructors in Python. 3.2 Inheritance: single, multiple, multilevel, hierarchical inheritances 3.3 Polymorphism: Polymorphism with class method, polymorphism with inheritance, method overriding, and overloading. 3.4 Exception Handling: syntax errors, exceptions, need for exception handling, user-defined exceptions, raising exceptions, handling exceptions, catching exceptions, Try - except - else clause, Try - finally clause, recovering and continuing with finally, built-in exception classes. 3.5 File Handling: text file and binary file, file types, open and close files, reading and writing text files, reading and writing binary files, file access modes 3.6 Modules and Packages: Importing modules using 'import', Regular Expressions, Exception Handling, PyPI Python Package Index, Pip Python package manager, Importing Libraries and Functions 3.7 Key features and methods for summarizing data in Python, Aggregation and Grouping, data visualization. 3.8 Pandas data structures: Series, Declaration, selecting elements, assigning values, Filtering values, operations, mathematical functions, evaluating values, handling missing data, creating series from dictionaries, adding two series. 3.9 Data Frame: Defining, selecting elements, assigning values, membership, deleting a column, and filtering. Index Objects: Indexing, Re-indexing, Dropping, sorting and ranking, Descriptive Statistics 3.10 Data Loading: Reading and Writing CSV, xls, Text Data Files, Data Cleaning and Preparation: Handling missing data, removing duplicates, replacing values, Vectorized String Methods, Hierarchical Indexing, Merging and Combining, Data aggregation and Grouping.	
TSO 4a. Explain the concept of Artificial Intelligence.	**Unit-4.0 Introduction to AI & ML**	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 4b. Differentiate the various learning paradigms. *TSO 4c.* Explain the use of a suitable machine learning algorithm for the given application. *TSO 4d.* Explain the procedure for validating the machine learning algorithm.	4.1 Overview of AI: Agents, Natural Language Processing & Decision Network 4.2 Learning Paradigms: Supervised, Unsupervised and Reinforcement Learning. 4.3 ML Algorithms: Supervised Learning Algorithms: Linear Regression, Logistic Regression, Random Forest, k-NN, Decision Tree, SVM, ANN, 4.4 Unsupervised Learning Algorithms: k-Means clustering and k-Mode Clustering 4.5 Reinforcement Learning Algorithm: Q-Learning.	
TSO 5a. Explain the process of exploring the various datasets to identify their characteristics and patterns. *TSO 5b.* Perform the feature scaling for the given dataset. *TSO 5c.* Perform the feature selection process on the given dataset. *TSO 5d.* Explain the procedure to create a model using data preprocessing and classification. *TSO 5e.* Explain the procedure to create multidisciplinary applications.	**Unit-5.0 Model Creation using Python** 5.1 Datasets: Kaggle, UCI Machine Learning Repository 5.2 Data Pre-processing: Feature Scaling and Feature Selection 5.3 Model creation using data pre-processing, Classification through ML algorithms using Python programming. 5.4 Creation of Multidisciplinary Applications	**CO5**
TSO 6a. Explain the role of AI and ML algorithms in decision-making on various applications. *TSO 6b.* Explain the features of the Weka Tool *TSO 6c.* Explain the features of the Orange3 Tool *TSO 6d.* Explain the features of Julia Tool *TSO 6e.* Differentiate the features of Weka, Orange3, and Julia. *TSO 6f.* Perform data preprocessing using Weka, Orange3, and Julia AI. *TSO 6g.* Explain the process of using classifiers for classification in Weka, Orange3, and Julia AI. *TSO 6h.* Use clustering methods for grouping the given data in Weka, Orange3, and Julia AI.	**Unit 6.0: Applications of AI & ML and Data Analysis Tools** 6.1 Role of AI & ML in Multidisciplinary, Applications 6.2 Introduction to Weka, Orange3, and Julius AI 6.3 Data pre-processing: Data cleaning, Removal of Stop words, Removal of Null values using Tools such as Weka, Orange3, and Julius AI 6.4 Data Visualization: Bar Chart, Pie Chart, Line Chart, Plot, etc. in Weka, Orange3, and Julius AI. 6.5 Classification through Weka, Orange3, and Julius AI 6.6 Regression through Weka, Orange3, and Julius AI 6.7 Clustering Process using Weka, Orange3, and Julius AI	**CO6**

J) Suggested Laboratory experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1. Implement conditional statements in Python.	1.	Write Python programs to demonstrate the use of the following conditional statements: a. If statements b. If-else statements, if-elif-else statements	CO1
LSO 2.1. Implement Loop statements in Python to solve iterative problems.	2.	Write Python programs to demonstrate the use of the following loop statements: a) While loop b) for loop c) Use of range function, break, continue	CO1
LSO 3.1. Manipulate given Sequence data types in Python	3.	Write and execute Python Programs to demonstrate various operations on the following sequence data types: a) String b) List	CO2
		Write and execute Python Programs to demonstrate various operations on the following sequence data types: a) Tuple b) Set, c) Dictionary	CO2
LSO 5.1. Create user-defined functions in Python	4.	Write and execute Python Programs to demonstrate creating and calling User-defined functions	CO2
LSO 5.3 Use NumPy and Pandas built-in functions	5.	Consider a dataset, and execute the following functions to analyze the dataset. a) Read, head, tail & arithmetic functions b) Loc (Location), iloc (Integer Location) c) Sort, Numpy with Arrays.	CO3
LSO 6.1 Use Python modules.	6.	Conduct a statistical learning process using the Chi-Square test by considering the parametric and Non-parametric tests.	CO3
LSO 7.1. Visualize the given data in various dimensions. *LSO 7.2.* Summarize the data according to the dataset's features.	7.	c) Demonstrate the data visualization of the given data. d) Summarize the data with respect to the different attributes of the given salary dataset.	CO3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 8.3 Apply Linear Regression and Multiple Linear Regression for predictive analysis. *LSO 8.4* Evaluate the Linear and Multiple Linear Regression models with respect to the standard evaluation metrics.	8.	c) Perform the predictive analysis using Multiple Linear Regression. d) Perform the predictive analysis using Linear Regression. e) Compare the performance of the Multiple Linear Regression and Linear Regression with respect to the prediction accuracy and time.	CO4
LSO 9.3 Implement the resampling process and feature selection using Python. *LSO 9.4* Apply the k-nearest neighbor classifier to perform the predictive analysis. *LSO 9.5* Evaluate the k-nearest neighbour with respect to the evaluation metrics.	9.	a) Perform the resampling process and feature selection using a suitable ML classifier. b) Perform the predictive analysis using k-Nearest Neighbor by considering the dataset with selected features. c) Evaluate the k-nearest neighbour classifier with respect to the standard evaluation metrics like precision, recall, f-measure and accuracy.	CO3, CO4
LSO 10.1. Solve the MCNFP problem for the optimal solution using Python. *LSO 10.2.* Evaluate the efficiency of the MCNFP in the process of optimization.	10.	Implement the Minimum Cost Network Flow Problem (MCNFP) method to find the new path in a transportation network.	CO3, CO4
LSO 11.1. Implement the stochastic decision tree to predict the risk. *LSO 11.2.* Evaluate the performance of the stochastic decision tree by using the evaluation metrics.	11.	Implement the stochastic decision tree algorithm to analyze the risk. (Prefer your own dataset)	CO3, CO4
LSO 12.1. Predict the future result by analyzing the given data using the Random Forest algorithm. *LSO 12.2.* Evaluate the performance of the classifier with respect to the standard evaluation metrics.	12.	a. Execute the source code of the random forest algorithm implementation for predicting diabetic and heart diseases b. Compare the performance of the random forest with k-nearest neighbor by considering the standard evaluation metrics.	CO3, CO4
LSO 13.1 Predict the future result by analyzing an image dataset using the SVM algorithm. *LSO 13.2* Evaluate the performance of the classifier with	13.	a) Implement the support Vector Machine (SVM) algorithm for image classification/ semantic segmentation (choose any dataset) b) Evaluate the algorithm's performance with	CO3, CO4

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
respect to the standard evaluation metrics. *LSO 13.3* Compare the performance of the SVM with MLP with respect to the standard evaluation metrics.		respect to the standard classifiers. c) Compare the performance of the SVM with the Multi-layer perceptron (MLP) by considering the standard evaluation metrics.	
LSO 14.1 Visualize the given dataset using the Weka Tool. *LSO 14.2* Visualize the given dataset using the Orange3 Tool. *LSO 14.3* Visualize the given dataset using the Julia AI tool.	14.	a) Perform the data visualization using the Weka Tool. b) Perform the data visualization using the Orange3 Tool. c) Perform the data visualization using the Julia AI tool.	CO5, CO6
LSO 15.1 Preprocess the given dataset using the Weka Tool. *LSO 15.2* Preprocess the given dataset using the Orange3 Tool. *LSO 15.3* Preprocess the given dataset using the Julia AI tool.	15.	a. Perform the data preprocessing on the given dataset using the Weka Tool. b. Perform the data preprocessing on the given dataset using the Orange3 Tool. c. Perform the data preprocessing on the given dataset using the Julia AI tool.	CO5, CO6
LSO 16.1 Classify the given dataset using the Weka Tool. *LSO 16.2* Classify the given dataset using the Orange3 Tool. *LSO 16.3* Classify the given dataset using the Julia AI tool.	16.	a) Perform the classification process on the given dataset using the Weka Tool. b) Perform the classification process using the Orange3 Tool. c) Perform the classification process using the Julia AI tool	CO5, CO6

K) Suggested Research Based Problems

i. Demonstrate the performance of the Multilayer Perceptron and Artificial Neural Network over a seizer dataset with respect to the detection accuracy and time.

ii. Develop a product recommendation system using a stochastic decision tree algorithm by analyzing a sales dataset. Further, the system needs to recommend the product requirement for the specific year and the required quantity to fulfill the customer needs with satisfaction.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- Python Libraries and Packages used in data analytics
- Comparison of various Data Visualization tools
- Role of predictive analysis in real-time applications
- ML algorithms in Decision Making
- ML algorithms in feature engineering
- Weka Vs Orange3 Vs Julia AI
- Role of AI and ML in Multidisciplinary Research

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1.0 Basics of Python Programming	10
CO2	Unit 2.0 Sequence data types, Functions.	10
CO3	Unit 3.0 OOPS, Data Analysis using Modules and Packages	10
CO4	Unit 4.0 Introduction to AI & ML	15
CO5	Unit 5.0 Model Creation using Python	15
CO6	Unit 6.0 Applications of AI & ML and Data Analysis Tools	10
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies: Different instructional/implementation strategies may be appropriately used in online and offline modes, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	Computer system	Processor Intel Core i7, 32 GB RAM, 15 GB free disk space	All
2.	Integrated Development and Learning Environment (IDLE)	S/w to be downloaded for Python 3.11.3 or higher	1-13
3.	Anaconda Navigator / Jupyter NoteBook	Server for Software Platform	1-13
4.	Weka	Software Tool	14,15 & 16
5.	Orange3	Software Tool	14,15 & 16
6.	Julia AI	Software Tool	14,15 & 16

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Python for Programmers	Paul Deitel and Harvey Deitel	Pearson Education, 1st Edition, 2021 ISBN-10 : 9353947987 ISBN-13 : 978-9353947989
2.	Artificial Intelligence – A Modern Approach	Stuart Russell and Peter Norvig	Fourth Edition, Pearson Education, 2021. ISBN-10 : 1292401133 ISBN-13 : 978-1292401133
3.	Machine Learning: An Algorithmic Perspective	Stephen Marsland	Chapman & Hall/CRC, 2nd Edition, 2014. ISBN-10 : 1138583405 ISBN-13 : 978-1138583405
4.	Data Analytics and Decision Making	Ali Abdul Hussein	Creative Commons Attribution 4.0 International License, University of Windsor, 2022.
5.	Python Data Analytics	Fabio Nelli	Apress,2015 ISBN: 9781484209585
6.	Python for Data Analysis: Data Wrangling with Pandas, Numpy, and Python	Wes McKinney	O'REILLY, 2017, Second Edition ISBN-10: 1491957662 ISBN-13:78-1491957660

b) Online Educational Resources (OER):

1) https://docs.python.org/3/tutorial/
2) https://nptel.ac.in/courses/106106145
3) https://www.w3schools.com/python/
4) https://www.tutorialspoint.com/python/index.htm
5) https://www.w3schools.com/python/pandas/default.asp

6) https://pandas.pydata.org/docs/user_guide/10min.html

7) http://bedford-computing.co.uk/learning/wp-content/uploads/2015/10/Python-Cookbook-3rd-Edition.pdf

8) Data Sources:

- https://archive.ics.uci.edu/ml/machine-learning-databases/auto-mpg/
- https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data
- https://www.kaggle.com/arshid/iris-flower-dataset
- https://www.kaggle.com/rohankayan/years-of-experience-and-salary-dataset
- https://www.kaggle.com/datasets/johnsmith88/heart-disease-dataset
- https://www.kaggle.com/datasets/harunshimanto/epileptic-seizure-recognition
- https://www.kaggle.com/datasets/mathchi/diabetes-data-set

Q) Course Curriculum Development Team

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A)	**Course Title:** Sports, Yoga & Meditation	Deemed to be University under Distinct Category
B)	**Course Code:** NEP01	
C)	**Pre- requisite (s):**	

D) **Rationale:** Sports or Physical Education, Yoga and Meditation is an integral part of a person's overall well-being and is imperative for a healthy mind and body balance. Integrating practical activities throughout the curriculum ensures that students not only gain theoretical knowledge but also develop practical skills, enhance their physical and mental well-being, and cultivate a deeper understanding and appreciation for sports, yoga, and meditation. Practical learning experiences are essential for reinforcing concepts, building competence, and fostering a lifelong commitment to health and wellness practices. It's also plays a major role in reducing level of stress/anxiety and add to the mental toughness. Looking to the ample benefits there is need to inculcate sports, Yoga and meditation as a day to day habit. So, it is necessary that every educational institutes should lay ample emphasis on including sports, yoga and meditation as a necessary part of education.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP01.CO1	Select appropriate physical activities to maintain healthy lifestyle.
NEP01.CO2	Apply basic principles and practices of Yoga and meditation for overall growth & development.
NEP01.CO3	Use fitness and wellness techniques for optimal health and wellbeing

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)		
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
NEP01.CO1	2	1	1
NEP01.CO2	2	1	1
NEP01.CO3	2	1	1

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP01	NEP	Sports, Yoga & Meditation	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Describe various sports, their benefits, and basic rules. *TSO 1b.* Explain the importance of physical fitness and basic conditioning exercises. *TSO 1c.* Select sports and exercises for physically challenged as per their need. *TSO 1d.* Explain the components of physical fitness (strength, flexibility, endurance). *TSO 1e.* Demonstrate proficiency in performing warm- up and cool-down routines. *TSO 1f.* Apply basic strength training and flexibility exercises to improve fitness levels.	**Unit-1.0 Introduction to Sports** 1.1 Definition of play, game, sports, exercise, psychology, sports psychology and exercise psychology, psychology and common-sense Overview of popular sports (football, basketball, tennis, etc.) 1.2 Benefits of sports for physical health and teamwork 1.3 Basic rules and equipment of selected sports 1.4 Components of physical fitness (strength, flexibility, endurance) 1.5 Warm-up and cool-down routines 1.6 Introduction to strength training and flexibility exercises 1.7 Adaptation of sports and exercises for physically challenged students in all levels.	**CO1**
TSO 2a. Apply principles and practices of yoga. *TSO 2b.* Explore techniques for mental relaxation and focus. *TSO 2c.* Explain history, philosophy, and principles of yoga. *TSO 2d.* Practice basic yoga asanas (poses) and their benefits. *TSO 2e.* Practice breath control (pranayama) and relaxation techniques effectively. *TSO 2f.* Develop a structured sequence of yoga poses for specific purposes (strength, flexibility, relaxation). *TSO 2g.* Integrate meditation techniques as part of their yoga practice. *TSO 2h.* Describe the benefits of meditation and mindfulness practices. *TSO 2i.* Apply mindfulness techniques to enhance focus, reduce stress, and improve overall well- being. *TSO 2j.* Select yoga and meditation for physically challenged as per their need.	**Unit-2.0 Yoga and Meditation** 2.1 History and philosophy of yoga 2.2 Role of yoga and meditation in purificatory process, in character building, developing concentration, will power and discipline 2.3 Types of yoga practices - asanas, pranayama, meditation 2.4 Basic yoga asanas (poses) and their benefits 2.5 Importance of breath control (pranayama) and relaxation techniques 2.6 Intermediate yoga asanas and their variations 2.7 Sequencing of yoga poses for different purposes (strength, flexibility, relaxation) 2.8 Introduction to meditation techniques 2.9 Benefits of meditation and mindfulness practices 2.10 Techniques: mindfulness meditation, guided visualization, body scan 2.11 Application of mindfulness in daily life and sports performance 2.12 Adaptation of yoga and meditations for physically challenged students in all levels	**CO2**
TSO 3a. Describe the mental aspects of sports and performance. *TSO 3b.* Apply skills learned in sports, yoga, and	**Unit-3.0 Sports, Mental Conditioning and Integration** 3.1 Mental preparation techniques for sports	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
meditation in practical settings *TSO 3c.* Integrate physical fitness, yoga, and mental conditioning into a comprehensive wellness routine. *TSO 3d.* Create and implement personalized fitness and wellness plans based on learned principles.	3.2 Goal setting and visualization 3.3 Overcoming performance anxiety and stress management 3.4 Integration of physical fitness, yoga, and mental conditioning 3.5 Creating personal fitness and wellness routines	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

a. Develop nutritional guidelines and programs that result in measurable improvements in athletic performance and recovery times.

b. Develop comprehensive mental health programs that effectively reduce anxiety, depression, and burnout in athletes.

c. Identify yoga practices that results in measurable improvements in mental health outcomes such as reduced stress, anxiety, and depression.

d. Identify and study specific neurobiological changes due to yoga, leading to enhanced mental and physical health.

e. Develop and validate meditation practices that significantly reduce symptoms of anxiety, depression, and PTSD.

f. Investigate group meditation dynamics that result in improved mental health outcomes and increased group cohesion.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignments: (Seminar Topics/ Visits/ Self- Learning Topics)
Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Calculate your Body Composition (BMI) and Cardiovascular Assessment
- Assessment for Muscular Endurance, Muscular Strength,
- Flexibility, Cardio-respiratory Endurance, Body Composition
- Rules and Regulations of different indoor and outdoor games.

b. Seminar Topics:

- Ethics in sports
- Application of principles of yoga in daily life.
- Strategies to Incorporate mindfulness practices into everyday activities

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications
1.	Soccer Ball	Size 5, made of synthetic leather, weight 410-450g
2.	Tennis Racket	Length 27 inches, strung with synthetic gut, weight 280-300g
3.	Badminton racket and net	-
4.	Table tennis racket and net	-
5.	Basketball	Size 7, made of leather, weight 567-650g
6.	Base ball set	-
7.	Cricket bat and ball	-
8.	Hockey sticks and balls	-
9.	Javelin Throw	Length: 2.6 - 2.7 meters (8 ft 6 in - 8 ft 10 in) Weight: 800 grams Material: Metal head with a hollow or solid shaft
10.	Discus Throw	Weight: 2 kg for men, 1 kg for women Diameter: 22 cm for men, 18 cm for women Circle Diameter: 2.5 meters (8.2 ft) Material: Made of metal, smooth surface
11.	Shot Put	Weight: 7.26 kg for men, 4 kg for women Diameter: 110-130 mm (4.3-5.1 inches) for men, 95-110 mm (3.7-4.3 inches) for women Circle Diameter: 2.135 meters (7 ft) Material: Made of steel
12.	Chess, carrom	Chess and carrom set
13.	Resistance Bands	Various resistance levels, latex material
14.	Dumbbells	1-10 lbs, adjustable weights
15.	Jump Rope	Adjustable length, durable material

S. No.	Name of Equipment, Tools and Software	Broad Specifications
16.	Exercise Mat	Non-slip surface, cushioned, 68 x 24 inches
17.	Step Platform	Adjustable height, sturdy, non-slip surface
18.	Hand Weights	1-5 lbs, ergonomic grip
19.	Heart Rate Monitor	Wrist-worn, accurate readings
20.	Fitness Ball	55-75 cm diameter, anti-burst material
21.	Aerobics mats -	• Thickness- approx. 1/4 to 1/2 inch for adequate cushioning • Material- Non-slip PVC, rubber, or foam • Size-minimum 68 x 24 inches and larger sizes • Portability- Lightweight and easy to roll up • Durability- Tear-resistant and easy to clean • Design- Textured surface for better grip • Weight- Lightweight (around 2-3 pounds) for easy transport
22.	Sports Wheelchairs	Customized for different sports, lightweight, adjustable
23.	Adaptive Bicycles	Handcycles, tricycles, recumbent bikes
24.	Modified Dumbbells	Adjustable grips for different hand sizes and strength levels
25.	Adaptive Treadmills	Hand-cranked or wheelchair-accessible treadmills
26.	Prosthetics	High-performance prosthetics for running, swimming, etc.
27.	Adaptive Yoga Mat	1/4-inch-thick, non-slip surface, 68 x 24 inches, extra cushioning for support
28.	Yoga Blocks	4 x 4 x 9 inches and various sizes, made of cork or foam
29.	Yoga Strap	6 feet long, adjustable buckle, Adjustable length, made of nylon
30.	Blanket	72 x 48 inches, made of cotton, lightweight
31.	Water Bottle	500ml capacity, BPA-free plastic, leak-proof
32.	Yoga Bolsters	Soft, supportive, various sizes
33.	Chair Yoga Props	Sturdy chairs with low back, no arms
34.	Meditation Cushion	12 x 12 inches, filled with buckwheat hulls or foam, supportive cushions
35.	Meditation Bench	12 inches wide, 18 inches long, adjustable height, comfortable seating
36.	Meditation Bell	2 inches in diameter, made of brass, produces clear sound
37.	Timer	Digital, with a soft alarm sound, battery-operated
38.	Essential Oil Diffuser	100ml capacity, adjustable mist settings, made of ceramic
39.	Blood pressure equipment	Blood pressure equipment
40.	Blood sugar equipment	Blood sugar equipment

S. No.	Name of Equipment, Tools and Software	Broad Specifications
41.	Massage therapy equipment, Hot and cold therapy equipment, Ultrasound therapy equipment for pain relief.	Massage therapy equipment, Hot and cold therapy equipment, Ultrasound therapy equipment for pain relief.
42.	Safety accessories	Helmet, Mouthguards, Protective Eyewear, Shin Guards, Knee Pads, Elbow Pads,Wrist Guards, Padded Shorts, Safety Harnesses, Life Jackets, etc

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Practical Applications in Sports Nutrition	Heather Hedrick Fink, Alan E. Mikesky	Jones & Bartlett Learning (2020) ISBN No: 978-1284181340
2.	ACSM's Guidelines for Exercise Testing and Prescription	Gary Liguori	LWW; (2021) ISBN-13: 978-1975150198
3.	Essentials of Strength Training and Conditioning	Javair Gillett	Human Kinetics, (2021) ISBN-13: 978-1718210868
4.	Practical Applications in Sports Nutrition	Heather Hedrick Fink, Alan E. Mikesky	Jones & Bartlett Learning, (2017) ISBN-13: 978-1284101393
5.	Health Fitness Management	Mike Bates, Mike Spezzano, Guy Danhoff	Human Kinetics, (2019) ISBN-13: 978-1450412230
6.	Yoga for Every Body: A beginner's guide to the practice of yoga postures, breathing exercises and meditation	Luisa Ray, Angus Sutherland	Vital Life Books (2022) ISBN-13: 978-1739737009
7.	Science of Yoga: Understand the Anatomy and Physiology to Perfect Your Practice	Ann Swanson	DK Publisher, (2019) ISBN-13: 978-1465479358
8.	Mudras for Modern Living: 49 inspiring cards to boost your health, enhance your yoga and deepen your meditation Cards	Swami Saradananda	Watkins Publishing (2019) ISBN-13: 978-1786782786
9.	Counselling Skills in Applied Sport Psychology: Learning How to Counsel	Paul McCarthy, Zoe Moffat	Routledge, (2023) ISBN-13: 978-1032592589
10.	Advancements in Mental Skills Training (ISSP Key Issues in Sport and Exercise Psychology)	Maurizio Bertollo, Edson Filho, Peter Terry	Routledge, (2020) ISBN-13: 978-0367111588
11.	The Relaxation and Stress Reduction Workbook	Martha Davis, Elizabeth Robbins, Matthew McKay, Eshelman MSW	A New Harbinger Self-Help Workbook (2019)
12.	Patanjalis Yoga Sutras	Swami Vivekananda	Fingerprint Publishing (2023) Prakash Books India Pvt Ltd, New Delhi ISBN-13: 978-9354407017

b) Online Educational Resources (OER):

1) https://onlinecourses.swayam2.ac.in/aic19_ed28/preview- introduction to Yoga and Applications of Yoga
2) https://onlinecourses.swayam2.ac.in/aic23_ge09/preview- Yoga for Creativity
3) https://onlinecourses.swayam2.ac.in/aic23_ge05/preview- Yoga for concentration
4) https://onlinecourses.swayam2.ac.in/aic23_ge06/preview- yoga for memory development
5) https://onlinecourses.nptel.ac.in/noc21_hs29/preview-Psychology of Stress, Health and Well being
6) https://onlinecourses.swayam2.ac.in/nce19_sc04/preview- Food Nutrition for Healthy Living - Course – Swayam
7) https://www.classcentral.com/course/swayam-fitness-management-17608- Fitness Management from Swayam
8) https://onlinecourses.swayam2.ac.in/nce19_sc04/preview-Food Nutrition for Healthy Living
9) https://onlinecourses.swayam2.ac.in/cec21_ed02/preview Health Education and Recreation
10) https://onlinecourses.swayam2.ac.in/cec22_ed31/preview Sports Administration and Management

Q) Course Curriculum Developer

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A)	**Course Title:** Open Educational Resources (OER)	Deemed to be University under Distinct Category
B)	**Course Code:** NEP02	
C)	**Pre- requisite (s):**	

D) **Rationale:** OER are freely and publicly available teaching, learning, and research resources that reside in the public domain in any format or have been released under an intellectual property license that permits their free use and re-purposing by others.

Learning about Open Educational Resources (OER), copyright, and Creative Commons licenses is a valuable endeavour for content creators, users, and anyone interested in sharing knowledge and creative works.

Creative Commons licenses, offer a standardized way to grant permissions for the use and sharing of creative works. Learning about OER, copyright, and Creative Commons licenses is an ongoing process. As these fields evolve, it's important to stay informed and continue exploring new resources and practices.

After going through this course, learners will at first place have reasonable idea to explore and use various OERs useful for their course of study and secondly, be motivated for fair use of resources available to them on various platform by understanding the restrictions and legal issues related to copyright and other licensing policies.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP02.CO1	Evaluate Open Educational Resources (OER) for its authentic use.
NEP02.CO2	Use copyright material appropriately.
NEP02.CO3	Implement suitable Creative Common License.

F) Suggested Course Articulation Matrix (CAM): (Not Applicable)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP02	NEP	Open Education Resources	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the difference between OER and other free educational materials. *TSO 1b.* Elaborate the challenges and benefits of using OER in a class. *TSO 1c.* Apply various aspects of evaluating OER before use *TSO 1d.* Explain the necessity to assess an OER's adaptability. *TSO 1e.* Perform preliminary search for open educational resource. *TSO 1f.* Find OER using various resources.	**Unit-1.0 Open Educational Resources** 1.1 OER - definition 1.2 What is NOT OER. 1.3 Benefits of using OER – Benefits to Students - Access to Quality Education 1.4 OER - Benefits to Faculty - Use, Improve and Share, Network and collaborate with peers, Lower Cost, Improve access to information 1.5 Challenges of Using OER – Subject Availability, Format and Material type availability, Time and Support availability 1.6 Evaluating OER – a) Clarity, Comprehensibility, and Readability, b) Content and Technical Accuracy, c) Adaptability and Modularity, d) Appropriateness and Fit, e) Accessibility 1.7 Finding Open Content - OER Search Scenario Filter by Usage Rights in Google, Repositories and Search Tools, Subject-	**CO1**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
	specific Repositories	
TSO 2a. Explain benefits of copyright protection for creator *TSO 2b.* Explain exceptions and limitations to copyright law *TSO 2c.* List rights granted to copyright holders. *TSO 2d.* Explain Exceptions and limitations to copyright law *TSO 2e.* Explain Fair use/fair dealing apply to copyright *TSO 2f.* Elaborate Public domain and how does it relate to copyright *TSO 2g.* Elaborate penalties for copyright infringement. *TSO 2h.* Explain copyright for digital content and the internet. *TSO 2i.* Explain use of copyrighted works in education *TSO 2j.* Explain the use of free licenses	**Unit-2.0 Copyright and Open Licensing** 2.1 Copyright and what it does protect, benefits of copyright protection for creators, duration of copyright protection last, rights granted to copyright holders. 2.2 Exceptions and limitations to copyright law, fair use/fair dealing apply to copyright 2.3 Public domain and its relation to copyright. 2.4 Penalties for copyright infringement 2.5 Apply copyright to digital content and the internet 2.6 Use of copyrighted works in education. 2.7 Open Licenses – GNU – Free Documentation license, Free Art License 2.8 Why Free Licenses – Retain, Reuse, Revise, Remix, Redistribute	**CO2**
TSO 3a. Describe the four different Creative Commons License components. *TSO 3b.* Explain the significance of No-Derivative license *TSO 3c.* Explain the Strengths and weaknesses of four Open CC Licenses *TSO 3d.* Choose the right Creative Commons license for work. *TSO 3e.* Apply a Creative Commons license to existing work. *TSO 3f.* Use Creative Commons licenses for commercial purposes. *TSO 3g.* Modify a work licensed under Creative Commons. *TSO 3h.* Revoke a Creative Commons license, combine works with different Creative Commons licenses *TSO 3i.* Differentiate between Attribution and Citation	**Unit-3.0 Creative Common Licenses** 3.1 Alternatives to copyright as Creative Commons licenses. 3.2 Four components of creative common Licenses – Attribution, Share- Alike, Non – commercial, No Derivatives 3.3 Choosing a Creative Common licenses – Wiley's 5 Rs and Creative Common Licenses 3.4 Four Open CC Licenses and Their Strengths and Weaknesses – (a) CC BY (b) CC BY SA (c) CC BY NC (d) CC BY NC SA 3.5 Attribution Vs Citation - Creative Commons licensed work without giving attribution 3.6 Apply a CC License - choose the right Creative Commons license for work, apply a Creative Commons license to existing work, Creative Commons licenses be used for commercial purposes, modify a work licensed under Creative Commons, revoke a Creative Commons license, combine works with different Creative Commons licenses	**CO3**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

i. Collect information on the impact of OER on cost savings and student engagement.

ii. Search at least four OER related to topic of your Engineering Discipline over Internet. Evaluate the material based on the relevance, accuracy and usability.

iii. Explore the different types of resources under creative Commons licenses (e.g., CC BY, CC BY-SA, CC BY-NC, etc.) and their specific permissions and restrictions.

iv. Create a comparative analysis chart or infographic that visually represents the key characteristics of each license. Select minimum 5 real-world examples from different domains (such as music, art, literature, or education) where creators have used Creative Commons licenses.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignments: (Seminar Topics/ Visits/ Self- Learning Topics)
Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- OER Quality Assurance
- OER Repositories and Platforms
- Creative Commons and Digital Media
- Creative Commons in the Visual Arts
- Examine the legal implications of using Creative Commons licenses, including the obligations and responsibilities of both creators and users and present it.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	The OER Starter Kit.	Abbey Elder - 2019	IA: Iowa State University Digital Press, available under a Creative Commons Attribution 4.0 International License. Retrieved from iastate.pressbooks.pub/oerstarterkit
2.	A Brief History of Open Educational Resources	Bliss, T J and Smith, M. - 2017	In: Jhangiani, R S and Biswas-Diener, R. (Eds.) Open: The Philosophy and Practices that are Revolutionizing Education and Science (pp. 9–27). London: Ubiquity Press. DOI: https://doi.org/10.5334/bbc.b.

b) Online Educational Resources (OER):

1) OER for Empowering Teachers Instructional Material by P. Malliga is licensed under a Creative Commons Attribution 4.0 International License.
2) William & Flore Hewlett Foundation. (n.d.). OER defined. Retrieved from https://hewlett.org/strategy/open-educational-resources/
3) Free Software Foundation. (2008). GNU Free Documentation License. Retrieved from https://www.gnu.org/licenses/fdl.html
4) Copyleft Attitude. (2007). Free Art License 1.3. Retrieved from http://artlibre.org/licence/lal/en/
5) Free Software Foundation. (n.d.). What is copyleft? Retrieved from https://www.gnu.org/copyleft/copyleft.html

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A)	**Course Title:** Professional Ethics	Deemed to be University under Distinct Category
B)	**Course Code:** NEP03	
C)	**Pre- requisite (s):** General awareness about moral values and about different workplaces	

D) **Rationale:** The Course on Professional Ethics equips graduates with the moral frameworks necessary to handle complex challenges inherent in any profession. In the course, graduates will be exposed to situations involving ethical dilemmas, where robust decision-making is critical for integrity, trust, and societal well-being. This course will cover concepts and principles associated with values, ethics, code of conduct, empathy, and compassion, with a view to fostering a proactive approach to ethical conduct and building resilience. It will also help to cultivate responsible leadership, enhance employability, mitigate risks, and empower individuals to contribute positively to their professions and the broader community in an increasingly interconnected world. This course is meant to sensitize students to ethical considerations within their professions and motivate them to demonstrate ethical behaviour in day-to-day activities.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP03.CO1	Make decisions considering values, moral and ethical framework.
NEP03.CO2	Propose fair professional practices considering the set of values and code of ethics in a simulated situation
NEP03.CO3	Demonstrate reasonable empathic and compassionate behaviour in professional settings.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)		
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
NEP03.CO1	3	3	1
NEP03.CO2	2	2	1
NEP03.CO3	2	2	1

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP03	NEP	Professional Ethics	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the interrelationship between values, morals and ethics. *TSO 1b.* Explain the influence of values, morals and ethics on the development of attitudes. *TSO 1c.* Identify values using self-assessment tools. *TSO 1d.* Describe a moral framework. *TSO 1e.* Use values and morally related criteria for making decisions in a given situation.	**Unit -1.0 Values, Morals and Ethics in Day-to-Day Life** 1.1 Introduction to values, moral, and ethics, definition, types of values, examples, Concept of attitude and development of attitude 1.2 Values identification using self-assessment tool, Moral Framework and its features, Importance of values and morals in day-to-day activities and at the workplace 1.3 Value-based decision criteria - Long-term versus short-term value considerations, Personal values alignment with professional choices 1.4 Moral Principles and Moral Reasoning Process	**CO1**
TSO 2a. Explain the characteristics that define a profession *TSO 2b.* Describe the role of professional associations in establishing and enforcing ethical standards. *TSO 2c.* Communicate effectively with integrity *TSO 2d.* Identify the ethical principles in the given professional codes *TSO 2e.* Suggest fair professional practices in simulated situation	**Unit-2.0 Professionalism and Codes of Conduct** 2.1 Profession and Professionalism 2.2 Role of Professional Associations and Societies 2.3 Ethics in communication**,** non-violent communication 2.4 Common Code of Ethics/Conduct for different professions, Academic ethics, environmental ethics, and Digital Ethics	**CO2**
TSO 3a. Explain the difference between compassion and empathy *TSO 3b.* Explain the role of emotional intelligence in empathy *TSO 3c.* Demonstrate empathy in a given situation *TSO 3d.* Explain the key stages for compassion development *TSO 3e.* Identify the compassion quotient using a questionnaire *TSO 3f.* Resolve ethical conflicts according to moral values and ethics. *TSO 3g.* Suggest for appropriate behaviour in a given personal and professional setting	**Unit-3.0 Empathic and Compassionate Behavior** 3.1 Introduction to Empathy and Compassion- Definition and Key Differences, Emotional Intelligence, and its role in empathy 3.2 Building blocks of empathy – active listening, Perspective-Taking, emotional cues 3.3 Key stages of compassion development in humans, compassion Quotient 3.4 Balance between Compassion and Empathy 3.5 Identification of activities in one's own area of work and related ethical and unethical behaviour, Ethical boundaries, Ethical Conflicts	**CO3**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

One problem is to allocate to each student. More such problems as mentioned below can be included by the teacher

i. Literature review on the psychology behind ethical and non-ethical behaviour

ii. Analysis of the ethical dilemma situation (such as the Ethical dilemma faced by engineers when they discover a design flaw or safety risk that a company is unwilling to address).

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s): Preparing a report, critique, undertaking discussion in groups after reading books related to values and ethics/Epics/ Daily newspapers and (Any one)

b. Activities: Group discussion, panel discussion, role play, case study, skits related to issues on values and ethics in the profession and day-to-day life. (These can be instructional strategies for the course, and can be specified clearly)

c. Micro Projects: Development of skits and performance, poster making,

d. Other (Any one Topic)

Suggested Seminar/ Debates on topics such as:

- Charters of professions
- Importance of values and ethics in the identified profession
- Issues of ethical conflicts
- Identified issues from scripts such as the Chanakya Neeti, Kabir ke Dohe etc.
- Lessons on ethics from religious scriptures
- Nonviolent communication for good work culture
- Compassion measurement at workplace
- Issued based on happenings reported in daily news

Teacher can suggest supporting material for reference and preparation.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Professional Ethics and Human Values	D. R. Kiran	McGraw-Hill Education Pvt. Ltd. 2007 ISBN: 9780070633872
2.	A Textbook on Professional Ethics and Human Values	Dr. R S Nagarajan	New Age International (P) Ltd., Publishers, 2017, ISBN: 8122419380, 9788122419382
3.	Ethics, Integrity and Attitude –Hindi (Paperback) (एथिक्स, सत्यनिष्ठा एवं अभिवृत्ति)	P.D Sharma	Rawat Publications, 2019 ISBN: 978-8131609941
4.	Chanakya - Niti (Sutra Sahit) (Hindi)	Chanakya	Maple Press. 2014 ISBN 978-9350335529
5.	Professional Ethics and Human Values	D. R. Kiran	McGraw-Hill Education Pvt. Ltd. 2007 ISBN: 9780070633872

b) Online Educational Resources (OER):

1) https://tibet.emory.edu/documents/Ozawa-deSilva-CompassionandEthics-FinalPrintVersion-JHSH2012.pdf
2) https://www.surendranathcollege.ac.in/wp-content/uploads/2024/02/7.1.9.-HUMAN-VALUES-AND-PROFESSIONAL-ETHICS.pdf
3) https://harmoniouscosmos.com/the-role-of-compassion-in-ethical-decision-making/
4) https://www.uhv.org.in/uhve
5) https://www.kaggle.com/rohankayan/years-of-experience-and-salary-dataset
6) http://gandhismriti.gov.in/sites/default/files/Nonviolent%20Communication%20Elements%20and%20Applications%20%281%29.pdf

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A)	**Course Title:** Financial Literacy	Deemed to be University under Distinct Category
B)	**Course Code:** NEP04	
C)	**Pre- requisite (s):**	

D) **Rationale:** Financial literacy is a critical life skill that everyone should have, yet many people struggle with it. This course explores the fundamentals of financial literacy, including budgeting, saving, investing, and debt management. The students will learn the fundamental principles of budgeting, saving, and investing, along with understanding the key factors that can impact the financial decisions.it communicates the different investment options and the risk-return trade-offs. It also can create a diversified portfolio that fits your risk tolerance and investment goals. In addition to investment strategies, this course covers topics such as credit and debt management, retirement planning, taxes, and insurance.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP04.CO1	Formulate the investment plan for various situation of income & expenditure of individuals.
NEP04.CO2	Identify various Investment Options for Retirement.
NEP04.CO3	Apply Tax-Effective Investment Decisions for various situations.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)				
	PO-1 Apply knowledge of management theories and practices to solve business problems.	**PO-2** Foster Analytical and critical thinking abilities for data-based decision-making.	**PO-3** Ability to develop Value based Leadership ability.	**PO-4** Ability to understand, analyze and communicate global, economic, legal, and ethical aspects of business.	**PO-5** Ability to lead themselves and others in the achievement of organizational goals, contributing effectively to a team environment.
NEP04.CO1	1	-	1	-	-
NEP04.CO2	1	1	1	-	-
NEP04.CO3	1	-	1	-	-

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP04	NEP	Financial Literacy	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the Personal Financial Goals for the given situation. *TSO 1b.* Explain Income/ Expenses/ Net Worth for the given situation.	**Unit-1.0: Basic Financial Concepts** 1.1 Personal Financial Goals 1.2 Income, Expenses, and Net Worth	**CO1, CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1c. Explain the steps of Budgeting for the given situation. *TSO 1d.* Explain the Cash Flow Management process for the given situation. *TSO 1e.* Explain Saving for household for the given situation. *TSO 1f.* Formulate the investment plan for the given individual. *TSO 1g.* Explain Inflation in the economy *TSO 1h.* Identify the factors effecting the Interest Rates in the economy for the given situation. *TSO 1i.* Explain the role of Bank Accounts in personal savings for the given situation. *TSO 1j.* Explain the Payment Methods. *TSO 1k.* Explain the Credit Management system for the given situation. *TSO 1l.* Explain Debt Management for the given situation. *TSO 1m.* Explain the Insurance plan for the given situation. ***TSO 1n.*** Formulate the investment plan for the given situation of income & expenditure of individuals.	1.3 Budgeting & Cash Flow Management 1.4 Saving 1.5 Investing 1.6 Inflation & Interest Rates 1.7 Bank Accounts and Payment Methods 1.8 Credit Management 1.9 Debt Management 1.10 Insurance	
TSO 2a. Identify the various the Investment option and types for the given situation. *TSO 2b.* Building a Diversified Portfolio applying risk-return trade-off for the given situation. *TSO 2c.* Apply the Risk-Return Trade-off for the given situation. *TSO 2d.* Explain Informed Investment Decisions for the given situation. *TSO 2e.* Write the steps in Retirement Planning for the given situation. *TSO 2f.* Explain Social Security and Pensions for the given situation. *TSO 2g.* Identify the Investment Options for Retirement Savings for the given situation. *TSO 2h.* Make Plans for Unexpected Events for the given situation. *TSO 2i.* List the Filing Taxes and Forms *TSO 2j.* Outline the Tax Laws and Regulations.	**Unit-2.0: Investing & Taxation** 2.1 Investment option and types 2.2 Building a Diversified Portfolio 2.3 Risk-Return Trade-off 2.4 Informed Investment Decisions 2.5 Retirement Planning 2.6 Social Security and Pensions 2.7 Estimating Future Retirement Expenses 2.8 Planning for a Comfortable Retirement 2.9 Investment Options for Retirement Savings 2.10 Planning for Unexpected Events 2.11 Filing Taxes and Forms 2.12 Tax Laws and Regulations 2.13 Minimizing Tax Liability 2.14 Making Tax-Effective Investment Decisions	**CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 2k. Minimizing Tax Liability for the given situation. *TSO 2l.* Make Tax-Effective Investment Decisions for the given situation.		
TSO 3a. Explain the importance of Entrepreneurship education *TSO 3b.* Outline the Entrepreneurial Opportunities for the given product. *TSO 3c.* Outline the Entrepreneurship Support Eco-System *TSO 3d.* Identify the Business opportunities for the given situation. *TSO 3e.* Identify the steps in market survey for an enterprise. *TSO 3f.* Identify the Procedure and formalities for Bank Finance for the given situation	**Unit-3.0: Entrepreneurship Support System** 3.1 Entrepreneurship education 3.2 Achievement Motivation 3.3 Entrepreneurial Opportunities 3.4 Entrepreneurship Support Eco-System 3.5 Business opportunities Identification 3.6 Market Survey 3.7 Procedure and formalities for Bank Finance	**CO3**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Visits:

- Arrange a visit to a tax filing consultancy nearby.

c. Group discussions on current print articles.

- Personal finance
- Taxation over last decade
- Essentials awareness for IT slabs.

d. Self-learning topics:

- Cash Management System for firms.
- Accounts receivable for firms.

e. Micro Projects: Suggested list of course wise micro projects are mentioned herewith

- Analysis of Situations where special provisions for saving has been observed
- Role of Media in Spreading Awareness regarding Tax filing.

f. Seminar Topics:

- The Evolution of the Indian Constitution: From the British Raj to Independence
- Filling Income tax as per Indian Provisions.
- Planning for retirement.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Exploring Financial Literacy	Judi Deatherage M. D	Goodheart-Willcox , ISBN-13: 9781635637069
2.	The Money Guide by	Anushka Rathod	Zebralearn Pvt Ltd, ISBN-13: 978-8196373566
3.	Money Works: The Guide to Financial Literacy	Abhijeet Kolapkar	Publisher Penguin Business, ISBN-13: 978-0143461647
4.	Financial Literacy	Prof. Rajni and Dr. Abhishek Kumar Singh	JSR Publishing House LLP
5.	Taxmann's Financial Literacy – Equip Yourself With The Knowledge And Skills To Achieve Financial Independence and Make Informed Financial Decisions Confidently	Prof. (Dr.) Amit Kumar Singh	Taxmann Publications Private Limited; ISBN-13 : 978-9357785464
6.	Personal Finance: A Treatise on Financial Literacy	Prof (Dr.) Kana Sukumaran	Notion Press, ISBN-13: 979-8894463421
7.	The Legacy Of Financial Literacy : Guiding My Child To Financial Success	Jyotinath Ganguly	Notion Press, ISBN-13: 978-1637453223

b) Online Educational Resources (OER):

1) https://www.investopedia.com/guide-to-financial-literacy-4800530#:~:text=Financial%20literacy%20is%20the%20ability%20to%20understand%20and,money%2C%20compound%20interest%2C%20managing%20debt%2C%20and%20financial%20planning.
2) https://www.fidelity.com/learning-center/smart-money/financial-literacy
3) https://www.forbes.com/sites/truetamplin/2023/09/21/financial-literacy--meaning-components-benefits--strategies/
4) https://yourstory.com/2023/07/financial-literacy-is-key-to-unlocking-india-economy
5) https://www.investopedia.com/financial-literacy-5224001

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A)	**Course Title:** Engineering Economics	Deemed to be University under Distinct Category
B)	**Course Code:** NEP05	
C)	**Pre- requisite (s):**	

D) **Rationale:** The need of engineering economy is primarily motivated by the fact that everything in engineering has to be carried out economically and optimally - whether designing an equipment, choosing between alternatives, operating a plant, marketing a product or maintaining a plant, all of which involve a decision-making process. The decision-making process involves the fundamental elements of cash flows of money, time, and interest rates. This course introduces the basic concepts and terminology necessary for an engineer to combine these three essential elements to solve problems that will lead to better decisions.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP05.CO1	Apply the laws of economics for various situations.
NEP05.CO2	Evaluate the various engineering project w.r.t. Present worth method, Future worth method, Net present value method, internal rate of return method, Cost-benefit analysis in public projects
NEP05.CO3	Prepare cost sheets for the various products.

F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)				
	PO-1 Apply knowledge of management theories and practices to solve business problems.	**PO-2** Foster Analytical and critical thinking abilities for data-based decision-making.	**PO-3** Ability to develop Value based Leadership ability.	**PO-4** Ability to understand, analyze and communicate global, economic, legal, and ethical aspects of business.	**PO-5** Ability to lead themselves and others in the achievement of organizational goals, contributing effectively to a team environment.
NEP05.CO1	1	-	1	-	-
NEP05.CO2	1	1	1	-	-
NEP05.CO3	1	-	1	-	-

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP05	NEP	Engineering Economics	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Outline the scope of Engineering Economics. *TSO 1b.* Explain micro & macro-economics. *TSO 1c.* Explain the Theory of demand *TSO 1d.* Explain the demand function for the given situation. *TSO 1e.* List the exceptions of Law of Demand. *TSO 1f.* Explain the Elasticity of demand. *TSO 1g.* Explain the elasticity of demand for the given product. *TSO 1h.* Explain the Laws of variable proportions for the given situation. *TSO 1i.* Explain the Law of returns to scale. *TSO 1j.* Apply the relevant laws of economics for the given situation.	**Unit-1.0 Basic Economics Concepts** 1.1 Engineering Economics – Nature and scope 1.2 General concepts on micro & macro-economics. 1.3 The Theory of demand: Demand function, Law of demand and its exceptions, 1.4 Elasticity of demand, Law of supply and elasticity of supply. 1.5 Theory of production: Law of variable proportion, Law of returns to scale	**CO1**
TSO 2a. Identify the factors in Time value of money. *TSO 2b.* Explain the Principle of economic equivalence *TSO 2c.* Identify the methods of evaluation of engineering projects. *TSO 2d.* Calculate the Net present value method, internal rate of return method, Cost-benefit analysis for the given product	**Unit-2.0: Time Value of Money** 2.1 Time value of money: Simple and compound interest, Cash flow diagram, Principle of economic equivalence. 2.2 Evaluation of engineering projects: Present worth method, Future worth method, Net present value method,	**CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 2e. Explain Depreciation. *TSO 2f.* Distinguish the methods of depreciation. *TSO 2g.* Evaluate the given engineering project w.r.t. Present worth method, Future worth method, Net present value method, internal rate of return method, Cost-benefit analysis in public projects	internal rate of return method, Cost-benefit analysis in public projects. 2.3 Depreciation: Meaning Causes, Factors affecting depreciation, Methods of providing depreciation, Straight Line Method & Diminishing Balance Method	
TSO 3a. List the elements of costs. *TSO 3b.* Differentiate between fixed and variable costs *TSO 3c.* Explain BEP for the given product. *TSO 3d.* Calculate BEP for the given situation. *TSO 3e.* Explain the characteristic of the Indian banking system. *TSO 3f.* Explain the functions of commercial banks. *TSO 3g.* Explain the functions of Reserve Bank of India. *TSO 3h.* Outline the Indian Financial System. *TSO 3i.* Prepare a cost sheet for the given product.	**Unit-3.0: Cost and Banking Concepts** 3.1 Cost concepts: Elements of costs, Preparation of cost sheet, Segregation of costs into fixed and variable costs. Break-even analysis (Simple numerical problems to be solved) 3.2 Indian Banking System: Banks: Meaning, nature, characteristic of the Indian banking system, functions of commercial banks, functions of Reserve Bank of India, Overview of Indian Financial System.	**CO3**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

a. Cost-Benefit Analysis of Green Technologies

- Problem: How can cost-benefit analysis be used to justify investments in sustainable and green technologies in industries?
- Focus: Evaluation of long-term economic benefits vs. initial investment costs of green technologies such as solar power, energy-efficient systems, and eco-friendly materials.

b. Optimization of Project Scheduling Using Economic Principles

- Problem: How can engineering economic principles be applied to optimize project timelines while minimizing costs?
- Focus: Investigating the economic impact of scheduling delays and exploring methods like Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT).

c. Economic Viability of Renewable Energy Systems

- Problem: What is the economic feasibility of replacing traditional energy sources with renewable energy in large-scale projects?
- Focus: Cost analysis of renewable energy sources like wind, solar, and hydropower and their integration into existing infrastructures.

d. Risk and Uncertainty in Engineering Investment Decisions

- Problem**:** How can risk analysis techniques help improve investment decision-making in engineering projects?
- Focus: Exploring methods to quantify risk and uncertainty, such as Monte Carlo simulations or sensitivity analysis, and their application in engineering economics.

e. Economic Impact of Automation in Manufacturing

- Problem: What are the long-term economic effects of implementing automation in manufacturing processes?
- Focus: Investigating cost reduction, labor displacement, and productivity increases due to automation, and analyzing the return on investment (ROI).

f. Capital Budgeting and Infrastructure Development

- Problem: How can engineering economic models be used to evaluate large-scale infrastructure projects like bridges, highways, or airports?
- Focus: Applying techniques like Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period for evaluating capital expenditures in public infrastructure.

g. Lifecycle Costing in Engineering Design

- Problem: How can lifecycle costing be integrated into the design phase of engineering projects to improve long-term financial outcomes?
- Focus: Assessing the total cost of ownership (TCO) of systems or products from conception to disposal and its impact on engineering decisions.

h. Sustainability vs. Profitability in Engineering Projects

- Problem: How can sustainability practices be balanced with profitability in engineering project management?
- Focus: Analyzing the trade-offs between short-term profits and long-term sustainability goals, and finding ways to integrate them economically.

i. Impact of Inflation on Engineering Project Costs

- Problem: What is the effect of inflation on the cost estimation and budgeting of long-term engineering projects?
- Focus: Developing models to predict and mitigate inflation's impact on project finances and exploring strategies to safeguard against cost overruns.

j. Economic Analysis of Infrastructure Resilience

- Problem: How can economic models be used to assess the cost-effectiveness of building resilient infrastructure in the face of climate change or natural disasters?
- Focus: Cost-benefit analysis of resilient infrastructure investments, including disaster recovery costs and insurance savings.

k. Evaluating Engineering Project Feasibility Using Real Options Theory

- Problem: How can real options theory be applied to evaluate the feasibility and flexibility of engineering projects under uncertainty?
- Focus: Investigating how real options, such as delaying or expanding projects, can be modeled to improve decision-making in uncertain environments.

l. Public-Private Partnerships in Engineering: Economic Considerations

- Problem: What are the key economic challenges and benefits of public-private partnerships (PPP) in engineering infrastructure projects?
- Focus: Exploring the economic models that can be used to balance risks, rewards, and resource allocation between public and private sectors.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

i. Time Value of Money (TVM) Calculations

- Assignment: Explain and apply the concept of the time value of money. Calculate the future value and present value of different cash flows using different interest rates. Analyze how inflation impacts these calculations.
- Objective: Understand and apply TVM concepts to real-world investment decisions.

ii. Cost-Benefit Analysis for a New Engineering Project

- Assignment: Perform a cost-benefit analysis for a hypothetical or real-world engineering project (e.g., construction of a bridge, solar power plant, or water treatment facility). Identify all potential costs and benefits, and calculate the net benefit.
- Objective: Apply cost-benefit analysis techniques to evaluate the feasibility of engineering projects.

iii. Break-even Analysis in Manufacturing

- Assignment: Conduct a break-even analysis for a manufacturing process. Identify fixed and variable costs, and determine the break-even point. Create different scenarios by changing costs and price points.
- Objective: Learn how to determine profitability thresholds and manage operational costs in manufacturing.

iv. Capital Budgeting for Infrastructure Projects

- Assignment: Using techniques like Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period, evaluate a proposed infrastructure project (e.g., road construction, airport expansion). Analyze the financial viability and make a recommendation.
- Objective: Apply capital budgeting techniques to large-scale engineering projects.

v. Depreciation Methods and Their Impact on Project Economics

- Assignment: Explore various depreciation methods (e.g., straight-line, declining balance, sum-of-years-digits) and apply them to engineering assets (e.g., machinery, vehicles). Analyze how different methods affect tax savings and project economics.

- Objective: Understand how depreciation impacts financial decision-making and project budgeting.

vi. Life-Cycle Cost Analysis of Engineering Equipment

- Assignment: Perform a life-cycle cost (LCC) analysis for an engineering system or equipment (e.g., HVAC system, machinery). Consider initial costs, operation, maintenance, and disposal. Compare two alternatives based on LCC.
- Objective: Assess the total cost of ownership of engineering systems from inception to disposal.

vii. Sensitivity Analysis for an Engineering Project

- Assignment: Perform a sensitivity analysis on an engineering project's financial model. Identify critical variables (e.g., cost of materials, labor rates, interest rates) and assess how changes in these variables affect the project's profitability.
- Objective: Learn how to account for uncertainty and variability in project costs and decision-making.

viii. Inflation and Its Impact on Long-Term Engineering Projects

- Assignment: Analyze the impact of inflation on long-term engineering projects, such as power plants or public infrastructure. Calculate how inflation rates affect future costs and overall project budgets.
- Objective: Understand how inflation impacts project budgeting and long-term financial planning.

ix. Economic Analysis of Renewable Energy Projects

- Assignment: Evaluate the economic feasibility of a renewable energy project (e.g., wind farm, solar energy plant) by calculating the return on investment, break-even point, and long-term financial benefits.
- Objective: Learn how to assess the financial viability of sustainable engineering solutions.

x. Risk and Uncertainty in Investment Decisions

- Assignment: Analyze a case study of an engineering project where risk and uncertainty played a significant role. Use probabilistic methods, such as Monte Carlo simulations or decision trees, to model the impact of uncertainty on project outcomes.
- Objective: Develop skills in managing risk and uncertainty in engineering economics.

xi. Public-Private Partnership (PPP) Analysis

- Assignment: Analyze a public-private partnership (PPP) project in engineering (e.g., highway construction or airport management). Assess the risk-sharing model, economic benefits, and potential challenges from both public and private perspectives.
- Objective: Explore the economic considerations and challenges in engineering projects involving multiple stakeholders.

xii. Inventory Management and Economic Order Quantity (EOQ)

- Assignment: Apply the Economic Order Quantity (EOQ) model to an engineering firm's inventory management system. Calculate EOQ and analyze the trade-off between ordering costs and holding costs.

- Objective: Understand the principles of efficient inventory management in engineering operations.

xiii. Feasibility Study of Automation in a Production Line

- Assignment: Conduct a financial feasibility study to assess the benefits and costs of automating a manufacturing production line. Consider factors such as labor cost savings, capital costs, and operational efficiency.
- Objective: Assess the economic impact of automation in engineering.

xiv. Engineering Project Financing

- Assignment: Explore different financing options available for large engineering projects (e.g., project loans, bonds, equity). Analyze the pros and cons of each financing option and their impact on project cost and risk.
- Objective: Understand how financial structures affect the economics of engineering projects.

xv. Ethical and Economic Considerations in Engineering Projects

- Assignment: Analyze an engineering project with significant ethical and economic implications (e.g., building in environmentally sensitive areas, projects affecting communities). Explore the balance between economic benefits and ethical responsibility.
- Objective: Learn to integrate ethical considerations with economic decision-making in engineering projects.

b. Seminar Topics:

- Time Value of Money in Engineering Projects
- Cost-Benefit Analysis in Large Infrastructure Projects
- Depreciation Methods and Their Impact on Engineering Economics
- Economic Feasibility of Renewable Energy Projects
- Break-even Analysis in Engineering and Manufacturing
- Capital Budgeting Techniques in Engineering
- Risk and Uncertainty in Engineering Economic Decisions
- Lifecycle Costing in Engineering Systems
- Public-Private Partnerships (PPP) in Engineering Projects
- Sustainability and Economic Viability in Engineering
- Economic Order Quantity (EOQ) and Inventory Management
- Impact of Inflation on Engineering Projects
- Automation and Its Economic Impact on Manufacturing
- Economic Impact of Lean Manufacturing
- Financing Large-Scale Engineering Projects
- Feasibility Studies for Engineering Projects
- Economic Implications of Engineering Ethics
- Supply Chain Economics in Engineering
- Real Options in Engineering Project Evaluation
- Economic Evaluation of Disaster-Resilient Infrastructure

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Engineering Economics	Riggs, Bedworth and Randhwa	McGraw Hill Education India, ISBN: 9780079122483
2.	Principles of Economics	D.M. Mithani	Himalaya Publishing House, ISBN:978-93-5202-762-0
3.	Engineering Economics & Costing	Sasmita Mishra	PHI Learning Pvt. Ltd, ISBN: 9788120341678
4.	Engineering Economy	Sullivan and Wicks	Pearson Hall, ISBN: 9780132554909
5.	Engineering Economics	R.Paneer Seelvan	Prentice-Hall of India Pvt. Ltd, ISBN: 788120348370
6.	Managerial Economics	Gupta G	McGraw Hill Education, ISBN-13:978-0071067867
7.	Cost Accounting: Text, Problems and Cases	Jawahar Lal , Seema Srivastav , Manisha Singh	McGraw-Hill. ISBN-13: 978-9353168384

b) Online Educational Resources (OER):

1) http://courseware.cutm.ac.in/courses/engineering-economics-and-costing/
2) https://ep.jhu.edu/courses/715641-engineering-economics/
3) https://online.stanford.edu/courses/cee146s-engineering-economics-and-sustainability
4) https://ocw.mit.edu/courses/10-490-integrated-chemical-engineering-i-fall-2006/98288885a32c8a4054460082cb87a426_eng_econ_lecture.pdf
5) https://engineering.purdue.edu/online/courses/engineering-economic-analysis

Q) Course Curriculum Developer

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Course Curriculum Detailing- Offline Spell -2

S. No.	Course Codes	Course Titles	Page No.
1.	GTECH05	Wind Power Technology	84
2.	GTECH06	Modeling and Simulation of Green Energy Systems	93
3.	GTECH07-08	Stream Specific Diversified Course -1	103
4.	GTECH09-10	Stream Specific Diversified Course -2	129
5.	PD01	Project	143

A)	**Course Title:** Wind Power Technology	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH05	
C)	**Pre- requisite (s):** Basics of Electrical, Basics of Aerodynamics	

D) **Rationale:** Wind power technology course provides the basic principles and operational features of wind turbines and wind turbine generators. Skills needed to harness wind energy, designing of wind turbine generator and installation of wind power generation are covered in the course. Electricity generated by wind power is inexhaustible and pollution free and thus contributes to sustainable development. This course also provides grid connected and off grid applications of wind energy by equipping learners with the knowledge and skills needed to harness wind energy effectively.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry-expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH05.CO1	Model the wind regime for computing wind Energy assessment
GTECH05.CO2	Illustrate the operation of the grid-connected and off-grid applications of wind energy
GTECH05.CO3	Identify a suitable power electronic converter for wind energy systems
GTECH05.CO4	Write the procedure for the development of wind farm and its operation
GTECH05.CO5	Develop hardware related to system components and software tools for the design, analysis, and assessment of wind energy resources

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH05.CO1	3	2	3	2
GTECH05.CO2	3	2	3	3
GTECH05.CO3	3	2	3	3
GTECH05.CO4	3	2	3	3
GTECH05.CO5	3	2	3	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH05	PCC	Wind Power Technology	45	15	45	15	120	04	30	70	20	-	20	30	150

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the wind energy perspective in India *TSO 1b.* Create wind regime models to support the efficient siting and sizing of wind energy systems *TSO 1c.* Develop statistics of wind speed using measurements *TSO 1d.* Develop models for Weibull, Rayleigh distribution, and parametersfor wind resource assessments *TSO 1e.* Apply wind rose plots using real-world wind data to inform strategic decisions on wind turbine orientation *TSO 1f.* Use clustering algorithms to identify typical wind speed regimes	**Unit 1.0 Introduction to Wind Energy** 1.1 Wind energy in India- Current and future perspective 1.2 Wind Regime modelling and analysis 1.3 Measurement of wind 1.4 Wind speed statistics 1.5 Weibull, Rayleigh distribution, and parameter 1.6 Local wind systems and wind Rose 1.7 Energy estimation of wind regimes using AI	**CO1**
TSO 2a. Compute the power extracted from the wind turbine *TSO 2b.* Identify Betz limit, Airfoil Lift, and the drag characteristics *TSO 2c.* Develop models to predict and optimizewind turbine performance for site-specific conditions *TSO 2d.* Design and simulate blade performance models using computational tools to optimize torque output and structural integrity under varying wind conditions *TSO 2e.* Apply computational models to simulate and optimize turbine performance using the stream tube *TSO 2f.* Explain Linear momentum theory *TSO 2g.* Developmodels to optimize TSR for different turbine designs for maximizing energy extraction and system efficiency. *TSO 2h.* Calculate energy, Pitch, and stall regulation *TSO 2i.* Draw the power curve	**Unit 2.0 Wind Turbines** 2.1 Horizontal and vertical axis wind turbines 2.2 Power extracted from the wind turbine 2.3 Betz limit, Airfoil Lift and drag-characteristics 2.4 Thrust and torque 2.5 Steam tube model 2.6 Linear momentum theory 2.7 Tip-speed ratio 2.8 Pitch and stall regulation, power curve, energy calculation	**CO2**
TSO 3a. Describe the components of a stand-alone and grid-connected Wind Energy Conversion System *TSO 3b.* Demonstrate small wind turbine performance *TSO 3c.* Analyze fixed and variable speed systems applications using the power electronics interface in WECS *TSO 3d.* Apply the guidelines and regulations of WECS *TSO 3e.* Write steps for the installation and	**Unit 3.0 Wind turbine generators** 3.1 Stand-alone Wind Energy Conversion System (WECS) 3.2 Grid-connected systems 3.3 Wind pumps and small wind turbines 3.4 Fixed speed and variable speed systems applications in WECS 3.5 Power electronic interface 3.6 Government regulations and guidelines 3.7 Installation and commissioning of WECS	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
commissioning of WECS *TSO 3f.* Develop a central monitoring system using SCADA	3.8 Central monitoring system using SCADA	
TSO 4a. Analyze the economic performance indices and special considerations *TSO 4b.* Develop a criterion to integrate and operate the wind farm *TSO 4c.* Design financial assessment frameworks that incorporate subsidies, operational risks, carbon pricing, and policy fluctuations *TSO 4d.* Develop an offshore wind farm *TSO 4e.* Construct machine learning models using short-term and long-term meteorological data to predict wind variations *TSO 4f.* Explain the grid code for operating the wind farm	**Unit-4.0 Wind farm performance indices** 4.1 Wind farm performance indices 4.2 Wind farm development and operation 4.3 Economic performance indices and special considerations 4.4 Offshore wind farm development 4.5 Short-term wind forecasting using AI 4.6 Long-term wind forecastingusing AI 4.7 Grid code for wind farm operation	**CO4**
TSO 5a. Explain off-grid and grid-connected applications of the Wind Energy Conversion System *TSO 5b.* Summarize the techno-economic aspect of WECS *TSO 5c.* Select suitable hardware system components in WECS *TSO 5d.* Develop AI models for wind resource assessment	**Unit 5.0: Analysis and implementation of wind mills** 5.1 Off-grid and grid-connected applications of Wind Energy Conversion System 5.2 Conduction of techno-economic aspect 5.3 Hardware related to system components in WECS 5.4 Assessment of wind energy resources using AI	**CO5**

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1 Analyze wind velocity *LSO 1.2* Obtain the I-V and P-V characteristics of micro Wind Energy	1.	Performance assessment of micro Wind Energy Generator a) Measure voltage, current, and power developed from the micro Wind Energy Generator b) Analyze the performance of a micro Wind Energy Generator under various wind speeds	CO-1
LSO 2.1 Obtain the ratio of the power extracted by the wind turbine relative to the energy available (Cp) in the wind stream *LSO 2.2* Obtain Betz coefficient for	2.	Wind resource assessment techniques of a micro Wind Energy Generator a) Develop a setup for Wind resource assessment	CO-1

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
given wind mill		b) Measurewind velocity	
LSO 3.1 Obtain minimum wind speed required to rotate wind turbine (Start-up speed) *LSO 3.2* Obtain minimum wind speed required to power generated in the wind turbine (cut-in speed)	3.	Evaluation of Cut in Speed of the horizontal wind turbine Measure the minimum wind speed a) To rotate wind turbine and b) To generate power wind turbine generator	CO-1
LSO 4.1 Analyze the tangential speed of the tip of a blade *LSO 4.2* Obtain the actual velocity of the wind *LSO 4.3* Obtain tip speed ratio (tsr)	4.	Evaluation of the Tip Speed Ratio (TSR) at different wind speed. a) Measure the actual velocity of the wind	CO-1
LSO 5.1 Obtain the power output and wind speed *LSO 5.2* Plot curve between the power output obtained from the wind turbine	5.	Evaluation of turbine power versus wind speed curve. b) Measure the power output and wind speed Connect Solar PV module with blocking diode	CO-1
LSO 6.1. Evaluate the efficiency of charge controller used in the Wind Energy conversionSystem	6.	Evaluation of the charge Controller used in the wind energy system a) Measure Battery Current (A), Battery voltage (V) b) Measure DC load current (A), DC load voltage (V)	CO-1, CO-4
LSO 7.1 Obtain voltage, current and power by varying the speed of wind source *LSO 7.2* Obtain the I-V and P-V characteristics of wind power generator	7.	Real Time observationof I-V and P-V Characteristics of wind power generator a) Setup the Real Time wind power generator b) Setup the windenergy source using fan	CO-1, CO-4
LSO 8.1 Obtain the characteristics of wind turbine by varying the number of blades *LSO 8.2* Plot the graph between number of blade and power developed	8.	Effect of turbine blade parameters on wind power generation a) Measure the speed and power of wind turbine by addingblade-1 b) Measure the speed and power of wind turbine by addingblade-2 and 3	CO-1, CO-4
LSO 9.1 Determine the minimum wind speed required to rotate wind turbine (Start-up speed) *LSO 9.2* Determine the minimum wind speed required to power generated in the wind turbine (cut-in speed)	9.	Effect of wind speed on power generated in vertical axis wind turbine Measure the minimum wind speed a) To rotate wind turbine and b) To generate power wind turbine generator	CO-1, CO-3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 10.1 Obtain power generated in wind energy conversion system for various wind speed *LSO 10.2* Analyze the characteristics of wind power generation system	10.	Development of simulation model for wind energy system a) Develop wind turbine using simulation tool b) Develop wind energy conversion system using simulation tool	CO-1, CO-3
LSO 11.1 Measure power output for various pitch angle *LSO 11.2* Analyze the characteristics of power generation by varying pitch angle	11.	Development of simulation model for pitch controller in wind energy system a) Develop wind turbine using simulation tool b) Develop pitch controller in wind energy conversion system using simulation tool	CO-1, CO-3
LSO 12.1 Measure power output for various duty cycle *LSO 12.2* Analyze the characteristics of power generation by varying duty cycle	12.	Development of simulation model for power converter in wind energy system a) Develop wind turbine using simulation tool b) Develop power converter in wind energy conversion system using simulation tool	CO-1, CO-3
LSO 13.1 Analyze the characteristics of wind generator by varying the speed *LSO 13.2* Plot the graph between wind speed and power output	13.	Development of simulation model for plotting wind speed and power output a) Develop wind turbine using simulation tool b) Measure power generated and wind speed in wind energy conversion system using simulation tool	CO-1
LSO 14.1 Analyzethe characteristics of wind generator interconnected with grid using transformer *LSO 14.2* Plot the graph for power export and import on grid	14.	Simulation model development of grid and transformer integration for wind energy system a) Develop wind power generation interconnected with grid and transformer model in simulation tool b) Measure electrical parameters of wind power generation system	CO-1
LSO 15.1 Analyze supervisor control system inwind power generation *LSO 15.2* Plot the graph for various measurement obtained in supervisor control system	15.	Development of simulation model for supervisor control system for wind energy system a) Develop wind power generation with supervisor control system in simulation tool b) Measure electrical parameters of wind power generation	CO-1

K) Suggested Problems/Micro Projects: Problems/Micro projects may be designed for the attainment of identified COs/combination of COs

i. Design a rooftop vertical wind power generation unit for a given specification of load in the building.

- Lamps: 40W X 10 numbers
- Fans: 60WX10 Numbers
- Select other type of load with their ratings

ii. To promote ecologically sustainable growth in solar and wind energy, Government of India initiated research and development for achieving self-reliance in the power sector supplementing the core conventional resources. Wind turbines reduce electricity generation from fossil fuels, which results in lower total air pollution and carbon dioxide emissions. An individual wind turbine has a relatively small physical footprint

In this context, prepare a project proposal to implement "rooftop vertical wind power generation unit for a given specification".

- Total electrical load of the consumer with detailed specifications of all components/gadgets
- Daily, weekly and monthly load curve of the chosen consumer
- Daily, weekly and monthly wind velocity profile for the chosen location
- Detailed block diagram to setup vertical wind energy system on rooftop
- Estimating the size and specifications of vertical wind turbine system and accessories with justification.

iii. Simulations can accelerate the testing and development process by allowing multiple scenarios in wind energy conversion system to be tested quickly and simultaneously. Models allow different types and configurations of wind turbine to select suitable one for given location.

iv. Develop simulation model of the following:

- Singly fed induction generator connected to load with suitable converter
- Doubly fed induction generator connected to load with suitable converter

v. Perform the following with the developed simulation model:

- Analyze the power flow from stator side to the load in doubly fed induction generator
- Analyze the power flow from rotor side to the load doubly fed induction generator
- Analyze and compare the performance of singly fed and doubly fed induction generator

Note: Depending on the requirement of each laboratory experience, micro project and research based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- Wake effect
- Vortex wind power generator
- offshore wind forms

c. Self-Learning:

- Floating wind mill
- Aerodynamics model of wind turbine
- Industrial visit

d. Nearby Solar PV pool integrated with grid and prepare report on

- Wind power generated from one unit per day
- Wind power generated from wind farm per day
- Average annual power generated from the wind farm
- Type wind generator used in the farm with justification

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit -1.0 Introduction to Wind Energy	14
CO2	Unit -2.0 Wind Turbines	14
CO3	Unit -3.0 Wind Turbine Generators	14
CO4	Unit -4.0 Wind Farm performance Indices	14
CO5	Unit -5.0 Analysis and implementation of wind Mills	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	Vertical Axis Micro Wind Energy Generator	5A, 12V	1-2,9
2.	Horizontal Axis wind turbine	10 A, 12 V	3-5, 7-8
3.	Charge Controller	10 A,24 V	6
4.	MATLAB Software	Simulink tool box, Simscape tool box	10-15

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Wind Power Technology	Joshua Earnest	Edition, PHI Learning Pvt. Ltd., New Delhi, 2019
2.	Wind Energy: Fundamentals, Resource Analysis and Economics	Sathyajith Mathews	Springer, 2006
3.	Wind Energy Systems and Applications	D.P. Kothari and S. Umashankar	Alpha Science International, 2014
4.	Wind Power Plants and Project Development	Joshua Earnest and Tore Wizelius	Second Edition, PHI Learning Pvt. Ltd., New Delhi, 2017

b) Online Educational Resources (OER):

11) https://archive.nptel.ac.in/courses/108/105/108105058/
12) https://archive.nptel.ac.in › chap6 › teach_slides06
13) https://www.studocu.com/in/document/srm-institute-of-science-and-technology/electronics/wind-energy-nptel-written/53840938
14) https://nptel.ac.in/courses/103103206
15) https://archive.nptel.ac.in/courses/103/103/103103206/
16) https://onlinecourses.nptel.ac.in/noc21_ch11/preview
17) https://freevideolectures.com/course/4480/nptel-non-conventional-energy-resources/27
18) https://www.youtube.com/watch?v=EYYHfMCw-FI
19) https://www.youtube.com/watch?v=5vj6GwVhQT0
20) https://www.youtube.com/watch?v=rO5rUqeCFY4
21) https://www.youtube.com/watch?v=rI7GRfhcQbk

Q) Course Curriculum Developer

S. No.	Name	E-mail Address
1.	Prof. K. Manickavasagam	kmanickavasagam@nitttrbpl.ac.in

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A)	**Course Title:** Modeling and Simulation of Green Energy Systems	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH06	
C)	**Pre- requisite (s):** Renewable Energy Technologies, MATLAB, Basic Electrical Engineering	

D) **Rationale:** The world is transitioning towards sustainable energy sources to mitigate climate change and reduce reliance on fossil fuels. Renewable sources such as solar and wind exhibit variability due to weather conditions. Modeling and simulation play a crucial role to understand and mitigate challenges like grid stability, storage requirements, and optimal resource utilization. There is a wide range of simulation software available (e.g., MATLAB/Simulink, PSCAD, EnergyPlus) tailored for different aspects of green energy systems. These tools offer capabilities for modeling components (PV panels, wind turbines), system dynamics, control strategies, and economic assessments. Simulation allows for the optimization of renewable energy system design, layout, and operation to maximize efficiency and economic viability. It facilitates the evaluation of system performance under varying conditions, supporting informed decision-making in energy projects. The course fosters interdisciplinary collaboration between engineering, environmental science, economics, and policy studies. Students learn to integrate technical knowledge with environmental and economic considerations, addressing real-world energy challenges comprehensively. It equips them with technical skills, analytical capabilities, and a holistic understanding needed to drive the transition towards a sustainable energy future.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH06.CO1	Apply software tools and platforms used for modeling and simulating renewable energy systems
GTECH06.CO2	Develop simulation model of solar PV system under varying atmospheric conditions
GTECH06.CO3	Develop simulation model of wind energy conversion system for different wind speeds
GTECH06.CO4	Develop simulation model of hybrid energy systems
GTECH06.CO5	Develop Simulation model of a Fuel cell

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH06.CO1	2	2	2	2
GTECH06.CO2	2	2	2	2
GTECH06.CO3	3	3	2	3
GTECH06.CO4	3	2	3	3
GTECH06.CO5	3	2	3	2

Legend: High (3), Medium (2), Low (1) and Nomapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH06	PCC	Modeling and Simulation of Green Energy System	45	15	45	15	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Differentiate between continuous and discrete systems, linear and nonlinear systems, static and dynamic models. *TSO 1b.* Describe the principles used in modeling systems. *TSO 1c.* Explain the basics of simulation modeling. *TSO 1d.* Describe the role of simulation in evaluating and studying models. *TSO 1e.* Apply mathematical modeling techniques to represent real-world systems. *TSO 1f.* Utilize MATLAB as a generic modeling tool. *TSO 1g.* Simulate using computer software, specifically introducing MATLAB and PSpice with simple models.	**Unit-1.0 Modeling and Simulation** 1.1 Physical modeling: Concept of system and environment 1.2 continuous and discrete system 1.3 linear and nonlinear system 1.4 stochastic activities 1.5 Static and dynamic models 1.6 Principles used in modeling 1.7 Role of simulation in model evaluation and studies 1.8 Advantages and Disadvantages of simulation 1.9 Modeling of Systems 1.10 Mathematical Modeling 1.11 Introduction to modelling and simulation tools: 1.12 Generic modelling tool - MATLAB 1.13 Simulation of mathematical model using computer software; introduction to Matlab and PSpice using simple models. 1.14 Importance and types of graphical output.	**CO1**
TSO 2a. Assess shading affects on I-V curves in PV systems. *TSO 2b.* Explain the concept of Maximum Power Point Tracking (MPPT) in photovoltaic systems. *TSO 2c.* Describe grid-connected PV systems and stand-alone photovoltaic systems. *TSO 2d.* Model photovoltaic cells *TSO 2e.* Explain series-parallel connections of PV cells. *TSO 2f.* Explain the simulation model for the characterization of photovoltaic systems under varying radiation and shadow conditions. *TSO 2g.* Describe the simulation model of photovoltaic models for on-grid applications. *TSO 2h.* Describe the simulation model of off-grid (stand-alone) photovoltaic systems.	**Unit-2.0 Modelling and Simulation of Solar Photovoltaic Systems** 2.1 PV source, 2.2 Photovoltaic Cell, Cells to Modules to Arrays, 2.3 Equivalent Circuits 2.4 I –V Curve 2.5 Impacts of Temperature and Insolation 2.6 Shading impacts on I–V curves 2.7 MPPT 2.8 Grid-Connected Systems 2.9 Stand-Alone PV Systems 2.10 Dynamics of PV generation sources 2.11 Modelling of photovoltaic cell. 2.12 Series- Parallel connection of PV cell. 2.13 Simulation of PV system characterization under the influence of varying radiation and Shadow 2.14 Simulation of Photovoltaic Model for on-grid 2.15 Simulation of off-grid /stand-alone system	**CO1 & CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 3a. Analyze Fixed-speed Induction Generator (FSIG) based wind turbines. *TSO 3b.* Analyze Doubly Fed Induction Generator (DFIG) based wind turbines. *TSO 3c.* Analyze Fully Rated Converter-based (FRC) wind turbines. *TSO 3d.* Perform dynamic modeling and analysis of wind energy systems. *TSO 3e.* Explain the control systems used in wind energy applications. *TSO 3f.* Describe the simulation model of wind energy systems for analysis. *TSO 3g.* Describe the simulation model of wind energy systems to understand their performance under varying conditions.	**Unit-3.0 Modelling and Simulation of Wind Energy System** 3.1 Wind Energy- Systems 3.2 Power generation in the Wind 3.3 Maximum Rotor Efficiency, 3.4 Types of Wind Turbines: 3.5 Fixed-speed Induction Generator based Wind Turbines 3.6 Doubly Fed Induction Generator based Wind Turbines 3.7 Fully Rated Converter-based Wind Turbines 3.8 Dynamic modelling and analysis of wind energy system 3.9 Wind energy control system 3.10 Modelling of wind energy system 3.11 Simulation of wind energy system	**CO1&CO3**
TSO 4a. Perform dynamic modeling and simulation of Proton Exchange Membrane (PEM) fuel cells. *TSO 4b.* Perform dynamic modeling and simulation of Solid Oxide Fuel Cells (SOFC). *TSO 4c.* Describe the principles of operation and modeling of Electrolysers. *TSO 4d.* Describe power electronic interfacing circuits used in fuel cell systems. *TSO 4e.* Analyze applications and control of grid-connected fuel cell power generation systems. *TSO 4f.* Describe the simulation model of PEM Fuel Cells *TSO 4g.* Describe the simulation model of Solid Oxide Fuel Cells	**Unit-4.0 Modelling and Simulation of Fuel Cell** 4.1 Principles of Operation of Fuel Cell 4.2 Fuel cell characterization and analysis of polarization curve 4.3 Dynamic modelling and Simulation of PEM Fuel Cells 4.4 Dynamic modelling and Simulation of Solid Oxide Fuel Cells 4.5 Principles of Operation and modelling of Electrolysers 4.6 Power Electronic Interfacing Circuits for Fuel Cell 4.7 Applications, Analysis and Control of Grid Connected Fuel Cell Systems.	**CO1 & CO4**
TSO 5a. Explain the principles and operation of different types of biomass gasifiers: • Updraft gasifier • Downdraft gasifier • Cross-draft gasifier • Multi-fuel gasifier • Fixed bed gasifier • Fluidized bed gasifier *TSO 5b.* Describe the simulation model of biomass gasification systems *TSO 5c.* Analyze the characteristics and performance of biomass gasification	**Unit-5.0 Modelling and Simulation of Systems using Biomass** 5.1 Updraft gasifier 5.2 downdraft gasifier 5.3 cross draft gasifier 5.4 multi fuel gasifier 5.5 fixed and 5.6 fluid bed gasifier 5.7 Simulation and modelling of Biogas plant. 5.8 Characteristics and performance of biomass gasification processes.	**CO1 & CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
processes. *TSO 5d.* Explain the principles and operation of biogas plants.		

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1. Describe various software/tools for modeling renewable energy Systems (HOMER, RETScreen, and MATLAB Simulink) *LSO 1.2.* Develop proficiency in using simulation software tools to create and analyze models.	1.	Evaluate various modeling softwares and tools for modeling Renewable Energy Systems (HOMER, RETScreen, and MATLAB Simulink)	CO1
LSO 2.1. Develop simulation model of a solar PV energy system *LSO 2.2.* Evaluate the performance of the simulated solar PV system *LSO 2.3.* Measure key performance parameters, such as: • Output voltage and current • Power delivered • System efficiency • Voltage ripple and tracking accuracy	2	Develop simulation model and analyze performance of Solar PV Energy System.	CO1 &CO2
LSO 3.1. Develop simulation model of a wind energy generator system. *LSO 3.2.* Evaluate the performance and reliability of the simulated wind energy system, such as: • Rotor speed • Output voltage and frequency • Power output and efficiency	3.	Develop simulation model and analyze performance of Wind Energy Generator.	CO1 &CO3
LSO 4.1. Develop simulation model of a grid-connected DFIG wind generation system *LSO 4.2.* Evaluate the performance of simulated DFIG wind generation systemincluding: • Active and reactive power output • Rotor speed and electromagnetic torque • Stator voltage and current • DC-link voltage stability	4.	Simulation and Modelling of Grid connected DFIG wind generation and analyze performance under varying wind, and grid conditions.	CO1 & CO4
LSO 5.1. Develop simulation model of a fuel cell system. *LSO 5.2.* Analyze the performance of the simulated fuel cell system. *LSO 5.3.* Utilize simulation outputs to inform the integration of fuel cell systems into practical applications	5.	Modeling of Fuel Cell and performance evaluation	CO1 &CO4

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 6.1. Develop simulation model for a grid-connected PV system with P&O MPPT. *LSO 6.2.* Evaluate simulation parameters such as irradiance levels, temperature variations, and load conditions to observe the effect on PV system performance and MPPT accuracy. *LSO 6.3.* Evaluate the performance and efficiency of the P&O MPPT algorithm	6.	Simulation of Grid connected PV MPPT (P&O) single stage and analyze performance	CO2
LSO 7.1. Explain the dynamics of photovoltaic (PV) systems, *LSO 7.2.* Develop model of PV systems under various shading conditions *LSO 7.3.* Interpret simulation results to analyze the effect of shading on PV system parameters, including power output reduction, current-voltage characteristics, and hotspot formation. *LSO 7.4.* Utilize simulation outputs to inform the design and layout of PV installations.	7.	Simulation of PV generation and analyze performance of Shadowing effect	CO1 &CO2
LSO 8.1. Develop a simulation model for a hybrid (solar-wind) power system *LSO 8.2.* Analyze simulation results to assess the combined performance of solar and wind energy sources in the hybrid system	8.	Simulation study on Hybrid (Solar-Wind) Power System and analyze performance	CO1, CO2 &CO3
LSO 9.1. Develop a simulation model for a DFIG-based wind energy conversion system using appropriate simulation software. *LSO 9.2.* Analyze simulation results to evaluate the performance characteristics of the DFIG-based WECS	9.	Simulation of WECS with DFIG and analyze performance	CO1 &CO3
LSO 10.1. Develop simulation model for a biomass power plant using appropriate software tools *LSO 10.2.* Evaluate the performance of the modeled biomass plant	10.	Modeling of Biomass Plant and performance evaluation	CO1 &CO5

K) Suggested Research Based Problems

i. Develop models that simulate the interaction between different energy sources and storage to achieve maximum efficiency, reliability, and cost-effectiveness under various conditions.

ii. Develop simulation tools to model the performance, degradation, and economic viability of different storage technologies (e.g., batteries)

iii. Simulate EMS strategies that balance renewable energy generation, storage, and load demand, while minimizing operational costs and emissions.

iv. Develop efficient energy management systems to optimize the use of green energy in smart grids.

v. Develop advanced simulation models that integrate weather forecasts, historical data, and machine learning techniques to predict renewable energy output on different time scales (e.g., hourly, daily, seasonal)

Note: Depending on the requirement of each laboratory experience, micro project and research based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Practice setting up a basic PV system simulation (e.g., PVsyst, SAM).
- Study simulation techniques for modeling BESS operation and control.
- Practice modeling hybrid systems using simulation software (e.g., RETScreen, HOMER).
- Learn about control strategies for microgrid operation and resilience.
- Learn the principles of life cycle assessment (LCA) applied to renewable energy systems.
- Study software tools and databases used for conducting LCAs (e.g., SimaPro, GaBi).
- Explore case studies and methodologies for assessing environmental impacts of green energy technologies.
- Explore case studies and research papers on grid integration solutions.
- Compare different software tools used for modeling and simulating green energy systems

b. Seminar Topics:

- Discuss optimization methods used in modeling and designing solar photovoltaic (PV) systems to maximize energy output
- Explore modelling approaches and software tools used to simulate the performance of wind turbines
- Investigate modeling techniques and control strategies for battery energy storage systems integrated with renewable energy sources.
- Discuss the integration and optimization of hybrid renewable energy systems combining multiple sources such as solar PV, wind turbines, and energy storage.
- Examine simulation tools and methodologies used for modeling micro grids integrating renewable energy sources, energy storage.
- Explore the use of simulation techniques in conducting life cycle assessments (LCA) of renewable energy systems.
- Discuss modeling and simulation of smart grid technologies for efficient integration of renewable energy
- Explore simulation tools and methodologies for modeling energy-efficient buildings incorporating green technologies

- Discuss simulation-based studies on grid integration challenges associated with increasing penetration of renewable energy sources.
- Review various software tools and platforms used for modeling and simulating renewable energy systems.

c. Self-Learning:

- Industrial visit
- CoE Lab
- PV power plant
- Visit solar PV testing facilities to understand how performance data is collected and analyzed.
- Visit wind energy research sites with operational wind turbines.
- Visit sites with energy storage systems (e.g., battery banks, pumped hydro storage).
- Visit micro grid installations that incorporate renewable energy sources and smart grid technologies.
- Energy-Efficient Buildings and Sustainable Infrastructure.

d. Suggested Problems/Micro Projects: Problems/Micro projects may be designed for the attainment of identified COs/combination of Cos

- Hybrid Fuel Cell Based Energy System Case Studies
- Develop a simulation model to optimize the photovoltaic (PV) panels on rooftops to maximize solar energy capture throughout the year
- Create a simulation model to design and analyze the performance of a solar water heating system.
- Develop a simulation model to assess the performance and efficiency of a wind turbine system.
- Design a simulation model to analyze the operation and performance of a battery energy storage system integrated with renewable energy sources (e.g., PV or wind).
- Develop a simulation model for optimizing a hybrid renewable energy system combining multiple sources such as solar PV, wind turbines, and possibly energy storage.
- Develop a simulation model to analyze the energy performance of a building incorporating green technologies.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit -1.0 Modeling and Simulation	14
CO2	Unit -2.0 Modelling and Simulation of Solar Photovoltaic Systems	14
CO3	Unit -3.0. Modelling and Simulation of Wind Energy System	14
CO4	Unit -4.0 Modelling and Simulation of Fuel Cell	14
CO5	Unit- 5.0 Modelling and Simulation of systems using biomass	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	High end computers	Operating Systems • Windows 11, Any Intel or AMD x86-64 processor with four logical cores and AVX2 instruction set support, 3.4 GB of disk space for MATLAB only, 5-8 GB for a typical installation, RAM Minimum: 4 GB, Hardware accelerated graphics card supporting OpenGL 3.3 with 1GB GPU memory is recommended.	1 to 10
2.	MATLAB Software	Developer: MathWorks Platform: Windows 10/11 (64-bit), macOS (Ventura/Sonoma), Linux (64-bit) Processor: Intel or AMD x86-64 processor RAM: Minimum 4 GB (8 GB or more recommended) Storage: ~3–5 GB for MATLAB only (up to 20 GB with toolboxes) Display: 1366×768 minimum (1920×1080 recommended) GPU Support: Optional (for deep learning and acceleration) Key Toolboxes: Simulink	1-10

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		Simscape / Electrical Control System Toolbox Powertrain & Vehicle Dynamics Blockset Battery Management Toolbox Embedded Coder Deep Learning Toolbox	

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Simulation Modeling and Analysis	Averill Law	Publisher Mc Graw Hill, Edition, Publication Date, 2015, ISBN10: 0073401323, ISBN13: 9780073401324
2.	Wind Energy Generation Modelling and Control	O. Anaya-Lara, N. Jenkins, J. Ekanayake, P. Cartwright, M. Hughes	Publisher: John Wiley & Sons 1st edition (2009), Language: English Paperback: 288 pages ISBN: 978-0-470-71433-1
3.	Modeling and Control of Fuel Cells: Distributed Generation Applications	M. H. Nehrir, C. Wang	ISBN: 978-0-470-23328-3, March 2009 Wiley-IEEE Press, 312 pages
4.	Modeling of photovoltaic system using MATLAB: simplified Green Codes	Tamer Khatib, Wilfried Elmenreich	First Edition, Wiley, 2016, ISBN: 978-1-119-11810-7, July 2016, 240 pages
5.	An Engineer's Guide to MATLAB® With Applications from Mechanical, Aerospace, Electrical, Civil, and Biological Systems Engineering	Edward B. Magrab, Shapour Azarm, Balakumar Balachandran, James H. Duncan, Keith E. Herold Fischell Gregory C. Walsh	Publisher, Pearson Prentice Hall, Edition 3rd, Publication Date, 2000, ISBN 13: 978-0-13-199110-1 ISBN 10: 0-13-199110-8

b) Online Educational Resources (OER):

1) Courses available through NPTEL. - website:
   - https://archive.nptel.ac.in/courses/117/108/117108141/
   - https://archive.nptel.ac.in/courses/112/107/112107214/
   - https://onlinecourses.nptel.ac.in/noc22_ch27/preview
   - http://acl.digimat.in/nptel/courses/video/103101215/L62.html

2) https://www.mathworks.com/help/sps/ug/single-phase-grid-connected-in-pv-system.html3.
3) https://www.mdpi.com/journal/applsci/topical_collections/Susta_Energy2.
4) https://www.syscop.de/files/2018ss/WES/handouts/script.pdf6.

Q) Course Curriculum Developer

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A)	**Course Title:** Electric Vehicle Technology	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH07	
C)	**Pre- requisite (s):** Basic Electrical and Electronics Engineering, Power Electronics and Electric Machines and Electric Drives	

D) **Rationale:** With mounting environmental concerns and the urgent need to reduce dependence on fossil fuels, EVs offer a viable and transformative alternative to conventional internal combustion engine vehicles. Simultaneously, Artificial Intelligence (AI) and Machine Learning (ML) are emerging as game-changers in the EV ecosystem. These technologies are increasingly being integrated into various aspects of electric vehicle design, operation, and management. Key applications of AI/ML in EV technology include: Battery Management Systems (BMS), Predictive maintenance, Energy-efficient route planning, smart charging and grid integration, etc. This course is designed to provide participants with a comprehensive understanding of electric vehicle technology while introducing cutting-edge AI/ML tools and techniques relevant to EV applications. It aims to bridge theoretical foundations with practical insights, preparing learners for emerging roles in EV design, manufacturing, data-driven diagnostics, and intelligent control systems. As the EV industry expands and converges with digital technologies, there is an urgent need to equip engineers, researchers, and technocrats with the interdisciplinary skillset necessary to drive innovation in this rapidly evolving domain. This course addresses that need, fostering future-ready professionals capable of contributing to the advancement and intelligent transformation of electric mobility.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH07.CO1	Analyse the performance of various EV types and their components
GTECH07.CO2	Develop simulation models to predict vehicle dynamics and range under various driving scenarios
GTECH07.CO3	Develop intelligent model to predict propulsion system performance under real-time operating conditions.
GTECH07.CO4	Select Power Electronics Solutions for EV Control and Charging
GTECH07.CO5	Evaluate the performance characteristics of Hybrid and Fuel Cell EV Systems

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH07.CO1	2	-	-	2
GTECH07.CO2	2	2	3	3
GTECH07.CO3	3	3	3	3
GTECH07.CO4	3	3	3	3
GTECH07.CO5	3	2	3	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH07	SSC	Electric Vehicle Technology	45	15	45	15	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Compare electric vehicles (EVs) with internal combustion engine (ICE) vehicles *TSO 1b.* Analyze the benefits and trade-offs of various EV architectures. *TSO 1c.* Illustrate the emissions profile of EVs compared to conventional vehicles and their role in reducing greenhouse gas emissions *TSO 1d.* Analyze energy storage systems and their advantages. *TSO 1e.* Explain the importance of energy management strategies. *TSO 1f.* Analyse the role of CAN in enabling communication between various EV components. *TSO 1g.* Analyse EV Charging Technologies	**Unit-1.0 Electric Vehicles** 1.1 Overview of Electric Vehicles 1.2 Comparison of Electric Vehicles with Internal Combustion Engines 1.3 EV architectures 1.4 EV types: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs) 1.5 Electric Vehicle components and sizing 1.6 Energy Storage system: Types of energy storage system 1.7 Energy management strategies (Battery Management System) 1.8 Communication system: CAN 1.9 EV Charging Technologies	**CO1**
TSO 2a. Explain various vehicle dynamics *TSO 2b.* Analyze the motion behavior of electric and hybrid vehicles by considering various resistive forces and external influences including rolling, gradient, and aerodynamic drag. *TSO 2c.* Describe the principles of vehicle dynamics in vehicle design and performance. *TSO 2d.* Evaluate Vehicle performance in terms of plant and transmission characteristics *TSO 2e.* Describe simulation models to predict vehicle performance. *TSO 2f.* Describe the concept of driving cycles and their importance in modeling electric vehicle range. *TSO 2g.* Describe simulation-based models integrating AI/ML techniques to predict vehicle performance metrics.	**Unit-2.0 Vehicle Dynamics** 2.1 Vehicle Dynamics 2.2 Rolling, Grading resistance, Road, and Acceleration resistance 2.3 Total driving resistance 2.4 Aerodynamic drag 2.5 Performance metrics: acceleration, top speed, range, energy consumption 2.6 Vehicle power plant and transmission characteristics and vehicle performance including braking performance 2.7 Simulation models to describe vehicle performance. 2.8 Modelling Electric Vehicle Range: Driving cycles	**CO2**
TSO 3a. Analyze various EV powertrain architectures *TSO 3b.* Illustrate various types of electric motors used in EVs, including DC motors, brushless DC motors, induction motors, permanent magnet synchronous motors, and switched	**Unit-3.0 Electric Vehicle Power Train and Propulsion System** 3.1 Powertrain architectures: series, parallel, and series-parallel configurations 3.2 Electric Motors for EV applications 3.3 Types of Motors: DC, Brushless DC,	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
reluctance motors. *TSO 3c.* Identify the key performance metrics and requirements for motors used in EVs. *TSO 3d.* Assess the factors influencing the rating and selection of motors for EV applications. *TSO 3e.* Select suitable motors based on application-specific parameters. *TSO 3f.* Analyze how different types of motors facilitate regenerative braking *TSO 3g.* DescribeML models for the power traction system of EVs.	Induction, Permanent Magnet Synchronous Motors, Switched Reluctance Motors 3.4 Characteristics of motors 3.5 Rating and selection criteria of motors 3.6 Physical location of motors 3.7 Regenerative braking 3.8 Mechanical and Electrical connections 3.9 ML models for predicting motor performance under dynamic driving conditions.	
TSO 4a. Analyse the operation of four-quadrant DC choppers and their application. *TSO 4b.* Evaluate the performance and characteristics of induction motor drives in various operating conditions. *TSO 4c.* Describe the principles and advantages of permanent magnet motor drives in EVs *TSO 4d.* Analyze the characteristics, benefits, and challenges of using switched reluctance motor drives in EVs. *TSO 4e.* Assess the design, implementation, and control of EV charging systems, including the distinctions between Level 1, 2, and 3 chargers *TSO 4f.* Describe the role of power electronics in on-board and off-board chargers *TSO 4g.* Explain the potential of smart charging using basic AI algorithms.	**Unit-4.0 Power Electronics for EV** 4.1 Electronic controller: Power converters 4.2 DC Motor drive: Four quadrant DC chopper 4.3 Induction Motor drive 4.4 Permanent Magnet Motor drives 4.5 Switch Reluctance Motor drives 4.6 Electric Vehicle Charging • ON Board chargers – Off board chargers • Level 1 Charging • Level 2 Charging • Level 3 Charging 4.7 Smart charging systems and basic role of AI in charge scheduling	**CO4**
TSO 5a. Categorize hybrid and conventional vehicle configurations. *TSO 5b.* Analyze various hybrid drivetrain architectures to determine their suitability for. *TSO 5c.* Classify hybrid electric vehicles (HEVs) based on their degree of hybridization. *TSO 5d.* Describe the operating principles of hydrogen fuel cells and their integration within electric vehicle platforms. *TSO 5e.* Evaluate the characteristics and limitations of different types of fuel cells.	**Unit -5.0 Hybrid and Fuel Cell Vehicle** 5.1 Concept of hybrid vehicles 5.2 Hybrid drive train architecture – series, parallel torque, and speed coupling. 5.3 Hybrid Electric Vehicles classification: Micro, Mild, Full, Plug-in EV. 5.4 Fuel cell EVs: Technologies & Types 5.5 Operation principle 5.6 Fuel cell Characteristic 5.7 Data-driven models using AI/ML for performance prediction under varying load and environmental conditions	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 5f. Describe the Simulation model of fuel cell using AI-based performance prediction algorithms under varying operating conditions.		

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1. Develop simulation models of EVs using tools such as MATLAB/Simulink, or ANSYS. *LSO 1.2.* Estimate the vehicle's range based on various factors such as driving conditions, battery state-of-charge, and power consumption.	1.	Simulation of Electric Vehicle to analyze the effect of changing parameters on vehicle range and performance	CO1
LSO 2.1. Develop a simulation model of an EV that can accommodate various driving cycles. *LSO 2.2.* Demonstrate how different driving cycles impact the overall performance and efficiency of the EV.	2.	Simulation model of EV for analysing different driving cycles	CO1, CO3
LSO 3.1. Develop the simulation models of electric motors using tools like MATLAB/Simulink or ANSYS *LSO 3.2.* Analyze the torque-speed characteristics of electric motors. *LSO 3.3.* Illustrate how these characteristics vary with different operating conditions?	3.	Simulation of Electric Motor Performance Characteristics	CO2, CO3
LSO 4.1. Develop a simulation model of a four-wheeler EV using software such as MATLAB/Simulink *LSO 4.2.* Estimate the vehicle's range under various conditions and identify factors that influence range.	4.	Simulation of 4-Wheeler Electric Vehicle and performance analysis	CO1, CO2, CO3, CO4
LSO 5.1. Develop simulation model of the buck-boost converter using software such as MATLAB/Simulink. LSO 5.2. Evaluate voltage and current ripple in the converter output. LSO 5.3. Illustrate different control strategies for DC-DC converters	5.	Simulation of buck-boost type of DC-DC Converter for Battery Charging Application in Electric Vehicle and evaluation of performance parameters	CO4
LSO 6.1. Analyze the torque-speed characteristics of the BLDC motor *LSO 6.2.* Evaluate the performance of the BLDC motor *LSO 6.3.* Develop speed control algorithms to maintain desired motor speeds under varying load conditions.	6.	Performance study of BLDC electric vehicle motor (Hub) -BLDC (Brushless DC) Motor Trainer	CO3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 7.1. Determine key performance metrics such as capacity (Ah), energy density (Wh/kg), and power density (W/kg). *LSO 7.2.* Demonstrate the charging and discharging behaviour of lithium-ion batteries, including charge/discharge curves and efficiency. *LSO 7.3.* Determine the factors affecting battery cycle life and how to measure and interpret cycle life data.	7.	Performance parameters analysis of Lithium-ion battery for Electric Vehicle - Battery Characteristics Trainer	CO1, CO3
LSO 8.1 Analyze motor performance characteristics. *LSO 8.2* Determine the dynamics of EVs *LSO 8.3* Analyse the functions of the BMS *LSO 8.4* Evaluate performance metrics such as range, efficiency, and power consumption under different driving conditions.	8.	Evaluate performance metrics: range, efficiency, and power consumption under different driving conditions of EV: Electrical Vehicle Training System	CO1, CO2, CO3, CO4
LSO 9.1 Evaluate BMS effectiveness, including state of charge (SOC) accuracy, balancing efficiency, temperature control, and fault detection sensitivity. *LSO 9.2* Analyse different cell balancing techniques employed by the BMS	9.	Performance study of battery management system in Electric Vehicle Battery Management Systems.	CO1, CO3
LSO 10.1 Evaluate input/output voltage-current characteristics and boost ratio under varying load/sunlight conditions. *LSO 10.2* Evaluate output voltages, switching patterns, motor speed, and torque characteristics under various loading conditions.	10.	Performance study of 3 ϕ Inverter with MPPT DC-DC boost Converter and Bi-Directional Battery Charger For 48 V BLDC motor	CO1, CO4
LSO 11.1. Perform troubleshooting and diagnosis of the EV system *LSO 11.2.* Analyse the working of components and power supply from the battery *LSO 11.3.* Evaluate output voltages, switching patterns, motor speed, and torque characteristics under various loading conditions. *LSO 11.4.* Calculate system efficiency based on input power and mechanical output.	11.	Evaluate output voltages, switching patterns, motor speed, and torque characteristics under various loading conditions: 4-Wheeler Test Rig with Remote &IoT controlling features	CO1, CO2, CO3, CO4
LSO 12.1 Measure and record voltage, current, power, speed, and distance traveled during a test run. *LSO 12.2* Calculate system efficiency based on input power and mechanical output. *LSO 12.3* Analyze battery energy usage during a standard driving cycle. *LSO 12.4* Measure acceleration time, braking distance, and load-handling capacity.	12.	Evaluate output voltages, switching patterns, motor speed, and torque characteristics under various loading conditions: 2-Wheeler EV System	CO1, CO2, CO3, CO4

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 13.1 Measure open circuit voltage (OCV), and connect to a load to observe current-voltage characteristics. *LSO 13.2* Demonstrate the reactions occurring at the anode and cathode. *LSO 13.3* Evaluate energy conversion efficiency.	13.	Evaluate energy conversion efficiency: Fuel Cell Operation Principle Using PEM Fuel Cell	CO5
LSO 14.1 Measure the load in steps and measure: Voltage, Current, Power, Efficiency *LSO 14.2* Plot V-I and P-I curves. *LSO 14.3* Evaluate key fuel cell performance characteristics such as polarization curve, power curve, efficiency curve, and load behavior.	14.	Evaluate performance Characterics of Fuel Cell Performance Under Varying Load	CO5
LSO 15.1 Develop AI/ML model that predicts fuel cell output performance under varying load and environmental conditions. *LSO 15.2* Calculate dataset that includes: Input: Load (W), Temperature (°C), Humidity (%), Pressure (bar)Output: Voltage, Current, Efficiency *LSO 15.3* Evaluate Fuel Cell Performance Using AI/ML Models	15.	Predicting Fuel Cell Performance Using AI/ML Models	CO5

K) Suggested Research Based Problems

i. Investigate alternative materials like solid-state batteries or lithium-sulfur batteries to improve performance, longevity, and safety: Enhancing energy density and reducing charging time in lithium-ion batteries

ii. Develop smart grid solutions and vehicle-to-grid (V2G) technology that allows EVs to interact with the grid efficiently: Optimizing the charging infrastructure to support the growing number of EVs while minimizing the strain on the power grid.

iii. Develop algorithms that manage the energy consumption of autonomous EVs, including route optimization and energy-efficient driving patterns: Integrating autonomous driving technology with EVs to optimize energy use and improve safety.

iv. Develop efficient and safe wireless charging systems for EVs: Improving the efficiency, safety, and cost-effectiveness of wireless power transfer systems for dynamic and stationary charging scenarios.

v. Evaluate the environmental impact of EVs throughout their lifecycle, from production to disposal: Conducting comprehensive lifecycle assessments (LCAs) to identify areas for reducing the carbon footprint of EVs.

vi. Explore methods to harvest energy from various sources (e.g., solar panels, regenerative braking) to extend EV range.

vii. Explore wide-bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN) to create smaller, more efficient power electronics systems: Improving the efficiency and size of power electronics components like inverters and converters.

viii. Design a hybrid AI model to predict battery degradation trends and estimate RUL using real-world usage data.

ix. Develop a machine learning framework for real-time diagnosis of faults in inverters, converters, and traction motors.

x. Design a smart charging strategy that uses AI to manage EV charging loads, minimize cost, and maintain grid stability.

xi. Apply ML techniques to predict thermal loads and optimize thermal management systems for battery packs and power electronics.

xii. Implement AI for optimal control, fault detection, and health monitoring in fuel cell electric vehicles (FCEVs).

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted Cos.

- A 60 kWh battery is used in an EV. Calculate the estimated range of the vehicle if its average energy consumption is 150 Wh/km.
- An electric motor has an efficiency of 90% and draws 50 kW from the battery. Calculate:
    a. Mechanical power output
    b. Energy lost as heat
- Design a basic EV drivetrain block diagram including all major power flow components. Label each component clearly.
- Discuss the role of **charging infrastructure** in EV adoption. Compare Level 1, Level 2, and DC fast charging in terms of time, power rating, and use case.
- Perform a basic **comparison between an EV and ICE vehicle** in terms of total cost of ownership (TCO) over 5 years assuming given fuel and electricity prices.

b. Seminar Topics:

- Integration of EVs in smart grid
- Advancements in Battery Technology for Electric Vehicles
- Social dimensions of EVs.
- Electric Vehicle Charging Infrastructure: Challenges and Solutions
- Vehicle-to-Grid (V2G) Technology and Its Impact on the Energy Ecosystem
- Power Electronics in Electric Vehicle: Innovations and Applications

c. Self-Learning:

- Industrial visit

- EV Manufacturing Plants: Observe its production lines, battery manufacturing, and vehicle assembly.
- EV Charging Stations: Observe its infrastructure, technology behind fast charging, and user experience.
- EV Dealerships: Experience test drives, and learn about vehicle features.
- EV Fleet Operators: Observe the fleet management practices, operational challenges, and benefits of EV fleets.
- Charger Manufacturing companies Observe power electronics chargers
- History and evolution of EVs
- Battery Chemistry and Types (Lithium-ion, solid-state, and other emerging battery technologies)
- Fast charging and wireless charging technologies
- Key challenges and solutions for widespread adoption
- Vehicle-to-Grid (V2G) Technology
- Thermal Management in EVs
- Life Cycle Assessment of EVs
- Environmental impact from production to disposal
- Wireless charging of EVs, Battery swap technology, and Charging EVs from renewable energy sources
- Digital Twin Technology in Electric Vehicles
- Vehicle-to-Grid (V2G) and Bidirectional Power Flow Concepts
- AI-Enabled Fault Detection in Inverters and Converters
- Sensor Data Analytics for Predictive Diagnostics in Power Electronics

d. Suggested Problems/Micro Projects: Problems/Micro projects may be designed for the attainment of identified COs/combination of Cos

- Design and development of Power Electronic level 1 charger for EVs
- Design and development of EV cycle, car
- Integration of EV charging with PV
- Design and development of power electronics controller for EV traction system
- Case studies on: Policy and Market Trends or Global EV Market Trends
- Microcontroller-based Battery Monitoring System
- Regenerative Braking System demonstration model
- EV Charging Station Model
- Electric Bike Conversion
- Solar-Powered EV Charger
- Microcontroller-based Smart EV Dashboard (Indicating parameters)
- Wireless EV Charging System
- Microcontroller-based Energy Management System for EVs
- Design and development of Dual active bridge (DAB) for EV chargers
- Design a BMS health monitoring model using ML algorithms (e.g., K-Means or Isolation Forest) to detect anomalies in voltage, current, and temperature readings.
- Create a smart charging scheduler that uses AI to optimize charging time, grid load balancing, and energy cost.

- Develop an ML model to predict overheating risks in power converters and suggest pre-emptive cooling strategies.
- Implement a deep learning model to monitor power converter waveforms and detect faults such as short-circuit, open-circuit, and insulation failure.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1.0 Electric Vehicles	10
CO2	Unit-2.0 Vehicle Dynamics	16
CO3	Unit-3.0 Electric Vehicle Power Train and Propulsion System	16
CO4	Unit-4.0 Power Electronics for EV	14
CO5	Unit-5.0 Hybrid and Fuel Cell Vehicle	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	MATLAB/Ansys SIEMENS	**Developer**: MathWorks **Platform**: Windows 10/11 (64-bit), macOS (Ventura/Sonoma), Linux (64-bit) **Processor**: Intel or AMD x86-64 processor **RAM**: Minimum 4 GB (8 GB or more recommended) **Storage**: ~3–5 GB for MATLAB only (up to 20 GB with toolboxes) **Display**: 1366×768 minimum (1920×1080 recommended) **GPU Support**: Optional (for deep learning and acceleration) **Key Toolboxes**: Simulink	**1-15**

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		Simscape / Electrical Control System Toolbox Powertrain & Vehicle Dynamics Blockset Battery Management Toolbox Embedded Coder Deep Learning Toolbox	
2.	BLDC (Brushless DC) Motor Trainer	• 200W BLDC Type DC machine • Voltage rating should be 24V • 8Amp. Current • Speed should be 2500 RPM ±10%, • Mechanical Loading arrangement, • Onboard 300V Digital DC voltmeter • 10A DC Ammeter, should be provided • 20000 RPM –on board digital Tachometer speed measurement should provide with setup.	6
3.	Lithium-ion battery for Electric Vehicle -Battery Characteristics Trainer	• 12V, 7 to 7.8Ah Li-Ion battery • On board 20V DC voltmeter • 10Amp DC ammeter should be provided • PWM based Charge controller should be inbuilt • LCD display should provide for Battery level indicator • Software shall be provided for data logging of battery characteristic parameters.	7
4.	Electrical Vehicle Training System	• Electric Vehicle Training System a real time and interactive, provide with operational block diagram of E-Vehicle for understanding, it should also provide with • sensors and its functionality, should provide • Onboard meters (AC Voltmeter, AC Ammeter, DC Voltmeter, DC Ammeter, RPM meter, Battery capacity meter) for measurement analysis. • 250W 36V Hub type BLDC Motor should have approx. 200 RPM approx. on full load, • 36V 10 AH Li-ion battery should be provided. • Package should include: Key switch, Head light, Tail light, Brake, Horn and Battery level indicator	8
5.	Battery Management System in Electric Vehicle	• Onboard, • Voltage measurement • Current measurement • Temperature measurement • Cell balancing. • All these parameters to be display on big graphical LCD. • Single Phase, 230V 50Hz, • BLDC Machine, Motor: Type: BLDC, • Rating: 24V, • Speed: 2800 RPM±10%. Tachometer – 20000 RPM, Contactless type • Facility to measure all individual cell voltages at a time on display.	9

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		Battery Pack: Detachable with DIN cable 6 no. String, Li-Ion Rating: 3000mAh. Configuration: Series. Control Panel consist of high grade FRP material for better safety and in compliance with IS302-1/IEC60335-1, tested from NABL accredited Lab. BS10 safety terminals are in compliance with IS302-1/IEC60335-1, tested from NABL accredited Lab.	
6.	3 ϕ Inverter with MPPT DC-DC boost Converter and Bi-Directional Battery Charger For 48 V BLDC motor	Performance study of 3 ϕ Inverter with MPPT DC-DC boost Converter and Bi-Directional Battery Charger For 48 V BLDC motor • 2x500 W Solar Panel • DC-DC Boost Converter with MPPT • 3 phase Inverter • 48 v/1kW BLDC Motor • Bi Directional DC-DC Converter for Li-Ion Battery • 48V/60 Ah Li-Ion Battery • Li-Ion Battery Charger	10
7.	Advanced 4 Wheeler Electric Vehicle Simulator with Loading & Data Extrapolation Facility	Advanced 4 Wheeler Electric Vehicle Simulator with Loading & Data Extrapolation Facility • Complete 4 wheeler system with subsystems electrical and electronics and sensors fitted for real-time data • FieldProgrammable data acquisition system. • Data relay over WIFI. • Manual loading of motor at different Load • Interactive UI • Save, Calculate, Export, plot data on UI • Carry Experimental Setup on UI • Heat analysis of Different components • Auto/Manual Acceleration and Cutoff • WHTC, WHVC, FTP 72, FTP 75, MIDC etc test cycles available for testing • Interactive python IDE in UI. 12. Additional features can be added to UI.	11
8.	Advanced 2 Wheeler Electric Vehicle Simulator with Loading & Data Extrapolation Facility Test Bench/Rig	Advanced 2 Wheeler Electric Vehicle Simulator with Loading & Data Extrapolation Facility Test Bench/Rig • Complete 2 wheeler system & subsystems with electrical and electronics and sensors fitted for raltime data Field • Programmable data acquisition system • Data relay over WIFI. 4. Manual loading of motor at different Load	12

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		• Interactive UI • Save, Calculate, Export, plot data on UI • Carry Experimental Setup on UI • Heat analysis of Different components • Auto/Manual Acceleration and Cutoff • WHTC, WHVC, FTP 72, FTP 75, MIDC etc test cycles available for testing • Interactive python IDE in UI. 12. Additional features can be added to UI	
9.	High end computers	High end computers Processor Intel Core i9 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10	13
10.	Power Analyser	Power Analyser • Voltage Cord (L1000)- 1 Nos. • AC Adaptor (Z1002) – 1 Nos. • Battery Pack (Z1003) – 1 Nos. • USB Cable – 1 Nos. • SD Card 2 GB (Z4001) – 1 Nos. • AC Current Sensor (CT7136) – 4 Nos. • Patch Cord (L1021-02) – 3 Nos. • Carrying Case (C1009) – 1 Nos. User Manual/Software CD	6-15
11.	PEM Fuel Cell Trainer Kit	PEM Fuel Cell Trainer Kit Power: 10–50 W, Voltage: 0.6–1.2 V/cell, Stack: 5–20 cells, Input: H_2/O_2 or air	13,14 & 15
12.	Hydrogen Supply with Flow Regulator	Cylinder or electrolyzer source, Flow range: 0–1 L/min	13
13.	Oxygen/Air Supply with Flow Control	Oxygen/Air Supply with Flow Control Air pump with moisture trap or O_2 cylinder, Flow range: 0–2 L/min	13
14.	DC Programmable Electronic Load	DC Programmable Electronic Load Voltage: 0–150 V, Current: 0–10 A (or as per fuel cell output), Modes: CC/CV/CR	6-15
15.	Digital Multimeter (3 Nos.)	Digital Multimeter (3 Nos.) Voltage range: 0–600 V, Current range: up to 10 A, Accuracy: ±0.5%	6-15
16.	Data Acquisition System (DAQ)	Data Acquisition System (DAQ) 4–8 channels, USB interface, Sampling rate: ≥10 kS/s	6-15
17.	Temperature & Humidity Sensor Module	Temperature & Humidity Sensor Module DHT22 or SHT31, Range: -40°C to +125°C, 0–100% RH, Accuracy: ±2%	6-15

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles	Mehrdad Ehsani, Yimin Gao, Stefano Longo, KambizEbrahimi	Publisher, CRC Press, Edition 3 Publication Date, 28 March 2018 ISBN-13: 978-1498761772
2.	Hybrid, Electric and Fuel Cell Vehicles	Jack Erjavec and Jeff Arias	Publisher: Cengage Learning, Inc; 2nd edition (6 June 2012), Language: English, Paperback: 400 pages ISBN-10: 0840023952 ISBN-13: 978-0840023957
3.	Hybrid Electric Vehicle System Modeling and Control	Wei Liu	General Motors, USA, John Wiley & Sons, Inc., 2017. ISBN: 978-1-119-27932-7 March 2017, 584 pages
4.	Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market	Noshirwan K. Medora	Elsevier, Hardback ISBN: 9780444535658 Paperback ISBN: 9780444638250 eBook ISBN: 9780444535665
5.	Electric and Hybrid Vehicles	Tom Denton, Hayley Pells	Publisher Routledge, Edition 1 Publication Date 3 July 2017 ISBN 9781032556796
6.	Electric and Hybrid Vehicles: Design Fundamentals.	Iqbal Husain	Publisher, CRC Press, Edition 2, Publication Date, 16 August 2010, ISBN-13: 978-1439811757

b) Online Educational Resources (OER):

1) https://nptel.ac.in/courses/108106170
2) https://archive.nptel.ac.in/courses/108/103/108103009/
3) https://www.coursera.org/learn/electric-vehicle-powertrain
4) https://www.coursera.org/learn/electric-cars
5) https://www.edx.org/course/electric-cars-business-and-technology

Q) Course Curriculum Developer

S. No.	Name	E-mail Address
1.	Prof. Pallavee Bhatnagar	pbhatnagar@nitttrbpl.ac.in

****

A)	**Course Title:** Energy Conservation and Audit	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH08	
C)	**Pre- requisite (s):** Basic Electrical Engineering, Basic Mechanical Engineering, Electrical Machines and Drives, Power Systems, Mathematics	

D) **Rationale:** Energy conservation is nothing but saving the energy not compromising with the comfort of life. Energy audit is providing an effective solution for energy conservation which provides vital information base for overall energy conservation program. The energy consumption is continuously increasing every year. Maintaining supply- demand gap calls for more capital investment. Energy management, energy efficiency, energy conservation and using renewable energy sources are the most cost-effective measures to reduce the demand supply gap, which also reduces environmental impact. This course will enable the students with essential theoretical and practical knowledge about the different approaches of energy conservation, efficient operation, energy management and energy audit practiced in industry. The integration of AI/ML techniques enhances the capability to analyze complex energy systems and predict energy consumption patterns, enabling data-driven conservation strategies.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH08.CO1	Interpret energy conservation policies and government initiatives in India.
GTECH08.CO2	Carry out comprehensive energy audits using modern instruments and softwares.
GTECH08.CO3	Evaluate energy conservation opportunities in electrical machines and drives with techno-economic feasibility analysis.
GTECH08.CO4	Evaluate energy conservation opportunities in electrical installation Systems with techno-economic feasibility analysis.
GTECH08.CO5	Develop Co-generation solutions and tariff optimization for reducing energy bill.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH08.CO1	3	3	2	2
GTECH08.CO2	3	3	2	2
GTECH08.CO3	3	3	2	2
GTECH08.CO4	3	3	2	2
GTECH08.CO5	3	3	2	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH08	SSC	Energy Conservation and Audit	45	15	45	15	120	04	30	70	20	-	20	30	170

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP: 2020, unique features like Green skills, Multidisciplinary Aspects, Societal Connect, IKS, Renewable Energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Analyze the energy scenario of conventional and non-conventional energy sources in India as on date. *TSO 1b.* Analyze the energy conservation initiatives by Government of India *TSO 1c.* Explain the concept of Energy management, Energy conservation, energy audit and energy efficiency with one example each. *TSO 1d.* Describe the salient features of Energy conservation act 2001. *TSO 1e.* Describe the role of a given national or state level agency. *TSO 1f.* Interpret the Star Labeling of the given electrical equipment. *TSO 1g.* Choose the mandatory and voluntary appliances from the given list of various star labeled appliances *TSO 1h.* Use AI and ML for analyzing the energy forecast.	**Unit-1.0 Elements of Energy Conservation** 1.1 Energy Scenario in India: conventional and non-conventional energy 1.2 Primary and Secondary energy sources, Energy demand and supply 1.3 Definition: Energy management Energy audit, Energy conservation and Energy efficiency and difference between them with examples 1.4 Energy conservation Policy in India 1.5 Energy conservation initiatives by GoI: i. Standards and Labelling ii. Energy Conservation Building Codes (ECBC) iii. Promotion of Energy Efficient LED Bulbs iv. Promotion of Electric Vehicle 1.6 Energy Conservation Act 2001: Relevant clauses of energy conservation 1.7 Role of National and state nodal agencies - BEE/MP Urja Vikas Nigam (MPUVNL), NPC, MNRE 1.8 Star Labelling: Need and its benefits, Mandatory and Voluntary appliances. 1.9 Machine learning fundamentals for energy applications 1.10 Use of AI and ML for forecasting the energy trends	**CO1**
TSO 2a. Define energy audit and its types justifying its need and significance. *TSO 2b.* Differentiate between various energy audit methodologies. *TSO 2c.* Develop a typical questionnaire for energy audit of the projects. *TSO 2d.* Describe the use of relevant energy audit instruments for the specified energy audit with examples. *TSO 2e.* Design energy measurement. monitoring and data collection procedures. *TSO 2f.* Calculate the Simple Pay Back period for the given situation. *TSO 2g.* Prepare comprehensive audit report for the given facility/apparatus. *TSO 2h.* Apply big data analytics for energy optimization	**Unit-2.0 Energy Audit of Electrical Systems** 2.1 Energy audit (definition as per Energy Conservation act), need and significance 2.2 Types of energy audit (walk through, detailed and investment grade 2.3 Questionnaire for energy audit projects 2.4 Energy measurement and monitoring techniques 2.5 Data acquisition systems and IoT integration 2.6 Energy audit instruments and their applications 2.7 Report preparation and presentation techniques 2.8 Financial analysis techniques -Simple payback period, Time value of Money, Net present value (NPV), Return on Investment (ROI), Internal Rate of Return (IRR), Risk and sensitivity analysis, numerical -Case Studies. 2.9 Big data analytics in energy sector	**CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 3a. Analyze losses in electrical machines and identify energy conservation opportunities *TSO 3b.* Describe the significant features of energy efficient motors listing their advantages and limitations *TSO 3c.* Design motor management and maintenance strategies *TSO 3d.* Analyze losses in transformer and identify energy conservation opportunities *TSO 3e.* Describe briefly the energy conservation techniques in a Transformer *TSO 3f.* Describe the significant features of given energy efficient transformer listing their advantages and limitations *TSO 3g.* Describe briefly the use of a given energy conservation equipment in a given electrical system	**Unit-3.0 Energy Conservation in Electrical Machines and Electric Drives** 3.1 Losses in Electrical machines and their minimization 3.2 Energy efficient motors and their selection criteria 3.3 Variable Frequency Drives and their applications 3.4 Motor management programs- Improving Power quality, Motor survey, Matching motor with loading, Minimizing the idle and redundant running of motor, Operating in star mode, Periodic maintenance 3.5 Rewinding of motor v/s Replacement economics 3.6 Condition monitoring and predictive maintenance 3.7 Losses in transformer and their minimization 3.8 Energy conservation techniques in Transformer -Load sharing, Parallel operation, Isolating techniques, Replacement by energy efficient transformers, Periodic maintenance **3.9** Energy Conservation Equipment: Soft starters, Automatic star delta convertor, Variable Frequency Drives, Automatic Power Factor Controller (APFC), Intelligent Power Factor Controller (IPFC)	**CO3**
TSO 4a. Implement power factor improvement techniques *TSO 4b.* Design power quality improvement systems *TSO 4c.* Optimize lighting and building energy systems *TSO 4d.* Integrate renewable energy with existing installations *TSO 4e.* Integrate smart grid technologies and demand response systems *TSO 4f.* Describe the building energy Management Systems *TSO 4g.* Integrate energy storage system in the distribution system.	**Unit-4.0 Energy Conservation in Electrical Installation Systems** 4.1 Power factor improvement techniques and benefits 4.2 Harmonic analysis and mitigation 4.3 Lighting systems optimization i. Energy-efficient lighting systems – Relamping with energy efficient LED lamps and luminaries ii. Improving lighting controls – Infrared sensors, automatic timers, motion sensors(PIR and Ultrasonic sensors),dimmers, smart control, iii. Centralized street light control-GSM/GPRS based systems and SCADA system, replacing energy inefficient accessories with new energy efficient fixtures and ballast, installation of separate transformer servo stabilizer for lighting	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
	4.4 Periodic survey and adequate maintenance programs 4.5 Energy management in UPS and battery backup systems 4.6 Building energy management systems (BEMS) 4.7 Smart grid integration and demand response 4.8 Energy-efficient wiring and distribution systems 4.9 Integration of renewable energy sources in existing installations 4.10 Energy storage system integration	
TSO 5a. Analyze the need of the cogeneration system for the given facility. *TSO 5b.* Design cogeneration systems for specific applications *TSO 5c.* Analyze tariff structures and develop optimization strategies *TSO 5d.* Conduct techno-economic feasibility studies of cogeneration project *TSO 5e.* Describe the working of a given type of Co-generation with the help of a neat sketch in a facility. *TSO 5f.* Implement optimization algorithm for cogeneration energy systems	**Unit-5.0 Energy Conservation through Cogeneration and Tariff** 5.1 Principles of cogeneration technology, combined Heat and Power (CHP)systems and Waste heat recovery systems 5.2 Types of Cogeneration systems and their applications: i. On the basis of sequence of energy use a. Topping cycle b. Bottoming cycle ii. On the basis of technology iii. Steam turbine Cogeneration iv. Gas turbine cogeneration v. Reciprocating engine Cogeneration 5.3 Performance evaluation and selection criteria for cogeneration 5.4 Tariff structures and optimization strategies 5.5 Tariff and Types of tariff structure: - LT and HT Tariff - Special tariffs - Time-off-day tariff - Peak-off-day tariff - Power factor tariff - MaximumDemand tariff - Load factor tariff and - Availability BasedTariff (ABT). 5.6 Application of tariff system to reduce energy bill. 5.7 Recent Madhya Pradesh Vidyut Vitaran Company's tariffs for different consumers 5.8 Optimization algorithms for Co generation energy systems	**CO5**

J) Suggested Laboratory Experiences:

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 1.1. Identify star labelled appliances and compare them for various star ratings *LSO 1.2.* Proficiency in analyzing the data sheets	1.	Identification of Star labelled electrical appliances and compare data sheets of various star ratings	CO-1
LSO 2.1. Identify various energy audit instruments used for audit in electrical utilities along with its use. *LSO 2.2.* Develop proficiency in using energy audit tools and techniques in electrical utilities	2.	Energy audit tools and techniques used for energy audit in electrical utilities	CO-2
LSO 2.3. Identify various energy audit instruments used for audit in thermal utilities along with its use *LSO 2.4.* Develop proficiency in using energy audit tools and techniques in thermal utilities	3.	Energy audit tools and techniques used for energy audit in thermal utilities	CO-2, CO5
LSO 2.5. Prepare a sample energy audit questionnaire for a given facility. *LSO 2.6.* Develop proficiency in analyzing the data collected	4.	Energy audit data collection through questionnaire for the given facility (Phase I,2 and 3) and its analysis	CO-2
LSO 2.7. Carry out energy audit and prepare energy audit report of your electrical department (Phase 1)	5.	Carry out energy audit and prepare Energy audit report of electrical department (Phase 1)	CO-2
LSO 2.8. Carry out energy audit and prepare energy audit report of your electrical department (Phase 2)	6.	Carry out energy audit and prepare Energy audit report of electrical department (Phase 2)	CO-2
LSO 2.9. Carry out energy audit and prepare energy audit report of your electrical department (Phase 3)	7.	Carry out energy audit and prepare Energy audit report of electrical department (Phase 3)	CO-2
LSO 3.1. Implement energy conservation techniques in a 3-phase induction motor *LSO 3.2.* Identify the effect of voltage reduction on motor performance and energy consumption	8.	Determination of reduction in power consumption in star mode operation of 3 phase Induction motor compared to delta mode	CO-3
LSO 3.3. Analyze the energy efficient operation in a given electric drive using different types of starters	9.	Analysis of the energy efficient operation in a given electric drive using different types of starters	CO-3
LSO 3.4. Analysis of the energy conservation measures in a given transformer	10.	Energy conservation measures in a given transformer	CO-3
LSO 3.5. Estimation of energy saving by improving power factor and load factor for given cases.	11.	Estimate energy saving by improving power factor and load factor for given cases.	CO-3
LSO 3.6. Use APFC for improvement of p. f. of electrical load	12.	Use of APFC for improvement of p. f. of electrical load	CO-3

Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment Titles	Relevant CO Number (s)
LSO 3.7. Use IPFC for improvement of p. f. of electrical load	13.	Use of IPFC for improvement of p. f. of electrical load.	CO-3
LSO 4.1 Compare power consumption of different types of TL with choke, electronic ballast and LED lamps by direct measurements	14.	Comparison of power consumption of different types of TL with choke, electronic ballast and LED lamps by direct measurements	CO-4
LSO 4.2 Measurement of energy conserved using automatic timers, motion sensors (PIR and ultrasonic sensors), and dimmers in a given lighting system	15.	Implementation of energy conservation techniques in lighting system	CO-4
LSO 4.3 Compare the energy efficient opportunities in Lamp replacements	16.	Comparison of energy efficient opportunities in Lamp replacements	CO-4
LSO 5.1. Analysis of energy conserved by using a cogeneration and captive power plant in a facility	17.	Analyze energy conserved by using a cogeneration and captive power plant in a facility	CO-5
LSO 5.2. Suggest suitable tariff or energy conservation and reduction of energy bill for an industrial customer *LSO 5.3.* Interpreting electricity bill of an industrial consumer	18.	Tariff for industrial consumer for reducing the electricity bill	CO-5
LSO 5.4. Suggest suitable tariff or energy conservation and reduction of energy bill for a commercial customer *LSO 5.5.* Interpreting electricity bill of a commercial customer	19.	Tariff for commercial consumer for reducing the electricity bill	CO-5
LSO 5.6. Suggest suitable tariff for energy conservation and reduction of energy bill for a residential customer *LSO 5.7.* Interpreting electricity bill of a residential customer	20.	Tariff for residential consumer for reducing the electricity bill	CO-5

K) Suggested Research Based Problems

i. Evaluating the effectiveness of integrating renewable energy sources (solar, wind, etc.) into existing energy systems in terms of efficiency and economic viability.
ii. Comparative analysis of energy conservation techniques in industrial motor systems
iii. Behavioral Aspects of Energy Conservation: Analyzing how human behavior affects energy consumption and exploring ways to encourage more sustainable practices.
iv. Studying the impact of energy conservation awareness programs and feedback systems on consumer behavior.
v. Optimization of Energy Audit Techniques: Developing new methods or improving existing techniques for more accurate and cost-effective energy audits in various types of buildings (e.g., residential, commercial, industrial).
vi. Machine learning approaches for anomaly detection in industrial energy consumption
vii. Development of IoT-based real-time energy monitoring and optimization system

viii. Integrating advanced sensors and data analytics to enhance audit precision and provide real-time feedback.

ix. Developing models to predict and optimize the integration of renewables based on local energy consumption patterns.

x. Advanced Energy Management Systems (EMS)

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted Cos.

- Carry out an internet survey to analyze the Indian energy scenario based on demand supply of both renewable and non-renewable energy sources and submit a report
- Carry out an internet survey to analyze the per capita electrical energy consumption of different countries in relation with the GDP and submit a report.
- Carry out internet survey (BEE) to collect information and prepare report related to any 2 Energy conservation projects.
- Collect the catalogues of various star labeled equipment's and Compile the energy saved in at least 5 star labeled consumer appliances and prepare a report.
- Write report on performance of motor after rewinding.
- Compare the energy conserved in different types of lamps and energy efficient luminaries and prepare a report on it.
- Visit a facility adopting cogeneration system and analyze the amount of energy conserved, prepare a presentation.
- Prepare a report on maintenance procedure followed for improving efficiency of a given lighting scheme.

b. Seminar Topics:

- Salient features of Energy conservation act 2001
- Energy audit instruments and their function
- Cogeneration and its advantages in energy conservation
- "Bachat Lamp Yojana" Scheme.
- Green buildings
- Development of AI-based energy management system for campus buildings

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1.0 Elements of Energy Conservation	10
CO2	Unit 2.0. Energy Audit of Electrical Systems	16
CO3	Unit 3.0 Energy Conservation in Electrical Machines	14
CO4	Unit 4.0 Energy Conservation in Electrical Installation Systems	16
CO5	Unit 5.0 Energy Conservation through Cogeneration and Tariff	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
1.	Portable Combustion Analyzer (PCA)	This instrument has in-built chemical cells which measure various gases such as O2, CO, NOX and SOX. The portable digital instrument performs the measurements and reads out combustion efficiency in percent's. reliable and easy-to-use tool for energy auditors who need to determine carbon monoxide (CO) safety and combustion efficiency in residential or commercial furnaces, hot water heaters, and boilers. The Good combustion usually means high carbon dioxide (CO2), low oxygen (O2), and little or no trace of carbon monoxide (CO).	3,17
2.	BASIC Energy Analyzer (also called a power meter	It can locate, predict, prevent, and troubleshoot power quality problems in single-phase and three-phase power distribution systems, to help facilities reduce electrical power consumption and to improve the performance of electro-mechanical equipment. The analyzer measures voltage, current, dips, swells, interruptions, harmonics, power, energy, frequency, inrush, and power inverter efficiency. It calculates the monetary cost of poor power	All

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		quality and helps to pinpoint the origin of energy waste in a system. The logger function, activated by a button, allows user-configurable, long-term recording of minimum, maximum, and average readings for up to 150 parameters on all three phases and neutral. The USB port and cable (included) transfers data to a PC for trend and waveform data analysis in Power Log software (included).	
3.	Fuel Efficiency Monitor:	This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency	17
4.	Fyrite:	A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O2 and CO2 measurement.	17
5.	Contact thermometer:	These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.	All
6.	Infrared Thermometer:	Used for measuring temperatures from a distance using infrared technology. This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.	2,3
7.	Thermal Insulation scanner	Used for measuring loss of energy in kcal per unit area from hot/cold insulated surfaces. The total loss can be obtained by multiplying the total surface under study	3
8.	Demand analyzer	Used for measurement of load and analysis of electrical load and demand control	15,16
9.	Power Analyzer	Portable, digital, Used for measurement and analysis of electrical power and pf	15,16
10.	Harmonic Analyzer	Used for analysis of harmonics in power system	15,16
11.	Clip on digital wattmeter	Used for measuring power without interrupting connections	All
12.	Clip on digital pf meter	Used for measuring power factor without interrupting connections	All
13.	Clamp on ampere meter	Used for measuring current without interrupting connections	All
14.	Digital multimeter	Used for measurement of voltage, current and resistance of different ranges	All
15.	Frequency meter	Used for measurement of power supply frequency	All
16.	Water flow meter:	This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.	3
17.	Speed Measurements:	Digital, contact type,5 digits, auto ranging, 2.5 ~ 99999 RPM ,Hz: 0.05 ~ 1666Hz, memory-Max value, Min value & Last value automatically stored in memory & save 96	9

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience /Practical Number
		set of continuous data.	
18.	Ultrasonic Leak Detectors:	Used to detect leak of compressed air and other gases. Ultrasonic leak detector has the following applications: Leaks in pressure and vacuum systems, Electrical discharge, Control of tightness with ultrasonic transmitter, Internal leaks in hydraulic systems, and Function control of steam traps.	ALL
19.	Digital Lux meters	Used for measurement of illumination levels. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.	14,15,16
20.	Flue gas analyzer	Used for optimizing the combustion efficiency by measuring /monitoring the oxygen and CO levels in flue gas boilers, furnaces etc., and calculation of CO2 percentage in excess air level and efficiency	3
21.	Automatic Weather Station Portable	Data logger with inbuilt Wifi OR GSM 32bit controller Wind Speed Sensor - Cup type Three cups: 0.5to70m/sec Accuracy:±3%WindDirection sensor: Arrow type Temperature:-40~75°C, Accuracy:-2% Humidity:0 to100%,Accuracy:5% Rain Gauge Mounting Arrangement: Minimum 3 meter pole to be mounted at Roof top Complete	All
22.	Data logger	No. of channels: 30 (expandable to 300 with plug-in input modules) Fully programmable	All
23.	Simulation Software	MATLAB/Simulink, ETAP	All

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Energy Management	Murphy W R	Elsevier/BSP Books Pvt. Ltd. (1 January 2003), ISBN-10: 8131207382 ISBN-13: 978-8131207383
2.	Energy Engineering and Management	Amlan Chakrabarti	PHI Learning; 2nd edition (30 January 2019), ISBN-10: 9387472892 ISBN-13: 978-9387472891
3.	Handbook of energy audit	Sonal Desai	McGraw Hill Education Private Ltd., 1 edition, ISBN: 9789339221331, 9339221338
4.	Energy Management audit and Conservation.	De, B. K	2nd edition, Vrinda Publication, 2010 ISBN: 9788182813434, 8182813433
5.	Energy Management Principles: Applications, Benefits, Savings	Craig b Smith	Pergamon Press, New York ISBN-10: 0080280366 ISBN-13: 978-0080280363
6.	Energy conservation Guidebook	Dale R. Patrick, Stephen W. Fardo, Ray E. Richardson, Steven R. Patrick	Fairmont Press; 2nd edition (29 January 2007), ISBN-10: 9780849391781 ISBN-13: 978-0849391781
7.	Energy Management Handbook	Steve Doty, Wayne C. Turner	Fairmont Press; 8th edition (14 December 2012), ISBN-10: 1466578289 ISBN-13: 978-1466578289

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
8.	Industrial energy conservation manual	Elias P Gyftopoulos	MIT Press (26 May 1982) ISBN-10: 0262090252 ISBN-13: 978-0262090254
9.	Energy Conservation	Diwan Parag	Pentagon Press ISBN: 9788182743502, 9788182743502
10.	Energy Management	Sanjeev Singh, Umesh Rathore,	S K Kataria&Sons, New Delhi ISBN-13: 9789350141014
11.	Energy Conservation and Audit	K. V. Sharma , P. Venkataseshaiah	I K International Publishing House Pvt. Ltd, 978-9381141298
12.	Energy Audit of Buildings: A Workbook for Energy Management in Buildings" -,	Tarun Gupta	Fairmont Press, ISBN: 978-0881735439
13.	Applied Machine Learning for Smart Energy Systems	Masoud Farzaneh	John Wiley & Sons, ISBN: 978-1119651871

b) Online Educational Resources (OER):

1) Bureau of Energy Efficiency (BEE) India: https://beeindia.gov.in/
2) International Energy Agency (IEA): https://www.iea.org/
3) ASHRAE Energy Efficiency Resources: https://www.ashrae.org/
4) Energy.gov Resources: https://www.energy.gov/
5) www.aipnpc.org
6) www.greenbusiness.com
7) https://powermin.gov.in/
8) https://akshayurja.gov.in/res/renw-all-india-cp
9) https://www.eia.gov/totalenergy/
10) https://www.energy.gov/energysaver/articles/8-online-tools-help-save-energy-and-money
11) https://www.iiec.org/
12) Home page - Central Electricity Authority (cea.nic.in)
13) TEDDY Year Book published by Tata Energy Research Institute (TERI)
14) Bureau of Energy Efficiency Study Material for Energy Managers and Auditors Examination Paper I to IV
15) MOOC Course on "Energy Within Environmental Constraints" - Harvard University (edX)
16) MOOC Course on "Introduction to Sustainable Energy" - University of British Columbia (edX)MOOC Course on "Machine Learning for Engineers" - University of Colorado Boulder (Coursera)
17) MOOC Course on "Energy Efficiency in Buildings" - University of Edinburgh (FutureLearn)

Q) Course Curriculum Development Team

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A)	**Course Title:** Energy Storage Systems	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH09	
C)	**Pre- requisite (s):**	

D) **Rationale:** The renewable and popular energy generation sources such as solar and wind generates energy in variable patterns. Energy storage is the capture of energy produced at one time for use at a later time to reduce imbalances between energy demand and energy production. The energy storage can be in various forms. Hence this course will acquaint the learners with the vital aspects of underpinning available and potential energy storage technologies that is becoming of major importance to store and supply energy without any interruption as well as for climate change mitigation and grid stability. This course will make the students understand how the key energy storage technologies work, solve real-world problems at domestic, city and grid scales and acquaint them with novel developments in energy storage technology research.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
GTECH09.CO1	Justify the need of energy storage and different types of energy storage.
GTECH09.CO2	Compare various ways to store electrochemical energy, its analysis and use.
GTECH09.CO3	Analyse features of thermal and mechanical energy storage system.
GTECH09.CO4	Evaluate techno-economic performance of hydrogen storage and fuel cell systems.
GTECH09.CO5	Apply EES systems to various applications/utility.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH09.CO1	3	3	2	2
GTECH09.CO2	3	3	2	2
GTECH09.CO3	3	3	2	2
GTECH09.CO4	3	3	2	2
GTECH09.CO5	3	3	2	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH09	SSC	Energy Storage Systems	45	15	-	30	90	03	30	70	20	-	-	-	120

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the concept of energy storage for continuous and flexible supply. *TSO 1b.* Enlist the various applications of energy storage systems. *TSO 1c.* Classify energy storage technologies *TSO 1d.* Compare various energy storage technologies. *TSO 1e.* Analyze the efficiency of energy storage systems.	**Unit-1.0 Overview of Energy Storage Technologies** 1.1 Concept of energy storage systems, role of energy storage systems, applications 1.2 Different types of energy storage: Mechanical, chemical, electrochemical, electrical. biological, magnetic, electromagnetic, thermal 1.3 Comparison of energy storage technologies, efficiency of energy storage systems,	**CO1**
TSO 2a. Explain the basic concepts related with batteries i.e. electro chemical energy storage systems. *TSO 2b.* Explain how artificial intelligence enhances traditional BMS functionality. *TSO 2c.* Analyze the factors to the life-time and operations of individual battery technologies. *TSO 2d.* Compare the pros and cons of different battery storage systems i.e. Lead-acid, Nickel-Metal hydride, Lithium Ion for individual applications. *TSO 2e.* Develop battery system model. *TSO 2f.* Explain superconducting magnetic energy storage.	**Unit-2.0 Electrochemical Energy Storage** 2.1 Battery – fundamentals, technologies, characteristics, and performance metrics 2.2 AI-based Battery Management Systems (BMS) 2.3 Comparison: Lead-acid, Nickel-Metal hydride, Lithium Ion 2.4 Battery system model, emerging trends in batteries 2.5 Super capacitors, Superconducting Magnetic Energy Storage (SMES), SMES with intelligent control 2.6 Charging methodologies, SoC, SoH estimation techniques	**CO1, CO2**
TSO 3a. Explain principles and applications of thermal energy storage. *TSO 3b.* Perform energy and exergy analysis of thermal energy storage. *TSO 3c.* Explain principles and applications of mechanical energy storage systems. *TSO 3d.* Compare FES, PHS and CAES with reference to principle, function and deployments.	**Unit-3.0 Thermal and Mechanical Energy Storage** 3.1 Thermal energy storage: Principles and applications, Sensible and Latent heat, Phase change materials; 3.2 Energy and exergy analysis of thermal energy storage, case studies. 3.3 Mechanical energy storage systems: Flywheel Energy Storage (FES), Pumped Hydropower Storage (PHS), and Compressed-Air Energy Storage (CAES) 3.4 Comparison and application of state-of-arts mechanical energy storage systems including principle, function and deployments, Technical characteristics in terms of power rating and discharge time, storage duration, energy efficiency, energy density, cycle life and life time etc.	**CO3, CO4**
TSO 4a. Elucidate the principle of direct energy conversion using fuel cells.	**Unit-4.0 Fuel Cells** 4.1 Hydrogen as energy carrier and storage;	**CO3, CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 4b. Compare AFC, PEMFC, MCFC, SOFC and Microbial Fuel cell. *TSO 4c.* Evaluate the performance of fuel cell using different analytical techniques. *TSO 4d.* Analyze fuel cell system components and their integration for the design of fuel cell system. *TSO 4e.* Analyze how AI enhances fuel cell performance, efficiency, and reliability. *TSO 4f.* Describe applications of fuel cells in the area of power and transportation.	Hydrogen resources and production 4.2 Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells 4.3 Fuel cell types: AFC, PEMFC, MCFC, SOFC, Microbial Fuel cell 4.4 Fuel cell performance, characterization and modeling 4.5 Fuel cell system design and technology, Use of AI in fuel cell applications, AI Applications in Fuel Cells 4.6 Applications of fuel cells in power systems and transportation	
TSO 5a. Explain how key energy storage technologies integrate with the micro-grid and smart grid. *TSO 5b.* Evaluate increase of energy conversion efficiencies by introducing energy storage. *TSO 5c.* Elucidate applications of energy storage in areas such as food preservation, waste heat recovery, greenhouse heating; drying and heating for process industries. *TSO 5d.* Describe configurations and applications of hybrid energy storage systems.	**Unit-5.0 Energy Storage Systems for various Applications** 5.1 Energy storage in micro-grid and smart grid, energy management with storage systems, battery SCADA, increase of energy conversion, efficiencies by introducing energy storage, AI-based energy management 5.2 Application of energy storage: Food preservation, waste heat recovery, greenhouse heating; drying and heating for process industries 5.3 Hybrid energy storage systems: Configurations and applications 5.4 Emerging AI technologies in energy storage	**CO4, CO5**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

i. Explore tactics to overcome difficulties regarding adequate grid level storage of energy.
ii. Review quality research papers to identify challenges of large-scale energy storage application in power systems.
iii. Examine the strategies for Improving on-board vehicle energy storage.
iv. Evaluate methods to optimize thermal energy storage systems for sustainable energy supply.
v. Investigate techniques to achieve high-energy and high-safety Lithium-Ion Batteries.
vi. Suggest approaches for integration of battery energy storage systems for increasing the penetration of variable sources into power grids.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- Comparative analysis of energy storage systems
- Roles of storage in energy system flexibility
- Trends in energy storage
- Energy storage for medium- to large-scale applications
- Economics of energy storage

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit - 1.0 Overview of Energy Storage Technologies	08
CO2	Unit - 2.0 Electrochemical Energy Storage	08
CO3	Unit - 3.0 Thermal and Mechanical Energy Storage	12
CO4	Unit - 4.0 Fuel Cells	14
CO5	Unit - 5.0 Energy Storage Systems for various Applications	14
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Energy Storage: Fundamentals, Materials and Applications	Robert A. Huggins	Springer Nature, Second Edition, 2016, ISBN: 978-3319212388
2.	Energy Storage: A New Approach	Ralph Zito, Haleh Ardebili	Wiley-Scrivener, Second Edition, 2019, ISBN: 978-1119083597
3.	Thermal Energy Storage: Systems and Applications	I. Dincer and M. A. Rosen	John Wiley & Sons, Third Edition, 2021, ISBN: 978-1119713159
4.	Energy Storage - Technologies and Applications	Ahmed Faheem Zobaa	InTech, First Edition, 2013, ISBN: 978-9535109518
5.	Energy Storage for Power Systems	G. Ter-Gazarian	The Institution of Engineering and Technology Publication, UK, Second Edition, 2011, ISBN: 978-1849192194
6.	Fuel cell Fundamentals	R. O' Hayre, S. Cha, W. Colella and F. B. Prinz	Wiley Pub., Third Edition, 2016, ISBN: 978-1119113805
7.	Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost	Gianfranco Pistoia and Liaw Boryann	Springer International Publishing AG, First Edition,2018, ISBN: 978-3319888668
8.	Chemical and Electrochemical Energy System	R. Narayan and B. Viswanathan	Universities Press, First Edition,1998, ISBN: 978-8173710698
9.	Battery Systems Engineering	C. D. Rahn and Wang C.	Wiley, First Edition, 2013, ISBN: 978-1119979500
10.	Artificial Intelligence for RenewableEnergy Storage Roadmap for 2030	Fouad Soliman, Karima Mahmoud	LAP Lambert Academic Publishing First Edition, 2024, ISBN: 978-6208065478

b) Online Educational Resources (OER):

1) https://onlinecourses.nptel.ac.in/noc21_mm34/preview **on "Electrochemical Energy Storage" by Prof. Subhashish Basu Majumder from IIT Kharagpur**

2) https://onlinecourses.nptel.ac.in/noc24_ch01/preview on "Electrochemical Technology in Pollution Control" by Prof. J. R. Mudakavi from IISc Bangalore

3) **https**://onlinecourses.nptel.ac.in/noc24_ge24/preview **on "Non-conventional energy Resources" by Prof. Prathap Haridoss from IIT Madras**

4) Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits Electric Power Research Institute (USA), (1020676), December 2010http://large.stanford.edu/courses/2012/ph240/doshay1/docs/EPRI.pdf

5) https://www.nrel.gov/docs/fy10osti/47187.pdf on "The Role of Energy Storage with Renewable Electricity Generation"; Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, National Renewable Energy Laboratory (NREL) – A National Laboratory of the U.S. Department of Energy – Technical Report NREL/ TP6A2-47187, January 2010
6) https://www.sandia.gov/ess/publications/doe-oe-resources/eshb
7) https://ocw.tudelft.nl/course-lectures/introduction-energy-storage/
8) https://www.iea.org/reports/batteries-and-secure-energy-transitions
9) https://energy.mit.edu/research/future-of-energy-storage/
10) https://ocw.tudelft.nl/courses/technology-of-intelligent-and-integrated-energy-systems/

Q) Course Curriculum Developer

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A)	**Course Title:** Energy Economics and Policy	Deemed to be University under Distinct Category
B)	**Course Code:** GTECH10	
C)	**Pre- requisite (s):**	

D) **Rationale:** As the world confronts pressing challenges such as climate change, energy security, and sustainable development, there is a growing need for informed decision-making at the intersection of economics and energy policy. This postgraduate course in Energy Economics and Policy offers students a comprehensive understanding of Energy Economics, Energy policy, Energy regulation& Governance, Energy Demand Fore casting, Energy supply, energy security & environmental issues, Energy Markets, Energy Pricing taxation and Energy Policy & Policy Analysis. Upon completion, students will be able to critically assess the economic and policy dimensions of energy systems, conduct cost-benefit and impact analyses of energy policies, and recommend strategies for promoting energy efficiency, sustainability, and equity. Graduates will be prepared for roles in government agencies, international organizations, think tanks, consulting firms, and energy sector enterprises, where they can contribute to the formulation and evaluation of effective, data-driven energy policies.

E) **Course Outcomes (COs):** After the completion of the course, learners are expected to ensure the accomplishment and attainment of following industry aligned course learning outcomes.

Course Outcomes (COs)	Course Outcome Statements
GTECH10.CO1	Analyze energy economics, policies, and regulations to assess global energy trends and sustainability.
GTECH10.CO2	Evaluate energy demand using economic analysis techniques to assess investment decisions and risks in conventional and renewable energy systems.
GTECH10.CO3	Analyze energy supply systems, security concerns, and environmental impacts to support sustainable and economically viable energy policy decisions.
GTECH10.CO4	Evaluate the impact of the structure and dynamics of energy markets, pricing mechanisms, and taxation policies on energy trade and policy decisions
GTECH10.CO5	Analyze energy policies, planning frameworks, and institutional roles to evaluate policy formulation, implementation, and impact on national energy strategies.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)			
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** Design green energy systems for energy efficiency, techno economic viability, environmental impact, and social acceptance
GTECH10.CO1	2	2	2	3
GTECH10.CO2	2	2	2	3
GTECH10.CO3	3	2	2	3
GTECH10.CO4	2	3	2	3
GTECH10.CO5	3	3	2	3

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
GTECH10	SSC	Energy Economics and Policy	45	15	-	30	90	03	30	70	20	-	-	-	120

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain current status of energy use. *TSO 1b.* Identify the major energy source and their types. *TSO 1c.* Analyze global energy, climate policy trends and challenges including population dynamics. *TSO 1d.* Explain digital transformation in energy sector. *TSO 1e.* Analyze the link between energy access and poverty. *TSO 1f.* Examine regulatory approaches and the distributional impact of energy taxes and subsidies. *TSO 1g.* Analyze specific entries within the energy economics balance, considering their unique characteristics and implications. *TSO 1h.* Interpret energy balance information to assess energy consumption, production, and distribution patterns	**Unit-1.0 Introduction to energy economics and policy.** 1.1 Present status of energy use, Major types of energy resources, consumption patterns of energy. 1.2 Trends and challenges in global energy and climate policy, population and energy, digital transformation in energy sector 1.3 Link between energy access and poverty, valuing externalities, global climate change, policy initiatives, models of resource environment interaction. 1.4 Traditional regulation, price cap regulation, performance-based regulation, Distributional incidence of energy taxes and subsidies, reform of the energy industry. 1.5 Special Treatments of Some Entries in the Energy Economics Balance 1.6 Analysis of Energy Balance Information	**CO1**
TSO 2a. Differentiate between consumer, producer, and derived energy demand dynamics with comprehensive elasticity analysis and applications. *TSO 2b.* Evaluate energy projects using indicators such as net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR) to assess their economic viability and benefits. *TSO 2c.* Conduct comprehensive economic analysis of the given renewable energy systems including grid integration cost-benefit evaluation. *TSO 2d.* Apply energy economic analysis techniques to analyse the real-world case studies.	**Unit-2.0. Energy Demand Forecasting and Economic Analysis** 2.1 Energy demand fundamentals: Consumer vs producer demand, derived energy demand analysis, elasticity concepts and applications. 2.2 Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit-Cost Ratio (BCR) methodologies. risk assessment and management, financial vs economic analysis distinctions 2.3 Renewable energy economics - solar, wind, hydro economic analysis, bio-energy evaluation, grid integration cost-benefit analysis 2.4 Advanced economic modeling - life-cycle cost analysis, sensitivity analysis, scenario planning, portfolio optimization techniques	**CO2**
TSO 3a. Analyze energy supply chain economics including exploration, development, production, optimization, market dynamics, and distribution costs. *TSO 3b.* Evaluate geopolitical factors, security indicators, measurement frameworks,	**Unit-3.0 Energy supply system and security framework** 3.1 Energy supply chain economics - exploration, development, production economics, supply optimization, market dynamics, transportation and	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
and strategic reserve planning for comprehensive energy security. *TSO 3c.* Assess environmental externalities, carbon pricing mechanisms, trading systems, and climate change adaptation economics for sustainability. *TSO 3d.* Develop future energy scenarios through sustainability pathway analysis, low-carbon transition economics, and green accounting applications.	distribution costs. 3.2 Energy security analysis - geopolitical factors, security indicators, measurement frameworks, strategic reserve planning and management 3.3 . Environmental economics - externality assessment, carbon pricing and trading mechanisms, climate adaptation economics 3.4 Future energy scenarios - sustainability pathway analysis, low-carbon transition economics, green accounting principles.	
TSO 4a. Analyze energy market organization, competitive dynamics, cartel models, oligopoly analysis, and market failure identification with solutions. *TSO 4b.* Explain marginal cost pricing principles, peak-load pricing strategies, cross-subsidization techniques, and comprehensive tariff design methodologies. *TSO 4c.* Analyze global oil and gas markets, international electricity trade mechanisms, and energy diplomacy cooperation frameworks comprehensively. *TSO 4d.* Apply market regulation principles, competition policy frameworks, and consumer protection mechanisms in energy sector governance.	**Unit-4.0 Energy Markets and Pricing Mechanism** 4.1 Energy market structures - organization, competitive dynamics, cartel models, oligopoly analysis, market failure identification and solutions. 4.2 Pricing mechanisms and models - marginal cost pricing, peak-load pricing strategies, cross subsidization and tariff design. 4.3 International energy markets - global oil and gas dynamics, international electricity trade, energy diplomacy and cooperation. 4.4 Regulatory economics - market regulation principles, competition policy in energy, consumer protection mechanisms	**CO4**
TSO 5a. Explain energy policy formulation processes, stakeholder engagement, policy instrument selection, design, and implementation strategy development. Explain six dimensions to be considered for analyzing policies. *TSO 5b.* Apply multi-criteria decision analysis, cost effectiveness methodologies, and stakeholder analysis with comprehensive engagement strategies. *TSO 5c.* Develop long-term energy scenarios, integrated resource planning methodologies, and comprehensive energy-economy environment modeling approaches. *TSO 5d.* Use energy planning software tools for the scenario analysis, sensitivity testing, policy simulation, and gaming approaches for decision support.	**Unit-5.0 Policy Analysis and Energy Planning.** 5.1 Energy policy development - formulation processes, stakeholder engagement, policy instrument selection and design, implementation strategies 5.2 Policy analysis frameworks - multi-criteria decision analysis, cost-effectiveness methodologies, stakeholder analysis and engagement strategies. 5.3 National energy planning - long-term scenario development, integrated resource planning, energy-economy-environment modeling. 5.4 Decision support systems - energy planning software, scenario analysis, sensitivity testing, policy simulation and gaming.	**CO5**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

i. Compare the long-term economic, social, and environmental outcomes of grid vs. off-grid energy delivery models in under-electrified regions.
ii. estimate price elasticity of electricity demand across different income groups and propose differential pricing policies to improve energy efficiency.
iii. assess the economic viability and policy needs of energy storage technologies (batteries, pumped hydro) for grid integration in high-renewables scenarios.
iv. evaluate the cost-competitiveness of green hydrogen versus fossil-based alternatives and recommend policy interventions to scale up its deployment in India.
v. assess the cost-effectiveness and environmental externalities of waste-to-energy initiatives and propose a policy roadmap for scalability.
vi. forecast the macroeconomic impact of EV adoption on power demand patterns, electricity pricing, and public finances in India

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

- Integration of Traditional and Modern Energy Systems: Roles of indigenous knowledge in contemporary energy planning
- Blockchain and Energy Trading: Emerging technologies in energy market transformation
- Smart Grid Economics and Community Integration: Economic implications of AI-driven grid systems with traditional community structures
- Energy Policy in Digital Age: AI-enhanced governance and traditional wisdom integration
- Climate-Energy: Interdisciplinary approaches to sustainable energy transition

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit-1.0 Introduction to Energy Economics and Policy.	14
CO2	Unit-2.0 Energy demand Forecasting and Economic Analysis	14
CO3	Unit-3.0 Energy Supply System and Security Framework	15
CO4	Unit-4.0 Energy Markets and Pricing Mechanism	15
CO5	Unit-5.0 Policy analysis and Energy Planning	12
Total		**70**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition withISBN
1.	Energy Economics: Concepts, Issues, Markets and Governance,	Subhes C. Bhattacharyya	Springer London Ltd (10 March 2011) latest edition, ISBN-10: 0857292676 ISBN-13: 978-0857292674
2.	Energy Economics: A Modern Introduction	Ferdinand E. Banks	Springer; Edición 2000 (31 enero 2000) ISBN-10: 0792377001 ISBN-13: 978-0792377009
3.	Financial Evaluation of Renewable Energy Technology	Kandpal T. C. and Garg H. P	Mac Milan, 2003
4.	Energy Policy Analysis and Modeling	Munasinghe M. and Meier P	Cambridge University Press, 1993
5.	Energy Sources & Policies in India	Rishi Muni Dwivedi	New Century Publications (18 July 2011) ISBN-10: 817708271X, ISBN-13: 978-8177082715

S. No.	Titles	Author(s)	Publisher and Edition withISBN
6.	Energy Economics and Policy	J.M. Griffin, and H.B. Steele	Academic Press, 1985
7.	International Energy Markets: Understanding Pricing, Policies, and Profits	Carol A. Dahl	Tulsa: Pennwell, 2015 (second edition)

b) Online Educational Resources (OER):

1) URL: https://www.iea.org/training-programmes
2) URL: https://openei.org/wiki/Main_Page
3) URL: https://www.irena.org/publications
4) Energy Planning Reports of CMIE, State Governments & Govt. of India
5) International energy agency, India 2020, Energy policy review report
6) International handbook on the economics of energy Hunt, Lester C., and Joanne Evans, eds. Edward Elgar Publishing, 2011 (EEP)
7) The Handbook of Global Energy Policy by Andreas Goldthau © 2013 John Wiley & Sons, Ltd
8) https://beeindia.gov.in
9) www.Ireda.in
10) https://iced.cag.gov.in/
11) https://niti.gov.in
12) www.iea.org

Q) Course Curriculum Development Team

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A)	**Course Title:** Project	Deemed to be University under Distinct Category
B)	**Course Code:** PD01	
C)	**Pre- requisite (s):**	

1. **Rationale:** The national policy on education has made provision for the implementation of outcome-based education, the design of imaginative curriculum, use of engaging pedagogy and formative assessment to assure the quality of education. The project-based instructional method is a learner-centric method that develops higher-order learning skills such as creative skills, critical thinking, investigative skills, analytical skills, entrepreneurship skills, incubation skills, communication skills and collaboration skills as mentioned in the NEP 2020. The project-based learning is systematically planned and implemented at the institute level across the programmes to exploit its full potential for learning. A guideline for managing and assessing the learners' project work is prepared to make all the stakeholders aware and educate them to assure quality learning through project work, make the process transparent and relevant.

2. Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PD01	PD	Project	-	-	45	105	150	05	-	-	200	-	-	-	200

3. Broad guidelines for major project work

- The project's problems/themes/ should be relevant to current issues and practices of the industry/society.
- The project should address the majority of the outcomes at the programme level.
- Provision for self-assessment, assessment by teacher/expert should be incorporated to improve the quality of the project work and ensure a higher level of learning aligned to programme level outcomes.
- Provision to showcase a learning portfolio as a project output.
- The learners should be encouraged to publish the work (in the form of a paper, newspaper item, case study, report, etc.) after getting approval from the guide and the organization where the project is completed.

- The learners should submit the plagiarism check report during the final submission.
- Learners should record the output/ periodic achievements of significant interactions, feedback, discussions, and events at different milestones using a logbook.
- The schedule for project work is mentioned in table 1.
- The learners will be assessed during different stages of the project as per the rubrics mentioned in table 2.
- The project proposal and the report are to be prepared as per format 1 and format 2, respectively.

Table-1

4. Schedule of the Project work

S. No	Activities	Target Duration	Responsibility	Formative Assessment Marks Weightage	Output Expected
1.	**Conducting Orientation** • Rationale of the project • Credit of the project • Marks of the project • Expectations related to quality of project work • Road map of the project work	Week I	Dept. Team		
2.	**Stage 1: Project Planning**	Week II		20	
	• Preparation of synopsis/project proposal • Identification of project problem/theme • Interaction with the industry/organization resource person • Literature review • Tentative topic • Presentation and feedback (within department) • Finalization of topic • Preparation of project proposal/synopsis (as per format 1)				Draft Project Proposed
	• Presentation and assessment of project proposal • Approval of project proposal	Week IV	Dept. Team Using Rubric 1		Approved Project Proposal
3.	**Stage 2: Execution of Project Work as per the Project Proposal**	Week V		30	
	Execution of project work as per the action plan				
	Monitoring and assessment of progress and sharing of experience	Week VIII			
	Monitoring and assessment of progress and sharing of experience	Week XII			
4.	**Stage 3: Project Report Submission and Presentation**				
	Submission of draft report	Week XIV		20	Draft Report

S. No	Activities	Target Duration	Responsibility	Formative Assessment Marks Weightage	Output Expected
	• Presentation of draft project report • Internal assessment and review		Dept. Team		
	• Final submission • Presentation and assessment	Week XVI	Dept. Team and Expert		Final Project Report
	Submission of Report				

Format 1

Project Proposal

1. **Name of the Programme:**
2. **Broad Area/Theme of the Project:**
3. **Title of the Project:**
4. **Rationale:**
5. **Objectives:**
6. **Scope of the Project:**
7. **Project Outcomes:**

i. Carry out research /investigation independently
ii. Demonstrate a degree of mastery in areas of specialization and research
iii. Use alternative strategies/methods
iv. Demonstrate innovative abilities
v. Exhibit project management abilities
vi. Develop sustainable, environmentally and society-friendly output
vii. Demonstrate lifelong learning skills, learning-to-learn skills, and self-learning skills
viii. Adhere to professional ethics and values
ix. Write a technical project report
x. Defend project work

8. **Action Plan:**
9. **Literature Survey:**
10. **Proposed Methodology:**

i. Resources required
ii. Test
iii. Sampling
iv. Method
v. Model
vi. Any other (please specify)

11. **References:**
12. **Project Future Potential:**

Table 2

5. Assessment Rubrics for Project Work

S. No.	Criterion	Very Good (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
1.	**Project Planning** **Outcome:** Plan the Project Effectively				
1.1	**Rationale**	Clear and well-articulated. Strong justification based on real-world problems.	Depicts understanding of the background and purpose with some connection to practical or academic needs.	Rationale is stated but lacks depth or clarity. Justification is weak or only partially connected to real world problems.	Rationale is unclear. Fails to justify the need or relevance of the project.
1.2	**Literature Survey**	Comprehensive, well-structured review of relevant and up-to-date literature.	Adequate review covering relevant literature. Shows a good understanding of the topic.	Basic literature review with limited relevance or scope. Shows minimal understanding of the subject area.	Inadequate or poorly organized literature review. Sources are outdated, irrelevant, or insufficient.
1.3	**Outcome Proposed**	Proposed outcomes are well defined, realistic, and highly relevant to the problem statement.	Outcomes are adequately-stated and relevant to the problem statement.	Outcomes are defined but lack clarity. They are somewhat relevant but are vague.	Outcomes are poorly defined. They lack relevance to the problem statement.
2.	**Project Execution** **Outcome:** Execute the project as per the laid-down criteria				
2.1	**Appropriateness of the Methodology Adopted**	Methodology is highly appropriate and clearly aligned with project problem. Demonstrates deep understanding and use of tools/ techniques/ procedures.	Methodology is suitably aligned with the project problem. Shows good understanding and use of tools/ techniques/ procedures.	Methodology is somewhat appropriate but lack clarity or alignment with project problem. Shows basic understanding and use of tools/ techniques/ procedures.	Methodology is inappropriate, poorly explained. Shows little understanding and use of tools/ techniques/ procedures.
2.2	**Feasibility of Solution**	The proposed solution is highly feasible with clear consideration of time, resources, skills and constraints. Execution is practical.	The proposed solution is generally feasible with minor limitations. Resources and timelines are mostly considered. Some adjustments are needed for the project to be practical.	The proposed solution is partially feasible but shows gaps in planning or resource estimation. Face challenges in execution.	The proposed solution is not feasible due to unrealistic assumptions and poor planning. Execution appears impractical.
2.3	**Newness of the Project Work**	Project demonstrates high originality or innovation. Introduces a novel concept, approach, or solution that is significant different from existing work.	Project shows some originality. Modifies or improves existing ideas or solutions in a meaningful way. Offers partial innovation.	Project has limited newness. Mostly based on existing ideas with minor adjustments. Lacks significant innovation.	Project lacks originality. Direct replication of existing work with no new contribution.
2.4	**Resourcefulness**	Demonstrates exceptional initiativeness and creativity in	Shows good use of resources and tools. Demonstrate moderate	Makes basic use of resources with limited initiative. Relies heavily on	Shows poor ability of utilizing/arranging resources.

S. No.	Criterion	Very Good (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
		utilizing/arranging resources effectively.	initiativeness and creativity in utilizing/ arranging resources.	guidance.	
2.5	**Sustainability**	Project demonstrates strong sustainability considering all aspects like- environmental, economic, and social impacts.	Project demonstrates moderate sustainability practices considering some aspects like- environmental, economic, and social impacts.	Project demonstrates limited sustainability practices considering some aspects like- environmental, economic, and social impacts.	Project lacks sustainability considerations.
2.6	**Maintaining Daily Diary or Log Book**	Diary/log book is consistently and meticulously maintained. Entries are detailed, dated, and clearly reflect daily progress.	Diary/log book is periodically maintained with relevant entries. Most entries are dated and show a good record of activities and progress.	Diary/log book is maintained irregularly. Entries are brief or lack detail.	Diary/log book is poorly maintained or mostly incomplete. Important entries are missing or unclear.
3.	**Quality of Product/Process** **Outcome:** Ensure the Quality of Product/Process				
3.1	**Originality of Product**	The final product is original and creative. It presents unique features, functions, or designs not found in existing solutions.	The final product is somewhat original with some creative elements or improvements over existing ideas.	The product has limited originality. Mostly based on existing ideas or minor modifications.	The product lacks originality. It is a direct reproduction of existing work with no new features or creative input.
3.2	**Cost Effectiveness of Product/Process**	Process and/ product are highly cost-effective. Optimal use of resources. Demonstrates strong value-for-money.	Process and/ product are reasonably cost-effective. Resources are mostly used wisely, with acceptable cost.	Process and/ product show limited cost-effectiveness.	Process and/ product are not cost-effective. Inefficient use of resources.
3.3	**Proposed Outcomes Achieved**	All proposed outcomes are fully achieved.	Most of the proposed outcomes are achieved with satisfactory quality.	Some proposed outcomes are achieved with minor gaps.	A few or none of the proposed outcomes are achieved.
4.	**Project Report Writing** **Outcome:** Write Quality Project Report				
4.1	**Style and Language**	Language is clear, precise, and academically appropriate throughout. Style is formal, consistent, and well-suited, hence enhancing the overall quality of the report.	Language is generally clear and appropriate. Style is mostly formal and consistent. The quality of the report is acceptable.	Language is understandable, but is informal. Style occasionally deviates from the formal standards. The quality of the report is moderate	Language is unclear, informal, or inappropriate for a technical report. Style is inconsistent and affects the quality of the report.
4.2	**Quality of Related Diagrams/Drawings/Graphs in Project Report**	Diagrams/ drawings/ graphs are highly relevant, accurate, well-labelled and neatly presented.	Diagrams/ drawings/ graphs are mostly accurate, clear, and mostly relevant to the content. Properly labelled and adequately formatted.	Diagrams/ drawings/ graphs are present but lack clarity, proper labelling, or relevance.	Diagrams/ drawings/ graphs are missing/ incorrect, or poorly presented.

S. No.	Criterion	Very Good (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
4.3	**Future Scope of Project**	Demonstrates deep insight into how the project can be expanded/ improved/ applied in broader contexts.	Demonstrates awareness of how the project can be expanded/ improved/ applied in broader context, though some aspects may need more depth	Limited insight into how the project could be developed further.	No clear future scope identified or missing. Lacks understanding of how the project could be extended or applied further.
5.	**Quality of Presentation** **Outcome**: Demonstrate Good Presentation Skills				
5.1	**Comprehension of Concepts, Design and Methodology**	Demonstrates thorough understanding of underlying concepts, design and methodology.	Demonstrates good understanding of underlying concepts, design and methodology with minor gaps.	Demonstrates basic understanding of underlying concepts, design and methodology, but explanations are limited or partially correct with misconceptions developed.	Demonstrate poor or insufficient understanding of underlying concepts, design and methodology. Unable to explain or justify the approach clearly.
5.2	**Communication Skills**	Communicates ideas with exceptional clarity, fluency, and confidence. Language is precise and professional. Engages the audience effectively. Actively listens and responds thoughtfully.	Communicates clearly and confidently with minor lapses. Language is appropriate, and ideas are conveyed well. Demonstrate good listening skills.	Communicates basic ideas but with occasional lack of clarity or fluency. May struggle with appropriate vocabulary or organization of thoughts. Demonstrate fair listening skills.	Struggles to communicate ideas clearly. Lacks fluency, coherence, or appropriate vocabulary. Responses are unclear or incorrect. Poor listening and interaction with audience.
5.3	**Slide Organization**	Slides are visually appealing, well-organized, and professionally designed. Content is concise, relevant, and supports verbal presentation effectively. Excellent use of visuals (e.g., graphs, images, icons). Fonts, size, colours, and layout enhance readability.	Slides are well-structured. Content is mostly relevant and supports the spoken presentation. Visuals are used appropriately. Minor issues in font size, colour, and layout.	Slides have a basic structure but are cluttered. Lack proper visual support. Too much of text. Font size and colour is not appealing.	Slides are poorly designed or difficult to read. Content is disorganized, excessive, or irrelevant. Visuals are missing or irrelevant. Font size and colour are poor.
5.4	**Ability to Defend Questions**	Responds to all questions confidently, accurately and with deep understanding and proper justifications.	Responds to most questions correctly and confidently. Demonstrates good understanding with minor gaps in Justifications.	Responds to basic questions with partial accuracy. Shows limited understanding with weak justifications.	Unable to answer questions clearly or correctly. Responses reflect poor understanding.

Format 2

Project Report

1. **Name of the Programme:**
2. **Broad Area/Theme of the Project:**
3. **Title of the Project:**
4. **Rationale:**
5. **Objectives:**
6. **Scope of the Project:**
7. **Literature Survey:**
8. **Methodology used (as applicable):**

   i. Resources used
   ii. Test
   iii. Sampling
   iv. Method
   v. Model
   vi. Any other (please specify)

9. **Observation, Analysis, and Interpretation:**
10. **Reporting of Results and Conclusion:**
11. **Project Future Potential:**
12. **References:**
13. **Bibliography:**
14. **Annexure (as applicable):**

D) Course Curriculum Development Team

S. No.	Name	E-mail Address
1.	Prof. Sanjay Agrawal	sagrawal@nitttrbpl.ac.in
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Course Curriculum Detailing- Online Spell -1

S. No.	Course Codes	Course Titles	Page No.
1.	PC01	Research Methodology	151
2.	PC02	Curriculum & Assessment	157
3.	NEP06	Indian Knowledge System (IKS)	164

A)	**Course Title:** Research Methodology	Deemed to be University under Distinct Category
B)	**Course Code:** PC01	
C)	**Pre- requisite (s):**	

D) **Rationale:** This course deals with the principles of research and significant phases of research using realistic plans to be followed. After completing the course, the researcher can choose the research field, research topic and formulate the research problem. The research methodology course provides an idea of literature review, critical thinking and logical reasoning, designing experiments, data analysis and interpretation, thesis writing, scientific writing, and presentation skills. The need, therefore, is for those concerned with research to pay due attention to designing and adhering to the appropriate methodology to improve the quality of research. The course emphasizes the principles of effective research and the need for a proactive approach in a successful research program. The researchers will get an insight into the privilege, honour, and associated research responsibilities.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
PC01.CO1	Explain the basic concepts of research
PC01.CO2	Review the relevant literature effectively and efficiently
PC01.CO3	Make use of the guidelines to progress from the choice of the broad field of research to a specific topic of research
PC01.CO4	Apply critical thinking and analytical thinking in research methodology
PC01.CO5	Analyze well-structured research proposals and research papers invoking clearly outlined principles

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)		
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PC01.CO1	3	3	2
PC01.CO2	3	3	2
PC01.CO3	3	-	3
PC01.CO4	3	-	3
PC01.CO5	3	1	3

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PC01	PC	Research Methodology	30	-	-	30	60	02	30	50	20	-	-	-	100

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the History and Evolution of research and innovation *TSO 1b.* Classify the different types of research *TSO 1c.* Describe the step involved in the research *TSO 1d.* Explain the Relevance of Research for Innovation, Technology Development, and social relevance *TSO 1e.* State the importance of Hypotheses in Research	**Unit-1.0 Basic Concepts of Research** 1.1 History and Evolution of research and innovation 1.2 Types of Research 1.3 Research innovation and social relevance 1.4 Mandatory Steps in Research 1.5 Relevance of Research for Innovation and Technology Development 1.6 Importance of Hypotheses in Research	**CO1**
TSO 2a. Describe the Importance of Literature Review *TSO 2b.* Present a comprehensive overview of relevant research and theories on the topic *TSO 2c.* Apply strategies for good Literature Search *TSO 2d.* Organize Referencing Ethics, Paraphrasing, and Summarizing *TSO 2e.* Make use of literature review tools	**Unit-2.0 Literature Review** 2.1 Importance of Literature Review 2.2 Characteristics of Good Literature Review 2.3 Review and Strategies for Good Literature Search 2.4 Referencing Ethics, Paraphrasing and Summarizing 2.5 Tools for literature review	**CO2**
TSO 3a. Classify the data types for analysis *TSO 3b.* Design experiments *TSO 3c.* Describe the methods of data collection *TSO 3d.* Draw valid conclusions from sampling methods, statistical analysis *TSO 3e.* Identify the Research problem *TSO 3f.* Demonstrate narrowing down the problem *TSO 3g.* List the Factors to be considered for the selection of the problem	**Unit-3.0 Research Problem Formulation** 3.1 Data collection, data analysis, data types, and interpretation 3.2 Designing of Experiments 3.3 Methods of data collection 3.4 Sampling methods, statistical analysis, and displaying of data 3.5 Research problem identification 3.6 Narrowing down the problem 3.7 Factors to be considered for the selection of the problem	**CO3**
TSO 4a. Construct Out of the Box Thinking problem *TSO 4b.* Interpret Transformation to Impossible Thinking *TSO 4c.* Distinguish Convergent and Divergent Thinking *TSO 4d.* Evaluate the selection of idea *TSO 4e.* Evaluate the line of reason for thinking critically *TSO 4f.* Compare Critical and Analytical Thinking in Research Methodology	**Unit-4.0 Critical and Analytical Thinking** 4.1 Out-of-Box Thinking 4.2 Transformation to Impossible Thinking 4.3 Convergent and Divergent Thinking 4.4 Generation, Evaluation, and Selection of Ideas 4.5 Critical thinking 4.6 Comparison of Critical and Analytical Thinking	**CO4**
TSO 5a. Illustrate the Structure of a Good Research Proposal	**Unit -5.0 Research Proposal**	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 5b. Write good research proposal *TSO 5c.* List the tips for compilation *TSO 5d.* Classify the types of scientific report *TSO 5e.* Develop structure and components of the conference *TSO 5f.* Write the report with ethics and scientific conduct *TSO 5g.* Analyze the presenting work is from another source with or without consent of the original author	5.1 Getting Started to Write a Research Proposal 5.2 Tips for Compilation 5.3 Scientific writing: types of scientific report 5.4 Structure and components of a conference 5.5 Arts of writing, ethics, and scientific conduct 5.6 Journal articles and thesis writing 5.7 Plagiarism	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

i. Research is a unique combination of art and science. Research is presumed to be associated with unpredictable uncertainties and variable degrees of technological endeavour. Research methodology is a systematic approach to reducing the degree of uncertainties. It helps in shaping the research orientation of a researcher. In this module, students were introduced to various aspects of research methodology. The students have been exposed to effective methods of problem definition, literature survey, reading and analysing research papers, design of experiments, ethical issues, and academic standard issues.

ii. This part of the task is structured to test the researcher's comprehension skills and ability to adapt quickly to the rudimentary phase of the research cycle. The list of tasks to be performed is as follows.

- Identification of "Specific Field of Research" of the researcher's interest.
- Through a literature search, two doctoral theses have to be chosen that are closely related to an identified specific field of research
- The Abstract and Chapters on the Introduction, Conclusions, and Future recommendations of the two theses have to be reviewed

iii. Based upon the above-referred review, a technical note should be developed highlighting the:

- Introduction to the Identified "Specific Field of Research"
- Assumptions of the individual thesis
- Techniques invoked along with its merits and constraints of the individual thesis
- Relative differences in the approaches and scope of the two theses
- Views on the feasibility of incorporating the recommended suggestions of individual thesis
- Appreciation of the individual thesis reviewed with emphasis on introduction, problem definition and suggested future work

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Seminar Topics:

1. The Role of Literature Review in Building Research Frameworks
2. Digital Tools for Research Data Collection and Management
3. AI and Machine Learning in Research Methodology

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit-1.0 Basic Concepts of Research	08
CO2	Unit-2.0 Literature Review	08
CO3	Unit-3.0 Research Problem Formulation	12
CO4	Unit-4.0 Critical and Analytical Thinking	12
CO5	Unit -5.0 Research Proposal	10
Total		**50**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	The Craft of Research	Booth W. C, Colomb and G.G Williams	Chicago University Press
2.	Research Methods	Willium M.K and Trochim. (2003)	2nd Edition, Biztantra Publications
3.	The Foundation of Research	Jonathan Grix. (2004)	Palgrave Study Guides
4.	The Post Graduate Research	Wisker Gina. (2001)	Palgrave
5.	The Unwritten Rules of Ph.D research	Rugg G. and Petre M. (2004)	Open University Press

b) Online Educational Resources (OER):

1) https://www.youtube.com/watch?v=TEqYnV6KWfY
2) https://www.youtube.com/watch?v=hECPeKv5tPM
3) https://www.youtube.com/watch?v=G3DUaQokOK8
4) https://onlinecourses.nptel.ac.in/noc23_ge36/preview
5) https://nptel.ac.in/courses/121106007
6) https://www.youtube.com/watch?v=E2gGF1rburw
7) https://www.youtube.com/watch?v=E2gGF1rburw&list=PLyqSpQzTE6M8F_P8lgjvmqiDEoFGLzG4h
8) https://www.youtube.com/watch?v=NNPiJ20JcFI&list=PLyqSpQzTE6M8F_P8lgjvmqiDEoFGLzG4h&index=8

Q) Course Curriculum Developer

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A)	**Course Title:** Curriculum & Assessment	Deemed to be University under Distinct Category
B)	**Course Code:** PC02	
C)	**Pre- requisite (s):**	

D) **Rationale:** National Education Policy (NEP) 2020 envisions many innovations and reforms in the higher education. Major reforms mentioned are overhauling of curriculum, assessment and pedagogy. One of the major reforms is outcome-based curriculum design and development in the context of NEP:2020.

Accordingly, all universities and institutions have started transforming the curriculum of higher education programmes to align with national policy directives and stakeholder's need in the changed context and era of industry 4.0 and skills demands. Many challenges and issues are envisaged in curriculum design & development, implementation, pedagogy and assessment in the context of NEP 2020.

The course curriculum on curriculum and assessment aims to deliberate on capability and capacity building of learners, policy makers, teachers etc. trainers on different reforms in curriculum design & development, pedagogy and assessment.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
PC02.CO1	Develop awareness about the key concepts of outcome-based education and curriculum in the context of higher education.
PC02.CO2	Design innovative programme structure with scheme of studies and assessment as per the curriculum and assessment reforms envisaged in NEP 2020.
PC02.CO3	Implement the curriculum effectively to ensure the achievement of stated learning outcomes.
PC02.CO4	Revise the existing programme curriculum based on curriculum evaluation.
PC02.CO5	Assess the learners' performance by using the appropriate tools of assessment, as per need.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)		
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PC02.CO1	1	1	3
PC02.CO2	3	3	3
PC02.CO3	2	1	3
PC02.CO4	3	3	3
PC02.CO5	1	1	3

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PC02	PC	Curriculum and Assessment	30	-	-	30	60	02	20	30	50	-	-	-	100

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the concept of outcome-based education *TSO 1b.* Differentiate between outcome-based curriculum and conventional curriculum. *TSO 1c.* Identify the curriculum reforms envisaged in NEP 2020 *TSO 1d.* Distinguish between curriculum and syllabus *TSO 1e.* Identify the key stakeholders of curriculum document	**Unit-1.0 Outcome Based Education and Curriculum** 1.1 Outcome Based Education (OBE) and curriculum. 1.2 Curriculum reforms in the context of NEP 2020- multidisciplinary and holistic curriculum. 1.3 Curriculum &syllabus- purposes and scope 1.4 Stakeholders of curriculum document, 1.5 Characteristics of good Curriculum document. 1.6 Policy directives for outcome-based curriculum development-NBA, AICTE and UGC	**CO1**
TSO 2a. Use contemporary approaches for design and development of curriculum. *TSO 2b.* Identify the key stages in curriculum planning, design and development. *TSO 2c.* Conduct need assessment from stakeholders (students, teachers, industry and alumni). *TSO 2d.* Use the need assessment results to arrive at curriculum design decisions. *TSO 2e.* Develop programme structure with scheme of studies and assessment for multidisciplinary programme. *TSO 2f.* Integrate the key curriculum and assessment reforms outlined in NEP 2020. *TSO 2g.* Describe the key components of outcome-based curriculum document. *TSO 2h.* Identify the unique features of multidisciplinary outcome-based curriculum	**Unit-2.0 Outcome Based Curriculum Design & Development** 2.1 Approaches of Curriculum Development: Tyler and Taba Model. 2.2 Stages of curriculum development-: Curriculum planning & design 2.3 Need assessment for curriculum design and development from different stakeholders. Design of tools for need assessment. 2.4 NEP 2020 curriculum and assessment reforms. 2.5 Innovative and flexible Programme Structure Development– Scheme of studies and scheme of assessment. 2.6 Flexible curriculum – Integration of emerging areas/technology in programme structure development. 2.7 Unique features of multidisciplinary outcome-based curriculum. 2.8 Elements/ Components of whole programme curriculum document. 2.9 Elements/Components of course curriculum document. 2.10 Domains of learning and course outcomes. Formulating course outcomes.	**CO2**
TSO 3a. Identify the roles of different stakeholders in effective curriculum	**Unit-3.0 Curriculum Implementations & Evaluation**	**CO3, CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
implementation. *TSO 3b.* Evolve strategies for effective curriculum implementation. *TSO 3c.* Solve issues and challenges faced during effective implementation of curriculum. *TSO 3d.* Analyze critical factors that influence the success or failure of curriculum implementation. *TSO 3e.* Apply the CIPP model to review and evaluate curriculum. *TSO 3f.* Revise the curriculum of programme and courses. *TSO 3g.* Develop e-contents for specific topic/sub topic as per outcomes stated.	3.1 Effective Curriculum Implementation: Issues and Challenges. 3.2 Innovative pedagogical methods /strategies for effective curriculum implementation, use of ICT for teaching learning. 3.3 Role of different stakeholders in effective curriculum implementation. 3.4 Factors influencing curriculum implementations, institutional support, teacher's competence, and student's engagement, entry level knowledge, skills and attitude etc. 3.5 CIPP model of curriculum evaluation. 3.6 Curriculum evaluation –strategies for effective implementation of curriculum. 3.7 Develop action plan for review and revision of existing programme and courses curriculum, based on evaluation results and emerging trends in education world of work 3.8 Role of teachers in effective curriculum implementation & evaluation considering the four pillars of NEP 2020- Access, Equity, Quality and Accountability. 3.9 Frameworks for Learning/Instructional material development: ADDIE and ASSURE 3.10Leaning /Instructional materials development (e-contents).	
TSO 4a. Identify the purposes of outcome-based assessment *TSO 4b.* Differentiate between assessment, measurement and evaluation. *TSO 4c.* Apply appropriate assessment tools to assess the course outcomes across different learning domains. *TSO 4d.* Design rubrics for assessing student's performance during multiple tasks. *TSO 4e.* Design specification table *TSO 4f.* Design different types of questions	**Unit-4.0 Learners' Assessment** 4.1 Assessment, Measurement and Evaluation. 4.2 Characteristics of assessment – Validity, Reliability, Objectivity and Practicability. 4.3 Basic concepts of outcome-based assessment: Assessment for learning, Assessment of learning, Assessment as learning, Assessment before learning, process and product assessment. Issues and challenges in assessment. 4.4 Criterion Reference Testing (CRT) and Norms Reference Testing (NRT). 4.5 Direct and indirect tools of assessment 4.6 Assessment of outcomes in Cognitive, Affective, and Psychomotor domain.	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
	4.7 Rubrics based assessment: Design of Rubric for assessing Project work, Industrial Training, Seminar, Laboratory experiences, workshop experiences, etc. 4.8 Design of Specification table for assessment in cognitive and psychomotor domain. 4.9 Different types of questions-Multiple choice questions, short answer question, structured essay questions, etc. 4.10 Bloom's taxonomy and design of question paper.	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

i. Carry out the need assessment from different stakeholders and analyze the same to draw the curricular decisions for development of multidisciplinary flexible programme structure of Diploma/Degree programmes.

ii. Identify the norms of project, internship and industrial training in AICTE and UGC guidelines for integration in curriculum design and development.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Prepare a basket of emerging technology courses, open elective courses, emerging stream specific courses, NEP courses, NEP courses as per need of specific programme for integration in programme structure across the programme.
- Develop most valid and reliable T-L and assessment tool for effective implementation and assessment of capstone/major project work.
- Features of NCrF for Curriculum Design and Development
- Unique features of NHEQF
- Innovative programme structure development by integration of academic, experiential learning and vocational component.

b. Seminar Topics:

- Emerging and futuristic models and approaches of curriculum design and development
- NEP envisions and curriculum ad Assessment Reforms.
- Categorize the cluster of programme courses, as pre the different category of courses.
- Map the appropriate courses as per the different category of courses.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1.0 Outcome Based Education and Curriculum	04
CO2	Unit 2.0 Outcome Based Curriculum Design & Development	10
CO3, CO4	Unit 3.0 Curriculum Implementations & Evaluation	08
CO5	Unit 4.0 Learners' Assessment	08
Total		**30**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Curriculum: Foundations, Principles & Theories	Ornstein, A.C	Pearson; 7th edition (6 January 2016), ISBN-10: 0134060350, ISBN-13: 978-0134060354
2.	Concept-based Curriculum and Instruction	Erickson, H.L.	Publisher: Corwin; 1st edition (1 August 2006), ISBN-10: 141291700X, ISBN-13: 978-1412917001
3.	Principles of Curriculum Construction	Balasara, M	Kanishka; First Edition (1 January 2017), ISBN-10: 8173916217 ISBN-13: 978-8173916212

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
4.	Advanced Curriculum Construction	Prasad, J. &Kaushik, V. K	Publisher: Kanishka Prakshan; First Edition (1 January 2009), ISBN-10: 8173916772, ISBN-13: 978-8173916779
5.	'Curriculum theory and practice'	Smith, M. K. (1996, 2000)	www.infed.org/biblio/b-curric.htm.
6.	Outcome-Based Curriculum in Engineering Education	Shashi Kant Gupta, Joshua Earnest	PHI Learning; 1st edition (1 November 2021)
7.	Outcome Based Education: A Practical Guide for Higher Education Teachers	Deepesh Divaakaran	Notion Press (30 June 2023); Notion Press Media Pvt Ltd, ISBN-13: 979-8890268945
8.	Designing and Implementing the Outcome-Based Education Framework: Theory and Practice	P P Noushad	Springer (14 December 2024), ISBN-10: 9819604397, ISBN-13: 978-9819604395
9.	Assessment for Learning	Paul Black, Chris Harrison, Clara Lee, Bethan Marshall, Dylan Wiliam	Open University Press (16 September 2003), ISBN-10: 0335212972 ISBN-13: 978-0335212972
10.	ASSESSMENT FOR LEARNING [Paperback]	DR.A.JAHITHA BEGUM, DR.G.LOKANADHA REDDY	RAKHI PRAKASHAN; First Edition (1 January 2015), ISBN-10: 9385195247 ISBN-13: 978-9385195242
11.	Curriculum Implementation and Instruction	Abayomi Oluwatelure Temitayo	LAP Lambert Academic Publishing (2 March 2011), ISBN-10: 9783843362740, ISBN-13: 978-3843362740

b) Online Educational Resources (OER):

1) https://onlinecourses.swayam2.ac.in/ntr24_ed10/preview
2) https://nptel.ac.in/courses/127105017
3) https://onlinecourses.swayam2.ac.in/ntr20_ed03/preview
4) https://onlinecourses.swayam2.ac.in/ntr22_ed16/preview
5) https://onlinecourses.swayam2.ac.in/ntr19_ed16/preview
6) https://www.youtube.com/watch?v=zhvzu8WkQs4
7) http://youtube.com/watch?v=vRKRQi2QnAQ&t=5s

Q) Course Curriculum Developer

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A)	**Course Title:** Indian Knowledge System (IKS)	Deemed to be University under Distinct Category
B)	**Course Code:** NEP06	
C)	**Pre- requisite (s):**	

D) **Rationale:** This course will survey the basic structure and operative dimensions of Indian knowledge system. With the new education policy-NEP 2020 focusing on Indian Knowledge Systems (IKS) and Traditions of India. This course introduces the learners to the rich and varied knowledge traditions of India from antiquity to the present. This also helps the learner to know and understand their own systems and traditions which are imperative for any real development and progress. Also, it helps the learner to think independently and originally adopting Indian frameworks and models for solving the problems related to world of work where the student is supposed to perform.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP06.CO1	Identify the rich heritage and legacy residing in our Indian Knowledge systems.
NEP06.CO2	Correlate the technological & philosophical concepts of IKS with engineering domain specific problems and local problems for finding out possible solutions

F) **Suggested Course Articulation Matrix (CAM):**

Course Outcomes (COs)	Programme Outcomes (POs)				
	PO-1 Apply knowledge of management theories and practices to solve business problems.	**PO-2** Foster Analytical and critical thinking abilities for data-based decision-making.	**PO-3** Ability to develop Value based Leadership ability.	**PO-4** Ability to understand, analyze and communicate global, economic, legal, and ethical aspects of business.	**PO-5** Ability to lead themselves and others in the achievement of organizational goals, contributing effectively to a team environment.
NEP06.CO1	1	-	1	-	-
NEP06.CO2	1	1	1	-	-

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP06	NEP	Indian Knowledge System (IKS)	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the architecture of the Ancient Indian Knowledge Systems. *TSO 1b.* List the salient features of IKS. *TSO 1c.* Comprehend the given IKS model. *TSO 1d.* Identify the role and relevance of the given IKS model in contemporary society.	**Unit-1.0 Introduction to Indian Knowledge Systems** 1.1 Overview of IKS 1.2 Organization of IKS – चतुर्दश-विद्यास्थानं 1.3 Conception and Constitution of Knowledge in Indian Tradition 1.4 The Oral Tradition 1.5 Models and Strategies of IKS	**CO1**
TSO 2a. Enlist the importance of Veda, Vedanga, Visaya, Siksaka. *TSO 2b.* Describe the given IKS domain. *TSO 2c.* Identify elements of mentioned IKS domains that are relevant to Technical Education System. *TSO 2d.* Correlate the elements of mentioned IKS domains with given engineering domain.	**Unit-2.0 Overview of IKS domains and relevance in current Technical Education System.** 2.1 The Vedas as the basis of IKS 2.2 Overview of all the six Vedāṅgas 2.3 Relevance of following IKS domains in present Technical Education System: • Arthashastra (Indian economics and political systems) • Ganita and Jyamiti (Indian Mathematics, Astronomy and Geometry • Rasayana (Indian Chemical Sciences)	**CO1, CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
	• Ayurveda (Indian Biological Sciences / Diet & Nutrition) • Jyotish Vidya (Observational astronomy and calendar systems) • Prakriti Vidya (Indian system of Terrestrial/ Material Sciences/ Ecology and Atmospheric Sciences) • Vastu Vidya (Indian system of Aesthetics-Iconography and built-environment /Architecture) • Nyaya Shastra (Indian systems of Social Ethics, Logic and Law) • Shilpa and Natya Shastra (Indian Classical Arts: Performing and Fine Arts) • Sankhya and Yoga Darshna (Indian psychology, Yoga and consciousness studies) • Vrikshayurveda (Plant Science / Sustainable agriculture/food preservation methods)	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems:

a. Relevance of Ayurveda in Modern Healthcare

- Problem: How can Ayurvedic principles be integrated into modern medical practices to provide holistic healthcare solutions?
- Focus: Researching the efficacy of Ayurvedic treatments in chronic diseases, lifestyle disorders, and preventive healthcare, and exploring ways to bridge Ayurveda with modern healthcare systems.

b. Vedic Astronomy and Modern Astrophysics: A Comparative Study

- Problem: What are the similarities and differences between ancient Vedic astronomy and modern astrophysical theories?
- Focus: Exploring ancient Indian astronomical texts like the *Surya Siddhanta* and their insights into planetary motions, eclipses, and cosmology, and comparing these with contemporary astronomical models.

c. Yoga and Mental Health: A Scientific Perspective

- Problem: How can the practice of Yoga and its underlying philosophical principles contribute to mental health therapies in modern psychology?
- Focus: Exploring the psychological benefits of yogic practices like meditation, pranayama, and asanas, and scientifically evaluating their impact on anxiety, depression, and stress management.

d. The Role of Ancient Indian Agriculture in Sustainable Farming Practices

- Problem: How can ancient Indian agricultural practices, such as organic farming and crop rotation, be applied to address contemporary challenges in sustainable agriculture?
- Focus: Investigating ancient texts like the *Krishi-Parashara* and traditional knowledge in water management, soil conservation, and sustainable farming, and adapting these to modern agricultural practices.

e. Vedic Mathematics and Its Role in Contemporary Education

- Problem: How can Vedic Mathematics techniques be integrated into modern education systems to enhance students' computational skills and logical reasoning?
- Focus: Researching the techniques of Vedic Mathematics and exploring their effectiveness in improving mathematical literacy and problem-solving abilities among students.

f. Natyashastra and Its Influence on Modern Theatre and Performing Arts

- Problem: What are the enduring influences of *Natyashastra*, the ancient Indian treatise on performing arts, on modern theatre, dance, and cinema?
- Focus: Analyzing the principles of *Natyashastra* in terms of aesthetics, drama, and performance, and exploring its relevance and application in contemporary performing arts.

g. Traditional Indian Water Management Systems: Lessons for the Future

- Problem: How can traditional water management systems, like step wells and rainwater harvesting structures from ancient India, be revived to solve modern water scarcity issues?
- Focus: Investigating ancient Indian water management practices and their sustainability, and exploring their application in current water conservation efforts and urban planning.

h. Ancient Indian Contributions to Astronomy and Navigation

- Problem: What were the contributions of ancient Indian scholars to the field of navigation and astronomy, and how can this knowledge be applied in modern scientific advancements?
- Focus: Exploring the contributions of ancient Indian navigators and astronomers in calculating planetary positions, timekeeping, and navigation, and their influence on global knowledge systems.

i. Military Science in Ancient India and Its Lessons for Modern Defense Strategies

- Problem: What can modern military strategists learn from ancient Indian military texts like *Niyuddha Kala* and *Arthashastra*?
- Focus: Studying ancient Indian warfare techniques, battle strategies, and defense technologies, and their relevance in contemporary military science and national defense planning.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

b. Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

i. Comparative Study of Ayurveda and Modern Medicine

- Objective: Compare the principles of Ayurveda with modern medicine in the treatment of common diseases.
- Assignment: Select a particular health issue (e.g., diabetes, hypertension) and compare Ayurvedic approaches with modern medical treatments. Discuss the strengths and limitations of both systems.

ii. Contributions of Ancient Indian Mathematicians

- Objective: Explore the contributions of ancient Indian mathematicians like Aryabhata, Bhaskara, and Brahmagupta.
- Assignment: Write a research paper on a specific mathematical concept (e.g., zero, algebra) developed by ancient Indian scholars and its relevance in modern mathematics.

iii. Analysis of Vedic Astronomy and Its Accuracy

- Objective: Understand how ancient Indian astronomers calculated celestial movements.
- Assignment: Analyze a Vedic astronomical text, such as the Surya Siddhanta, and discuss its accuracy in predicting celestial phenomena like solar or lunar eclipses.

iv. Traditional Water Management Systems in India

- Objective: Investigate ancient Indian water management techniques and their sustainability.
- Assignment: Select a traditional water conservation structure (e.g., step wells, tanks) and analyze its design, efficiency, and potential application in addressing modern water scarcity.

v. Impact of Yoga on Mental and Physical Health

- Objective: Explore the benefits of Yoga on mental and physical well-being.
- Assignment: Research the scientific basis of a particular Yoga practice (e.g., pranayama, meditation) and its impact on health, using both ancient texts and modern scientific studies.

vi. Sustainable Agriculture Practices in Ancient India

- Objective: Investigate traditional agricultural methods in ancient India and their relevance today.
- Assignment: Study a specific ancient agricultural practice (e.g., organic farming, crop rotation) and evaluate how it can address current challenges like soil degradation or climate change.

vii. Chandashastra (Prosody) and Its Application in Modern Poetry

- Objective: Understand the significance of Chandashastra in shaping poetic meter and structure.
- Assignment: Select a Vedic meter (chandas) from Chandashastra and compare its structure with modern poetic forms, analyzing similarities and differences.

viii. Study of Natyashastra and Its Influence on Modern Performing Arts

- Objective: Analyze the influence of Natyashastra on modern performing arts.
- Assignment: Research a section of Natyashastra related to drama or dance, and explain how its principles are applied or can be applied in modern theatre or cinema.

ix. Indian Metallurgy: Ancient Innovations and Modern Applications

- Objective: Understand ancient Indian metallurgical practices and their significance.
- Assignment: Study an ancient Indian metallurgical achievement, such as the rust-resistant Iron Pillar of Delhi, and analyze the scientific techniques used. Compare this with modern metallurgical practices.

c. Seminar Topics:

- "Ayurveda: The Ancient Science of Healing in Modern Healthcare"
- "Mathematical Brilliance of Ancient India: Contributions of Aryabhata and Beyond"
- "Vedic Astronomy: Insights from the Cosmos in Ancient India"
- "Sanskrit and Artificial Intelligence: The Linguistic Bridge to Future Technologies"
- "Iron Pillar of Delhi: The Science Behind Ancient Indian Metallurgy"
- "Yoga for Mental Health: A Scientific Exploration of Ancient Practices"
- "Ancient Indian Water Management Systems: Lessons for Sustainable Development"
- "Ethics in the Mahabharata: Leadership Lessons for the Modern World"
- "Vedic Mathematics: Speed and Simplicity in Problem Solving"
- "Natyashastra: The Ancient Indian Treatise on Performing Arts"
- "Logic and Disputation in Ancient India: The Role of Anviksiki"
- "Traditional Indian Agriculture: Pathways to Sustainable Farming"
- "The Science of Consciousness: Vedantic Insights and Modern Neuroscience"
- "Ancient Indian Contributions to Navigation and Maritime Science"
- "Chandashastra: The Science of Prosody in Sanskrit Poetry"
- "Military Strategies of Ancient India: Lessons from the Arthashastra"
- "Environmental Conservation in Ancient Indian Philosophy: Vedic Insights"
- "Traditional Indian Medicine: Exploring the Efficacy of Siddha and Unani Systems"
- "Agricultural Economics in Ancient India: Insights from Arthashastra and Krishi-Parashara"
- "Traditional Indian Knowledge in Climate Change Adaptation"

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction to Indian Knowledge System: Concepts and Applications	Archak, K.B. (2012).	Kaveri Books, New Delhi ISBN-13:978-9391818203
2.	Introduction To Indian Knowledge System: Concepts and Applications	Mahadevan, B. Bhat, Vinayak Rajat Nagendra Pavana R.N.	PHI, ISBN: 9789391818203
3.	Glimpse into Kautilya's Arthashastra	Ramachandrudu P. (2010)	Sanskrit Academy, Hyderabad ISBN:9788380171074
4.	"Introduction" in Studies in Epics and Purāṇas, (Eds.)	KM Munshi and N Chandrashekara Aiyer	Bhartiya Vidya Bhavan

b) Online Educational Resources (OER):

1) http://bhavana.org.in
2) www.academia.edu/23254393/Science_in_Ancient_India_-_an_educational_module
3) www.academia.edu/23305766/Technology_in_Ancient_India_-_Michel_Danino
4) www.hamsi.org.nz/http://insaindia.res.in/journals/ijhs.php
5) www.niscair.res.in/sciencecommunication/ResearchJournals/rejour/ijtk/ijtk0.asp
6) www-history.mcs.st-andrews.ac.uk/Indexes/Indians.html
7) Swami Harshananda. "A bird's eye view of vedas". R K Math. Bangalore.,http:// rkmathbangalore. org/Books/ABirdsEyeViewOfTheVedas.pdf.
8) Sanskrit Prosody, https://en.wikipedia.org/wiki/Sanskrit_prosody.
9) Vartak, P.V. (1995). "Veda and Jyotish," Part II, Chapter 2, in Issues in Veda and Astrology, H Pandya (Ed.), pp 65 – 73.

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Course Curriculum Detailing- Online Spell -2

S. No.	Course Codes	Course Titles	Page No.
1.	PC03	Mooc Creation	172
2.	PC04	Learner Centric Instructional Methods	178
3.	NEP07	Intellectual Property Rights (IPR)	184

A)	**Course Title:** MOOC Creation	Deemed to be University under Distinct Category
B)	**Course Code:** PC03	
C)	**Pre- requisite (s):**	

D) **Rationale:** The exponential growth of online education, accelerated by global digital transformation, has created an unprecedented demand for high-quality Massive Open Online Courses (MOOCs). Engineering professionals are increasingly required to share their expertise through digital platforms, conduct training programs, and contribute to knowledge dissemination on a global scale. This course addresses the critical need to develop competencies in educational technology design, content creation, and online pedagogy. Students will gain practical experience in conceptualizing, designing, developing, and deploying MOOCs that can reach thousands of learners worldwide. The course integrates engineering problem-solving approaches with educational design principles, enabling graduates to create impactful learning experiences in their respective engineering disciplines. The course aligns with Industry 4.0 requirements, where professionals must not only possess technical expertise but also the ability to transfer knowledge effectively through digital mediums. This skill is particularly valuable for careers in academia, corporate training, consulting, and entrepreneurship in the education technology sector.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected toensuretheaccomplishmentoffollowingindustryexpectedcourseoutcomesbythelearners.

Course Outcomes (COs)	Course Outcome Statements
PC03.CO1	Develop a comprehensive MOOC course structure using instructional design principles.
PC03.CO2	Prepare sample e-content lessons.
PC03.CO3	Produce sample digital media content.
PC03.CO4	Upload the MOOC course structure and its components as per the given guidelines on the LMS.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)		
	PO-1 Independently carry out research/ investigation, and development work to solve practical problems.	**PO-2** Write and present a substantial technical report/ document.	**PO-3** Demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program
PC03.CO1	3	3	3
PC03.CO2	2	2	3
PC03.CO3	2	2	3
PC03.CO4	-	2	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PC03	PC	MOOC Creation	30	-	-	30	60	02	20	30	50	-	-	-	100

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the evolution, characteristics, and types of MOOCs. *TSO 1b.* Interpret learner demographics, motivations, and challenges in MOOC environments. *TSO 1c.* Apply instructional design framework and models for MOOC development. *TSO 1d.* Formulate MOOC outcomes. *TSO 1e.* Design the MOOC course structure.	**Unit-1.0 Foundation of MOOC Design** 1.1 History and evolution of MOOCs. 1.2 MOOCs types and their characteristics. 1.3 Role of learning theories in MOOC design. 1.4 Learner psychology in massive open environments. 1.5 Instructional design frameworks and Models – ADDIE, SAM, Advance Organizer. 1.6 MOOC Components. 1.7 Formulating MOOC outcomes. 1.8 Content structuring and organisation	**CO1**
TSO 2a. Explain the philosophy of self-learning material development. *TSO 2b.* Integrate principles of microlearning and media design for content creation. *TSO 2c.* Integrate elements of Dale's Cone of Experience and principles of micro-learning in the development of lessons. *TSO 2d.* Prepare a bank of OER to be integrated into the MOOC. *TSO 2e.* Prepare a lesson/s along with assessment questions and discussion forum statement as per the given guideline	**Unit-2.0 E-Content Lesson Development** 2.1 Philosophy for the development of self-learning material. 2.2 Principles of microlearning and Media design. 2.3 Dale's cone of experience. 2.4 Intellectual Property rights, OER and Creative Commons licenses. 2.5 Designing MCQ and Discussion forum. 2.6 Rubrics for ''Prepare a sample prototype E Content'' 2.7 Sample format/s for the development of lessons mentioned in the course structure.	**CO2**
TSO 3a. Design graphics, animation, presentation and interactive content using media design principles. *TSO 3b.* Create a sample podcast for MOOC. *TSO 3c.* Write a sample video script for the selected MOOC lesson. *TSO 3d.* Write a shooting script. *TSO 3e.* Plan for video production. *TSO 3f.* Present to camera in studio. *TSO 3g.* Edit the video and sound file for finalisation of the sample video.	**Unit-3.0 Digital Media Production** 3.1 Video production pipeline – Video production vocabulary. 3.2 Multi-camera studio production. 3.3 Podcast creation. 3.4 Video script development. 3.5 Graphics design and animation. 3.6 Shooting script development. 3.7 Interactive content creation tools. 3.8 Audio and video editing.	**CO3**
TSO 4a. Describe features of the SWAYAM MOOCs. *TSO 4b.* Design the course structure on ePrashikshan. *TSO 4c.* Verify that all MOOC components developed adhere to LMS guidelines.	**Unit-4.0 MOOC Course Configuration on LMS and its Guidelines** 4.1 SWAYAM Guidelines for MOOC development. 4.2 Overview of SWAYAM MOOC structure.	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 4d. Upload MOOC components on ePrashikshan. *TSO 4e.* Test the MOOC course using the pre-launch checklist.	4.3 LMS (ePrashikshan) and its features for MOOC 4.4 LMS-specific guidelines for video duration, file formats, accessibility standards, copyright policies, and assessment requirements 4.5 LMS structure design aspects aligned to course structure (course builder) 4.6 Steps for uploading the MOOC component on LMS 4.7 Steps for publishing MOOC content 4.8 Pre-launch Checklist for LMS - Test all links and embedded media, Review course flow from a learner's perspective, Check quiz functionality and grading settings, test for cross-device and browser compatibility 4.9 Pilot and beta testing	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems (10 marks- part of term work)

i. Prepare a review paper based on the latest research on the theme related to MOOC design/ delivery/ Assessment of Effectiveness of content/ Effectiveness of activities.

ii. Compare the MOOC course structure of various MOOCs offered on different platforms and present.

iii. Compare different video formats used in various MOOCs offered on different platforms and present.

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a. Assignment(s): A portfolio consisting of the following- (6 Marks each)

6.7.1.1 Design of Course Builder and Flyer
6.7.1.2 Create a bank of OERs related to the MOOC topic.
6.7.1.3 Design of Sample e-content lesson along with SAQs
6.7.1.4 Design of Presentation and video recording
6.7.1.5 Design of Assessment MCQs for the sample content produced

b. Seminar presentation: Presentation of the MOOC developed in the seminar (10 Marks)

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit 1.0 Foundation of MOOC Design	03
CO2	Unit 2.0 E-Content Lesson Development	06
CO3	Unit 3.0 Digital Media Production	15
CO4	Unit 4.0 MOOC Course Configuration on LMS and its Guidelines	06
Total		**30**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experience / Practical Number
1.	Multi-camera studio setup with teleprompter, chroma key set, storage system, lights and audio equipment	Three video cameras set up, HD/ 4K, with Camera Control Unit, Tripod, HD/ 4K recorder, Recording media, Studio lights, different types of microphones and storage system.	All
2.	DSLR Camera setup	Digital HD/ 4K still plus video camera with flash and recording media.	All
3.	Hi-end computer systems	HP Workstation with Intel Core i9 13900 Processor, 32 GB, 1 TB HDD for video editing and graphics preparation.	All
4.	Graphics designing software	Adobe Creative Suite CS 4, Adobe Creative Cloud 2025, Canva	All
5.	Video editing software	Adobe Creative Suite CS 4, Adobe Creative Cloud 2025	All
6.	Sound editing software	Adobe Creative Suite CS 4, Adobe Creative Cloud 2025	All

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	The Cambridge Handbook of Multimedia Learning	Edited by Richard E. Mayer, University of California, Santa Barbara, and Logan Fiorella, University of Georgia	Cambridge University Press, 3rd Edition, Online ISBN: 9781108894333 https://doi.org/10.1017/9781108894333

b) Online Educational Resources (OER):

1) https://storage.googleapis.com/swayam2_central/swayam1/wqimgtest_f8b95943-b963-49b9-85ed-416f2e15d1b4.pdf
2) https://storage.googleapis.com/swayam2_central/swayam1/UGC_Gazette-Credit_Framework_for_Online_Courses_through_SWAYAM.pdf
3) https://storage.googleapis.com/swayam2_central/swayam1/wqimgtest_9da02ba8-bdd8-409c-afdb-645e6dbc544f.pdf
4) https://swayam.gov.in
5) https://pmevidya.education.gov.in/swayam-portal.html
6) https://swayam.inflibnet.ac.in
7) https://spoken-tutorial.org
8) https://epgp.inflibnet.ac.in
9) https://search.creativecommons.org

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A)	**Course Title:** Learner Centric Instructional Methods	Deemed to be University under Distinct Category
B)	**Course Code:** PC04	
C)	**Pre- requisite (s):**	

D) **Rationale:** For planning and implementing a teaching learning session, number of instructional choices are involved, of which one of the vital decisions is regarding the instructional methods to be employed. Learner-centric approaches have proven more effective than traditional teacher-centric methods because they actively engage students in the learning process, empowering them to achieve intended outcomes through meaningful participation. Building on this foundation, Artificial Intelligence has emerged as a transformative force in contemporary education, creating new possibilities for personalized learning, adaptive instruction, and intelligent tutoring systems. This course introduces learners to a comprehensive range of learner centric instructional methods, including these AI-enhanced pedagogical approaches, enabling them to strategically match content with effective delivery strategies. Such alignment becomes particularly valuable for those considering teaching careers in educational institution. Furthermore, the course benefits all learners by equipping them with methods they can immediately apply to enhance their own learning experiences.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
PC04.CO1	Apply the principles of learning to enhance the effectiveness of instructional process to achieve intended learning outcomes in different domains.
PC04.CO2	Plan to use appropriate instructional method effectively for developing learning outcomes.
PC04.CO3	Interpret the suitability of small group methods to enhance teaching learning effectiveness ensuring learner participation.
PC04.CO4	Devise effective strategy using appropriate learner centred instructional methods and AI tools for a given content.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)		
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PC04.CO1	-	2	3
PC04.CO2	2	2	2
PC04.CO3	2	2	2
PC04.CO4	2	2	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
PC04	PC	Learner Centric Instructional Methods	30	-	-	30	60	02	30	50	20	-	-	-	100

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Justify the need for a variety of instructional methods to attain learning outcomes. *TSO 1b.* Formulate learning outcomes at different taxonomic levels of Cognitive, Affective and Psychomotor domains. *TSO 1c.* Enhance effectiveness of session integrating principles of learning and events of instruction. *TSO 1d.* Classify different types of instructional methods and strategies. *TSO 1e.* Identify potential issues and concerns associated with Teacher centric method *TSO 1f.* Develop an instructional session plan.	**Unit -1.0 Learning Principles and Instructional Methods** 1.1 Learning in different Domains, Learning Outcomes in different domains 1.2 Principles of Learning and Events of Instruction 1.3 Need for Variety of Instructional Methods 1.4 Classification of Instructional Methods and Strategies: Learner Centric and Teacher Centric Methods 1.5 Instruction Session Planning and Implementation	**CO1**
TSO 2a. Use tutorial method effectively. *TSO 2b.* Employ assignment method to develop the pre-determined outcomes. *TSO 2c.* Plan to use laboratory and workshop as an effective instructional method for developing practical skills. *TSO 2d.* Interpret the different techniques of developing workshop related skills. *TSO 2e.* Use project work effectively in teaching-learning situations. *TSO 2f.* Describe how problem-based learning can build critical thinking and reasoning skills.	**Unit-2.0 Interactive and Action Oriented Instructional Methods** 2.1 Question-Answer Technique 2.2 Tutorial Method 2.3 Assignment Method 2.4 Laboratory Work 2.5 Workshop Method 2.6 Project work 2.7 Problem Based Learning	**CO2**
TSO 3a. Use seminar method effectively. *TSO 3b.* Employ case study and group discussion. *TSO 3c.* Explain the strategy to improve the effectiveness of classroom teaching-learning process using Buzz Group method.	**Unit-3.0 Small Group Instructional Methods** 3.1 Seminar Method 3.2 Case Study Method 3.3 Group Discussion 3.4 Buzz Group Session 3.5 Brain Storming Technique	**CO3**
TSO 4a. Describe the principles and advantages of individualized instruction. *TSO 4b.* Explain the need and abilities required for self-learning. *TSO 4c.* Justify the need for variety of ICT Based Techniques for enhancing learning. *TSO 4d.* Explain the way blended and flipped learning approaches can be applied in teaching learning process for improving students' learning. *TSO 4e.* Analyze how AI can enhance effectiveness of instructional sessions.	**Unit-4.0 Online Learning Methods** 4.1 Individualized learning 4.2 Self-Learning 4.3 ICT Based Techniques to enhance Learning (E-learning Platforms: MOOCs, LMS, Educational Apps and Tools, Online Collaboration Tools) 4.4 Applications of AI in Education, AI-powered virtual laboratories 4.5 AI-Powered Personalized Learning Systems: Intelligent Tutoring Systems,	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 4f. Evaluate AI-powered personalized learning systems and their effectiveness.	Adaptive Learning Platforms, AI Chatbots for Education 4.6 Blended and Flipped Learning Approach	

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

a. Perform a literature review on the features and effectiveness of instructional methods that have evolved during recent years.

b. Find out the common barriers perceived in an educational institution in adopting learner-centric instructional strategies.

c. Evaluate the learner satisfaction and motivation, comparing conventional lecture methods and learner-centric approaches

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a) Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Formulate learning outcomes at different taxonomic levels of Cognitive, Affective and Psychomotor domains for an identified course.
- Develop a simple case with brief for an identified course.
- Identify the practical outcomes to be developed through lab experiences for an identified course.
- Identify topics in your area where project method (both minor and major) can be used.
- Prepare instructional session plan for at least three lessons from a selected course.
- Implement the instructional session plan developed in Assignment a4 and upload the recorded video of simulated experience.

b) Seminar Topics:

- Inquiry-Based Learning: Fostering Critical Thinking and Student Investigation
- Theories of Learning
- Learning Styles
- Digital Tools for Student-Centered Education
- Differentiated Instruction process
- Student Self-Assessment
- Gamification and Game-Based Learning

- Experiential Learning: Learning through Direct Experience and Reflection

M) Suggested Specification Table for End Semester Theory Assessment (ETA): Questions may be designed based on the higher taxonomy level of cognitive domain.

COs	Relevant Unit Number and Title	Marks
CO1	Unit-1.0 Learning Principles and Instructional Methods	14
CO2	Unit-2.0 Interactive and Action Oriented Instructional Methods	14
CO3	Unit-3.0 Small Group Instructional Methods	12
CO4	Unit-4.0 Online Learning Methods	10
Total		**50**

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Teaching Strategies: A Guide to Effective Instruction	Orlich, Donald C., Harder, Robert J., Trevisan, Michael S., Brown, Abbie H., and Miller, Darcy E.	Cengage Learning, Eleventh Edition, 2017, ISBN: 978-1305960787
2.	Methods and Techniques of Teaching	Kochhar, S. K.	Sterling Publishers, 2018 ISBN: 978-8120700710
3.	A Taxonomy for Learning, Teaching and Assessing - A revision of Bloom's taxonomy of Educational Objectives	Anderson, L. W., and Krathwohl, D. R.	Pearson Education, First Edition, 2001 ISBN: 978-0801319037
4.	Effective Teaching Methods: Research-Based Practice	Borich, Gary D.	Pearson, Tenth Edition, 2021, ISBN: 978-0136794271
5.	Devise Teaching Strategies and Select Teaching Methods: Module No.2	Banthiya N. K., Earnest Joshua, Mathew Susan S. (Ed.)	TTTI Bhopal, 1999

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
6.	Teaching Strategies: A Guide to Effective Instruction	Donald C. Orlich, Robert J. Harder, Michael S. Trevisan, Abbie H. Brown, Darcy E. Miller	Cengage Learning, 2016, Eleventh Edition, ISBN: 978-1305960787
7.	Advanced Teaching Methods for the Technology Classroom	Petrina, Stephen	IGI Global, 2010, ISBN: 978- 1599043371
8.	Theory and Practice of Case Method of Instruction	Bahttacharya, B.	Excel Books, 2015, ISBN: 9788174465588
9.	Artificial Intelligence in Education: Promises and Implications for Teaching and Learning	Holmes, Wayne, Bialik, Maya, and Fadel, Charles	Center for Curriculum Redesign, 2019, ISBN: 978-1794237111
10.	AI for Teaching and Learning: A Guide for Educators	Chen, Li, Dede, Chris	Harvard Education Press, 2021, ISBN: 978-1682536094

b) Online Educational Resources (OER):

1) http://nufosece.ru/fipofoq.pdf; “Teaching Strategies: A Guide to Better Instruction”
2) http://ro.uow.edu.au/cgi/viewcontent.cgi?article=1413&context=asdpapers; Tools for learning: Technology and teaching strategies Michelle Eady and Lori Lockyer
3) https://onlinecourses.swayam2.ac.in/ntr24_ed52/preview; “Basic Instructional Methods”
4) https://onlinecourses.swayam2.ac.in/ntr24_ed49/preview; “Advanced Instructional Methods”
5) https://nittt.ac.in/modules/Module-4.pdf; “Module 4: Instructional Planning and Delivery”
6) http://unesdoc.unesco.org/images/0010/001095/109590eo.pdf; Delors, J. et al. 1996, Learning: The Treasure Within. Report to UNESCO of the International Commission on Education for the Twenty-First Century. Paris, UNESCO
7) https://www.edx.org/course/artificial-intelligence-in-education; "AI in Education: Fundamentals and Application
8) https://www.coursera.org/specializations/ai-for-teaching-and-learning; "AI for Teaching and Learning Specialization"
9) https://www.unesco.org/en/articles/artificial-intelligence-education-challenges-and-opportunities-sustainable-development; "UNESCO AI in Education Guidelines"
10) https://onlinecourses.swayam2.ac.in/ntr25_ed40/preview, “Integration of Artificial Intelligence in Educational Practices”

Q) Course Curriculum Development Team

S. No.	Name	E-mail Address
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2.	Prof. Chanchal Mehra	cmehra@nitttrbpl.ac.in

****

A)	**Course Title:** Intellectual Property Rights (IPR)	Deemed to be University under Distinct Category
B)	**Course Code:** NEP07	
C)	**Pre- requisite (s):**	

D) **Rationale:** Intellectual Property Rights encourage continued creativity and artistic innovation, enriching cultural heritage and promoting diversity in the creative industries by safeguarding the rights of creators and artists under appropriate acts/laws. This course will enable the students to protect their inventions, creative work/assets/product under intellectual property Rights such as patents, copyrights, trademarks, Geographical Indications, Industrial designs, layout of Integrated Circuit design, trade secrets, Traditional knowledge, Plant varieties and Farmer's protection under various IPR laws and acts to succeed in their career and avoid unnecessary litigations.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following industry expected course outcomes by the learners.

Course Outcomes (COs)	Course Outcome Statements
NEP07.CO1	Realize the need and significance of Intellectual property (IP), Intellectual Property Rights (IPR) and IPR policy in India.
NEP07.CO2	Protect your innovative product and creative original work under Patent, Copy right, Trademark, Geographical Indication and Plant variety and Farmer's right.
NEP07.CO3	Protect your innovative product under Industrial Design/ Layout design of Integrated Circuit/Trade secret.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)					
	PO-1 An ability to independently carry out research /investigation and development work to solve practical problems.	**PO-2** An ability to write and present a substantial technical report/document.	**PO-3** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	**PO-4** An ability to use different advanced software tools for analysis and design in the field of Green Technology.	**PO-5** An ability to acquire professional and intellectual integrity, ethics of research and an understanding of responsibility to contribute to the community for sustainable development of society.	**PO-6** An ability to engage in life-long learning with a high level of commitment to improve knowledge and competence continuously.
NEP07.CO1	2	2	1	-	2	2
NEP07.CO2	2	2	1	1	2	2
NEP07.CO3	2	2	1	1	2	2

Legend: High (3), Medium (2), Low (1) and No mapping (-)

G) Teaching & Learning and Assessment Scheme:

Course Code	Course Category	Course Titles	Teaching & Learning Scheme (Hours)						Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Component (TC)		Lab Instruction (LI)	Term Work (TW) + Self Learning (SL)	Total Hours (TC+LI+TW+ SL) (For 15 Weeks)	Total Credits (C)	Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
			Input (I)	Tutorial (T)					Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Term Work Assessment (PTWA)	End Term Work Assessment (ETWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
NEP07	NEP	Intellectual Property Rights (IPR)	15	-	-	15	30	01	25	-	25	-	-	-	50

H) Course Curriculum Detailing: For attainment of course outcomes, the students are expected to perform/ undergo various activities through classroom, laboratories/ workshops/ term work, self-learning/ field sessions. As per the requirements of NEP 2020, unique features like green skills, multidisciplinary aspects, societal connect, IKS, renewable energy are integrated appropriately.

I) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 1a. Explain the concept of Intellectual Property (IP) and Intellectual Property Right (IPR). *TSO 1b.* Enlist the types of IPR and the type of protection it offers to a product. *TSO 1c.* With the example of any product explain how the IPR is enforced on a product *TSO 1d.* Name the Legislations Covering different types of IPRs in India. *TSO 1e.* Explain the need and significance of IPR policy in an Institution. *TSO 1f.* Differentiate between limited and unlimited IP with examples	**Unit-1.0 Introduction to IP, IPR and its enforcement** 1.1 IP and IPR – Concept, need and its significance 1.2 Types of IPR – Patent, Copyright, Trademark, Geographical Indications, Industrial designs, Layout design of Integrated Circuit, trade secret, Traditional knowledge, Plant varieties and farmer's rights 1.3 Enforcement of IP on a given product, Overlapping rights 1.4 Legislations Covering IPRs in India 1.5 IPR Policy – Need and significance 1.6 Limited life and Unlimited life IPS	**CO1**
TSO 2a. Explain the need and significance of patent/Copyright/GI/ Plant variety and farmer's right/Traditional knowledge *TSO 2b.* Enlist the criteria for protection under patent/Copyright/GI/ Plant variety and farmer's right/Traditional knowledge *TSO 2c.* List the work protected under patent/Copyright/GI/ Plant variety and farmer's right/Traditional knowledge *TSO 2d.* Mention the legislation set up in India and fees applicable for getting Patent/Copyright/GI/ Plant variety and farmer's right. Also mention the tenure of protection *TSO 2e.* Describe in brief every step of process of patenting/Copyright /GI with the help of a flowchart	**Unit-2.0 Patent, Copyright and related rights, Geographical Indications, Plant Varity and farmer's right, Traditional knowledge** 2.1 Patent - Need and significance of patent, patentable and non-patentable inventions, types of Patent, tenure, legislation and organization set up in India, fees and brief procedure of patent filling in India indicating every step, Infringement, Commercialization of a patent. 2.2 Copyright and related rights - Need and significance of Copyright and related rights, entitlement to protection of copyright, works protected, tenure, legislation and organization set up in India, role of Copyright Board, copy right society, assignment and licensing, fees, brief procedure and infringement. 2.3 Geographical Indications (GI)- Need and significance of GI, entitlement to protection of GI, works protected, classes of GI, tenure, legislation and organization set up in India and fees, Passing and infringement of GI. 2.4 Plant Variety & Farmer's Rights – Need and significance, entitlement to protection of plant varieties, register able plant varieties in India, Duration of protection for a registered new plant variety. 2.5 Traditional knowledge (TK) – Significance, Agreement on TK and its protection.	**CO2**

Major Theory Session Outcomes (TSOs)	Units	Relevant CO Number(s)
TSO 3a. Explain the need and significance of Industrial Design/ Layout design of Integrated Circuit/Trademark/Trade secret. *TSO 3b.* Enlist the criteria for protection under of Industrial Design/ Layout design of Integrated Circuit/ Trademark/Trade secret. *TSO 3c.* List the work protected under Industrial Design/ Layout design of Integrated Circuit/Trademark/Trade secret. *TSO 3d.* Mention the legislation set up in India, fees, tenure infringement and remedies applicable for getting Industrial Design/ Layout design of Integrated Circuit, also mention the tenure of protection *TSO 3e.* Explain the strategies to protect trade secret in India with 2 examples	**Unit-3.0 Layout design of Integrated Circuits Industrial Designs, Trademark and Trade secrets,** 3.1 Layout design of Integrated Circuits - Need and significance of protection of layout designs for Integrated Circuits. entitlement to protection, works protected, tenure, legislation and organization set up in India and fees, and Infringement. 3.2 Industrial Designs - Need and significance of Industrial Designs, entitlement to protection of designs, works protected, tenure, who can apply, legislation and organization set up in India and fees, Infringement of design right. 3.3 Trademark – Need and significance, Types of trademark**,** entitlement to protection of trademark, tenure, legislation and organization set up in India and fees, who can apply, Procedure for filing application for Trademark, Passing and infringement of trademark. **3.4** Trade secret- Need and significance of Trade secret protection. entitlement to protection, works protected, tenure, legislation and organization set up in India and fees, strategies to protect trade secret in India.	**CO3**

J) Suggested Laboratory Experiences: (Not Applicable)

K) Suggested Research Based Problems

Note: Depending on the requirement of each laboratory experience, micro project and research-based problems, the performance may be conducted in online/offline mode and accordingly appropriate assessment tools may be used.

L) Suggested Term Work (TW):

a) Assignment(s):

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- A product is always protected simultaneously by more than one type of IPR and there is always the overlapping of rights. Considering the example of purple pill or any other product, highlight the enforcement of IP particularly Patent, Copyright, Trademark, design, and trade secret.

- Mr. Ram has created and designed an innovative website. Analyze the appropriate protection mechanism/s for that website.
- Is certification mark different from collective mark? Analyze and answer
- Who can register geographical indication in India?
- Is it possible to register the shape and configuration of a shock absorber under Industrial Design act in India? Analyze and answer
- What is the need of protection of IC Layout design?
- Differentiate between assignment and licensing in case of Copyright.
- Whether attributes of patented product can be protected by trade-secret? Analyze and answer
- Describe strategies used to protect trade secrets in Research Organizations and software companies.

M) Suggested Specification Table for End Semester Theory Assessment (ETA): (Not Applicable)

N) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately used in online and offline mode, as per the requirement of the outcome to be achieved. Some of them are improved lecture, tutorial, case method, group discussion, industrial visits, industrial training, field trips, portfolio based, learning, role play, live demonstrations in classrooms, lab, field information and communications technology (ICT)based teaching learning, blended or flipped mode, brainstorming, expert session, video clippings, use of open educational resources (OER), MOOCs etc. To ensure learning, research-based problems may be designed and implemented.

O) Major Equipment, Tools and Software for Laboratory and Research Work: (Not Applicable)

P) Suggested Learning Resources:

a) Books

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Fundamentals of Intellectual Property Rights: For Students, Industrialist and Patent Lawyers	Ramakrishna B and Anil kumar H.S.	Notion Press, 1 January 2017 ISBN-10 1946556319 ISBN-13 978-1946556318
2.	Intellectual Property Law	Narayan P.	Eastern Law House Private Ltd 1 January 2001, ISBN-10 8171772684 ISBN-13 978-8171772681
3.	Intellectual Property Rights: Text and Cases	Radhakrishnan R., Balasubramanian S	Excel Books July 30, 2008 July 30, 2008, ISBN-10: 8174466096 ISBN-13: 978-8174466099
4.	Law Relating to Intellectual Property	Wasehra B. L	Universal Law Publishing January 2016, ISBN-13 978-9350350300
5.	Intellectual Property Law	Meenu Paul	Allahabad Law Agency, ISBN-10: 8190286714, ISBN-13 : 978-8190286718
6.	Law of Intellectual Property	Myneni S. R.	Asia Law House (1 January 2019) ISBN-10: 9388437233 ISBN-13: 978-9388437233

b) Online Educational Resources (OER):

1) https://ipindia.gov.in/
2) https://nptel.ac.in/courses/109106137
3) https://books.openedition.org/iheid/652?lang=en

Others:

1) E book - https://dst.gov.in/sites/default/files/E-BOOK%20IPR.pdf
2) WIPO Intellectual Property Handbook
3) The Intellectual Property Handbook: A Practical Guide for Franchise, Business, and IP
4) Counsel Second Edition by Christopher P. Bussert, James R. Sims III
5) IPR Handbook for Pharma Students and Researchers Parikshit Bansal, Pharma Med Press, 2015
6) https://www.kaggle.com/rohankayan/years-of-experience-and-salary-dataset

Q) Course Curriculum Developer

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16. Annexure

16.1 Common Courses across the all M. Tech., MBA and M.Sc. programmes

S. No.	Common Courses Title
1.	Basics of Artificial Intelligence and Machine Learning
2.	Sports, Yoga & Meditation
3.	Open Educational Resources
4.	Professional Ethics
5.	Financial Literacy
6.	Engineering Economics
7.	Project
8.	Research Methodology
9.	Curriculum & Assessment
10.	Indian Knowledge System (IKS)
11.	Dissertation Part -I
12.	Dissertation Part - II
13.	MOOC Creation
14.	Learner Centric Instructional Methods
15.	Intellectual Property Rights (IPR)

Deemed to be University under
Distinct Category

NATIONAL INSTITUTE OF TECHNICAL TEACHERS' TRAINING AND RESEARCH (NITTTR), BHOPAL

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Madhya Pradesh, India

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