VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ELECTRONICS ENGINEERING

M. Tech Nanotechnology

(M.Tech MNT)

Curriculum

(*2019-2020 admitted students*)

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

World class Education: Excellence in education, grounded in ethics and critical thinking, for improvement of life.

Cutting edge Research: An innovation ecosystem to extend knowledge and solve critical problems.

Impactful People: Happy, accountable, caring and effective workforce and students.

Rewarding Co-creations: Active collaboration with national & international industries & universities for productivity and economic development.

Service to Society: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

To be a leader by imparting in-depth knowledge in Electronics Engineering, nurturing engineers, technologists and researchers of highest competence, who would engage in sustainable development to cater the global needs of industry and society.

MISSION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

- Create and maintain an environment to excel in teaching, learning and applied research in the fields of electronics, communication engineering and allied disciplines which pioneer for sustainable growth.
- Equip our students with necessary knowledge and skills which enable them to be lifelong learners to solve practical problems and to improve the quality of human life.

M. Tech. Nanotechnology

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry's technological problems.

2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry.

3. Graduates will function in their profession with social awareness and responsibility.

4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country.

5. Graduates will be successful in pursuing higher studies in engineering or management.

6. Graduates will pursue career paths in teaching or research.

M. Tech Nanotechnology

PROGRAMME OUTCOMES (POs)

PO_01: Having an ability to apply mathematics and science in engineering applications.

PO_02: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints, including public health, safety, culture, society and environment

PO_03: Having an ability to design and conduct experiments, as well as to analyse and interpret data, and synthesis of information

PO_04: Having an ability to use techniques, skills, resources and modern engineering and IT tools necessary for engineering practice

PO_05: Having problem solving ability- to assess social issues (societal, health, safety, legal and cultural) and engineering problems

PO_06: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO_07: Having a clear understanding of professional and ethical responsibility

PO_08: Having a good cognitive load management skills related to project management and financ

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Nanotechnology) programme, graduates will be able to

PSO1: Evolving crucial understanding of Physics & Chemistry of solids, Quantum physics of nanostructures, Nano-electronics and Nano-photonics.

PSO2 : Concentrating on specific skills on Synthesis of nanomaterials, thin film deposition and their characterization.

PSO3: Solve research gaps and provide solutions to socio-economic, and environmental problems.

Category-wise Credit distribution

Category	Credits
University core (UC)	**27**
Programme core (PC)	**19**
Programme elective (PE)	**18**
University elective (UE)	**6**
Bridge course (BC)	
Total credits	**70**

Detailed curriculum

(as given in the student curriculum view – in the order of UC, UE, PC and PE). Courses need not be listed under UE.

University Core - 27 Credits

S. No	Course Code	Course Title	L	T	P	J	C
1.	**MAT6001**	Advanced Statistical Methods	2	0	2	0	3
2.	**ENG5001 and ENG5002 (or) EFL5097**	Technical English I and Technical English II (or) Foreign Language	{0 0 2	0 0 0	2 2 0	0 0} 0	2
3.	**STS5001**	Soft Skills	0	0	0	0	1
4.	**STS5002**	Soft Skills	0	0	0	0	1
5.	**SET5001**	SET Project-I	0	0	0	0	2
6.	**SET5002**	SET Project-II	0	0	0	0	2
7.	**ECE6099**	Master's Thesis	0	0	0	0	16

University Elective – 6 Credits

S.No		Course Title	L	T	P	J	C
1		University Elective#	-	-	-	-	6

 # All courses offered by other M.Tech Programmes / PE of M.Tech (Nanotechnology)

Programme Core – 19 Credits

S. No	Course Code	Course Title	L	T	P	J	C
1	**ECE5031**	Quantum Physics for Nanostructures	2	0	0	0	2
2	**ECE5032**	Physics and Chemistry of Solids	2	0	0	0	2
3	**ECE5033**	Synthesis of Nanomaterials and Thin Film Deposition	2	0	2	4	4
4	**ECE 5034**	Nanomaterial Characterization Techniques	3	0	2	0	4
5	**ECE 6032**	Nanoelectronics	2	0	2	4	4
6	**ECE 6033**	Nanophotonics	3	0	0	0	3

Programme Electives - 18 Credits

S.No	Course Code	Course Title	L	T	P	J	C
1	**ECE 5035**	Semiconductor Device Physics and Technology	2	0	0	4	3
2	**ECE5036**	MEMS to NEMS	2	0	0	4	3
4	**ECE 5037**	Nanosensors	3	0	0	0	3
5	**ECE 5038**	Carbon Nanomaterials	3	0	0	0	3
6	**ECE 5039**	Lithographic Techniques for Device Fabrication	3	0	0	0	3
7	**ECE 5040**	Plasmonics	2	0	0	4	3
8	**ECE 6031**	Nanomagnetism- Fundamentals and Applications	3	0	0	0	3
9	**ECE 6034**	Energy Technologies	3	0	0	0	3
10	**ECE 6035**	Spintronics	2	0	0	4	3
11	**ECE6039**	Nanoelectronic Circuit Design	3	0	0	0	3

Syllabus

Course Code	Course Title	L	T	P	J	C
MAT6001	ADVANCED STATISTICAL METHODS	2	0	2	0	3
Pre-requisite	nil	Syllabus version				
		2.0				

Course Objectives:

1. To provide students with a framework that will help them choose the appropriate descriptive statistics in various data analysis situations.
2. To analyse distributions and relationships of real-time data.
3. To apply estimation and testing methods to make inference and modelling techniques for decision making using various techniques including multivariate analysis.

Expected Course Outcome:

1. Understand the value of statistics as a discipline and its relevance for Engineering
2. Analyze data using appropriate graphical methods and numerical summaries
3. Interpret and communicate the outcomes of estimation and hypothesis tests in the context of a problem
4. Perform large sample test and small sample testing of Hypothesis as well as calculate confidence interval for a population parameter for real time data.
5. describe and verify mathematical considerations for analyzing time series, including concepts of white noise, stationarity, auto-covariance, autocorrelation ; apply various techniques of time series models, including the regression with ARMA models

Module:1	Basic Statistical Tools for Analysis:	4 hours

Summary Statistics, Correlation and Regression, Concept of R^2 and Adjusted R^2 and and Partial and Multiple Correlation, Fitting of simple and Multiple Linear regression, Explanation and Assumptions of Regression Diagnostics

Module:2	Statistical inference :	9 hours

Basic Concepts, Normal distribution-Area properties, Steps in tests of significance –large sample tests-Z tests for Means and Proportions, Small sample tests –t-test for Means, F test for Equality of Variances, Chi-square test for independence of Attributes.

Module:3	Modelling and Forecasting Methods:	9 hours

Introduction: Concept of Linear and Non Liner Forecasting model ,Concepts of Trend, Exponential Smoothing, Linear and Compound Growth model, Fitting of Logistic curve and their Applications, Moving Averages, Forecasting accuracy tests.

Probability models for time series: Concepts of AR, ARMA and ARIMA models.

Module:4	Design of Experiments:	6 hours

Analysis of variance – one and two way classifications – Principle of design of experiments, CRD –

RBD – LSD, Concepts of 22 and 23 factorial experiments

Module:5	Contemporary issues:	2 hours

Lecture by Industry Experts

Total Lecture hours:		**30 hours**
Text Book(s)		
1.	Applied Statistics and Probability for Engineers, 6ed, (2016),Douglas C. Montgomery George C. Runger, John Wiley & Sons	
2	Time Series Analysis and Its Applications With R Examples (2017), by Shumway, Robert H., Stoffer, David S. Springer publications	
Reference Books		
1.	The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Second Edition (Springer Series in Statistics)(2017),by Trevor Hastie and Robert Tibshirani	
2	Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences(2017), Mc.Grawhill education by J. Susan Milton and Jesse Arnold	
Mode of Evaluation		
Digital Assignments, Quiz, Continuous Assessments, Final Assessment Test		
List of Challenging Experiments (Indicative)		
1.	Computing Summary Statistics using real time data	2 hours
2	plotting and visualizing data using Tabulation and Graphical Representations.	2 hours
3	Applying simple linear and multiple linear regression models to real dataset; computing and interpreting the coefficient of determination for scale data.	2 hours
4.	Testing of hypothesis for Large sample tests for real-time problems.	2 hours
5.	Testing of hypothesis for Small sample tests for One and Two Sample mean and paired comparison (Pre-test and Post-test)	2 hours
6.	Testing of hypothesis for Small Sample tests for F-test	2 hours
7	Testing of hypothesis for Small Sample tests for Chi-square test	2 hours
8	Applying Time series analysis-Trends. Growth ,Logistic, Exponential models	2 hours
9	Applying Time series model AR ,ARMA and ARIMA and testing Forecasting accuracy tests.	2 hours
10	Performing ANOVA (one-way and two-way), CRD, RBD and LSD for real dataset.	2 hours
11	Performing 22 factorial experiments with real time Applications	2 hours
12	Performing 23 factorial experiments with real time Applications	2 hours
	Total Laboratory Hours	24 hours
Mode of Evaluation		

Weekly Assessments, Final Assessment Test			
Recommended by Board of Studies	11-08-2017		
Approved by Academic Council	No.46	Date	24-08-17

Course code	Course title	L	T	P	J	C
ENG5001	Fundamentals of Communication Skills	0	0	2	0	1
Pre-requisite	Not cleared EPT (English Proficiency Test)	Syllabus version				
		1.0				

Course Objectives:

1. To enable learners learn basic communication skills - Listening, Speaking, Reading and Writing
2. To help learners apply effective communication in social and academic context
3. To make students comprehend complex English language through listening and reading

Expected Course Outcome:

1. Enhance the listening and comprehending skills of the learners
2. Acquire speaking skills to express their thoughts freely and fluently
3. Learn strategies for effective reading
4. Write grammatical correct sentences in general and academic writing
5. Develop technical writing skills like writing instructions, transcoding etc.,

Module:1	Listening	**8 hours**

Understanding Conversation
Listening to Speeches
Listening for Specific Information

Module:2	Speaking	**4 hours**

Exchanging Information
Describing Activities, Events and Quantity

Module:3	Reading	**6 hours**

Identifying Information
Inferring Meaning
Interpreting text

Module:4	Writing: Sentence	**8hours**

Basic Sentence Structure
Connectives
Transformation of Sentences
Synthesis of Sentences

Module:5	Writing: Discourse	**4hours**

Instructions
Paragraph
Transcoding

Total Lecture hours:	**30 hours**

Text Book(s)

1. Redston, Chris, Theresa Clementson, and Gillie Cunningham. Face2face Upper Intermediate Student's Book. 2013, Cambridge University Press.

Reference Books

1. Chris Juzwiak .Stepping Stones: A guided approach to writing sentences and Paragraphs (Second Edition), 2012, Library of Congress.
2. Clifford A Whitcomb & Leslie E Whitcomb, Effective Interpersonal and Team Communication Skills for Engineers, 2013, John Wiley & Sons, Inc., Hoboken: New Jersey.
3. ArunPatil, Henk Eijkman &Ena Bhattacharya, New Media Communication Skills for

	Engineers and IT Professionals,2012, IGI Global, Hershey PA. 4. Judi Brownell, Listening: Attitudes, Principles and Skills, 2016, 5th Edition, Routledge:USA 5. John Langan, Ten Steps to Improving College Reading Skills, 2014, 6th Edition, Townsend Press:USA 6. Redston, Chris, Theresa Clementson, and Gillie Cunningham. Face2face Upper Intermediate Teacher's Book. 2013, Cambridge University Press.
	Authors, book title, year of publication, edition number, press, place

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar

List of Challenging Experiments (Indicative)

1.	Familiarizing students to adjectives through brainstorming adjectives with all letters of the English alphabet and asking them to add an adjective that starts with the first letter of their name as a prefix.	2 hours
2.	Making students identify their peer who lack Pace, Clarity and Volume during presentation and respond using Symbols.	4 hours
3.	Using Picture as a tool to enhance learners speaking and writing skills	2 hours
4.	Using Music and Songs as tools to enhance pronunciation in the target language / Activities through VIT Community Radio	2 hours
5.	Making students upload their Self- introduction videos in Vimeo.com	4 hours
6.	Brainstorming idiomatic expressions and making them use those in to their writings and day to day conversation	4 hours
7.	Making students Narrate events by adding more descriptive adjectives and add flavor to their language / Activities through VIT Community Radio	4 hours
8	Identifying the root cause of stage fear in learners and providing remedies to make their presentation better	4 hours
9	Identifying common Spelling & Sentence errors in Letter Writing and other day to day conversations	2 hours
10.	Discussing FAQ's in interviews with answers so that the learner gets a better insight in to interviews / Activities through VIT Community Radio	2 hours
	Total Practical Hours	30 hours

Mode of evaluation: Online Quizzes, Presentation, Role play, Group Discussions, Assignments, Mini Project

Recommended by Board of Studies	22-07-2017		
Approved by Academic Council	No. 46	Date	24-8-2017

Course code	Course title	L	T	P	J	C
ENG5002	Professional and Communication Skills	0	0	2	0	1
Pre-requisite	ENG5001	Syllabus version				
		1.1				

Course Objectives:

1. To enable students to develop effective Language and Communication Skills
2. To enhance students' Personal and Professional skills
3. To equip the students to create an active digital footprint

Expected Course Outcome:

1. Improve inter-personal communication skills
2. Develop problem solving and negotiation skills
3. Learn the styles and mechanics of writing research reports
4. Cultivate better public speaking and presentation skills
5. Apply the acquired skills and excel in a professional environment

Module:1	Personal Interaction	2hours

Introducing Oneself- one's career goals

Activity: SWOT Analysis

Module:2	Interpersonal Interaction	2 hours

Interpersonal Communication with the team leader and colleagues at the workplace

Activity: Role Plays/Mime/Skit

Module:3	Social Interaction	2 hours

Use of Social Media, Social Networking, gender challenges
Activity: Creating LinkedIn profile, blogs

Module:4	Résumé Writing	4 hours

Identifying job requirement and key skills
Activity: Prepare an Electronic Résumé

Module:5	Interview Skills	4 hours

Placement/Job Interview, Group Discussions
Activity: Mock Interview and mock group discussion

Module:6	Report Writing	4 hours

Language and Mechanics of Writing

Activity: Writing a Report

Module:7	Study Skills: Note making	2hours

Summarizing the report
Activity: Abstract, Executive Summary, Synopsis

Module:8	**Interpreting skills**	**2 hours**
Interpret data in tables and graphs Activity: Transcoding		
Module:9	**Presentation Skills**	**4 hours**
Oral Presentation using Digital Tools Activity: Oral presentation on the given topic using appropriate non-verbal cues		
Module:10	**Problem Solving Skills**	**4 hours**
Problem Solving & Conflict Resolution Activity: Case Analysis of a Challenging Scenario		
	Total Lecture hours:	**30hours**

Text Book(s)	
	Bhatnagar Nitin and Mamta Bhatnagar, Communicative English For Engineers And Professionals, 2010, Dorling Kindersley (India) Pvt. Ltd.
Reference Books	
	Jon Kirkman and Christopher Turk, Effective Writing: Improving Scientific, Technical and Business Communication, 2015, Routledge Diana Bairaktarova and Michele Eodice, Creative Ways of Knowing in Engineering, 2017, Springer International Publishing Clifford A Whitcomb & Leslie E Whitcomb, Effective Interpersonal and Team Communication Skills for Engineers, 2013, John Wiley & Sons, Inc., Hoboken: New Jersey. ArunPatil, Henk Eijkman &Ena Bhattacharya, New Media Communication Skills for Engineers and IT Professionals,2012, IGI Global, Hershey PA.
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

List of Challenging Experiments (Indicative)		
1.	SWOT Analysis – Focus specially on describing two strengths and two weaknesses	2 hours
2.	Role Plays/Mime/Skit -- Workplace Situations	4 hours
3.	Use of Social Media – Create a LinkedIn Profile and also write a page or two on areas of interest	2 hours
4.	Prepare an Electronic Résumé and upload the same in vimeo	2 hours
5.	Group discussion on latest topics	4 hours
6	Report Writing – Real-time reports	2 hours
7	Writing an Abstract, Executive Summary on short scientific or research articles	4 hours
8	Transcoding – Interpret the given graph, chart or diagram	2 hours

9	Oral presentation on the given topic using appropriate non-verbal cues		4 hours
10	Problem Solving -- Case Analysis of a Challenging Scenario		4 hours
		Total Laboratory Hours	30 hours
Mode of evaluation: : Online Quizzes, Presentation, Role play, Group Discussions, Assignments, Mini Project			
Recommended by Board of Studies	22-07-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course Title	L	T	P	J	C
GER5001	Deutsch für Anfänger	2	0	0	0	2
Pre-requisite	NIL	Syllabus version				
		v.1				

Course Objectives:

The course gives students the necessary background to:

1. enable students to read and communicate in German in their day to day life
2. become industry-ready
3. make them understand the usage of grammar in the German Language.

Expected Course Outcome:

The students will be able to

1.create the basics of German language in their day to day life.
2.understand the conjugation of different forms of regular/irregular verbs.
3.understand the rule to identify the gender of the Nouns and apply articles appropriately.
4.apply the German language skill in writing corresponding letters, E-Mails etc.
5.create the talent of translating passages from English-German and vice versa and To frame simple dialogues based on given situations.

Module:1		3 hours

Einleitung, Begrüssungsformen, Landeskunde, Alphabet, Personalpronomen, Verb Konjugation, Zahlen (1-100), W-fragen, Aussagesätze, Nomen – Singular und Plural

Lernziel:

Elementares Verständnis von Deutsch, Genus- Artikelwörter

Module:2		3 hours

Konjugation der Verben (regelmässig /unregelmässig) die Monate, die Wochentage, Hobbys, Berufe, Jahreszeiten, Artikel, Zahlen (Hundert bis eine Million), Ja-/Nein- Frage, Imperativ mit Sie

Lernziel :

Sätze schreiben, über Hobbys erzählen, über Berufe sprechen usw.

Module:3		4 hours

Possessivpronomen, Negation, Kasus- AkkusatitvundDativ (bestimmter, unbestimmterArtikel), trennnbare verben, Modalverben, Adjektive, Uhrzeit, Präpositionen, Mahlzeiten, Lebensmittel, Getränke

Lernziel :

Sätze mit Modalverben, Verwendung von Artikel, über Länder und Sprachen sprechen, über eine Wohnung beschreiben.

Module:4		6 hours

Übersetzungen : (Deutsch – Englisch / Englisch – Deutsch)

Lernziel :

Grammatik – Wortschatz – Übung

Module:5		5 hours

Leseverständnis,Mindmap machen,Korrespondenz- Briefe, Postkarten, E-Mail

Lernziel :

Wortschatzbildung und aktiver Sprach gebrauch		
Module:6	.	**3 hours**
Aufsätze : Meine Universität, Das Essen, mein Freund oder meine Freundin, meine Familie, ein Fest in Deutschland usw		
Module:7		**4 hours**
Dialoge: a) Gespräche mit Familienmitgliedern, Am Bahnhof, b) Gespräche beim Einkaufen ; in einem Supermarkt ; in einer Buchhandlung ; c) in einem Hotel - an der Rezeption ;ein Termin beim Arzt. Treffen im Cafe		
Module:8		**2 hours**
Guest Lectures/Native Speakers / Feinheiten der deutschen Sprache, Basisinformation über die deutschsprachigen Länder		
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	**Studio d A1 Deutsch als Fremdsprache, Hermann Funk, Christina Kuhn, Silke Demme : 2012**
Reference Books	
1	Netzwerk Deutsch als Fremdsprache A1, Stefanie Dengler, Paul Rusch, Helen Schmtiz, Tanja Sieber, 2013
2	Lagune ,Hartmut Aufderstrasse, Jutta Müller, Thomas Storz, 2012.
3	Deutsche SprachlehrefürAUsländer, Heinz Griesbach, Dora Schulz, 2011
4	ThemenAktuell 1, HartmurtAufderstrasse, Heiko Bock, MechthildGerdes, Jutta Müller und Helmut Müller, 2010
	www.goethe.de wirtschaftsdeutsch.de hueber.de klett-sprachen.de www.deutschtraning.org

Mode of Evaluation: CAT / Assignment / Quiz / Seminar / FAT			
Recommended by Board of Studies	04-03-2016		
Approved by Academic Council	41	Date	17-06-2016

Course code	Course Title	L	T	P	J	C
FRE5001	FRANCAIS FONCTIONNEL	2	0	0	0	2
Pre-requisite	Nil	Syllabus version				
		1.0				

Course Objectives:

The course gives students the necessary background to:

1. demonstrate competence in reading, writing, and speaking basic French, including knowledge of vocabulary (related to profession, emotions, food, workplace, sports/hobbies, classroom and family).
2. achieve proficiency in French culture oriented view point.

Expected Course Outcome:

The students will be able to

1. remember the daily life communicative situations via personal pronouns, emphatic pronouns, salutations, negations, interrogations etc.
2. create communicative skill effectively in French language via regular / irregular verbs.
3. demonstrate comprehension of the spoken / written language in translating simple sentences.
4. understand and demonstrate the comprehension of some particular new range of unseen written materials.
5. demonstrate a clear understanding of the French culture through the language studied.

Module:1	Saluer, Se présenter, Etablir des contacts	**3 hours**

Les Salutations, Les nombres (1-100), Les jours de la semaine, Les mois de l'année, Les Pronoms Sujets, Les Pronoms Toniques, La conjugaison des verbes réguliers, La conjugaison des verbes irréguliers- avoir / être / aller / venir / faire etc.

Module:2	**Présenter quelqu'un, Chercher un(e) correspondant(e), Demander des nouvelles d'une personne.**	**3 hours**

La conjugaison des verbes Pronominaux, La Négation, L'interrogation avec 'Est-ce que ou sans Est-ce que'.

Module:3	**Situer un objet ou un lieu, Poser des questions**	**4 hours**

L'article (défini/ indéfini), Les prépositions (à/en/au/aux/sur/dans/avec etc.), L'article contracté, Les heures en français, La Nationalité du Pays, L'adjectif (La Couleur, l'adjectif possessif, l'adjectif démonstratif/ l'adjectif interrogatif (quel/quelles/quelle/quelles), L'accord des adjectifs avec le nom, L'interrogation avec Comment/ Combien / Où etc.,

Module:4	**Faire des achats, Comprendre un texte court, Demander et indiquer le chemin.**	**6 hours**

La traduction simple :(français-anglais / anglais –français)

Module:5	**Trouver les questions, Répondre aux questions générales en français.**	**5 hours**

L'article Partitif, Mettez les phrases aux pluriels, Faites une phrase avec les mots donnés, Exprimez les phrases données au Masculin ou Féminin, Associez les phrases.

Module:6	**Comment ecrire un passage**	**3 hours**
Décrivez : La Famille /La Maison, /L'université /Les Loisirs/ La Vie quotidienne etc.		
Module:7	**Comment ecrire un dialogue**	**4 hours**
Dialogue: d) Réserver un billet de train e) Entre deux amis qui se rencontrent au café f) Parmi les membres de la famille g) Entre le client et le médecin		
Module:8	**Invited Talk: Native speakers**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	Echo-1, Méthode de français, J. Girardet, J. Pécheur, Publisher CLE International, Paris 2010.
2	Echo-1, Cahier d'exercices, J. Girardet, J. Pécheur, Publisher CLE International, Paris 2010.
Reference Books	
1.	CONNEXIONS 1, Méthode de français, Régine Mérieux, Yves Loiseau,Les Éditions Didier, 2004.
2	CONNEXIONS 1, Le cahier d'exercices, Régine Mérieux, Yves Loiseau, Les Éditions Didier, 2004.
3	ALTER EGO 1, Méthode de français, Annie Berthet, Catherine Hugo, Véronique M. Kizirian, Béatrix Sampsonis, Monique Waendendries , Hachette livre 2006.

Mode of Evaluation: CAT / Assignment / Quiz / Seminar / FAT			
Recommended by Board of Studies	26.02.2016		
Approved by Academic Council	No.41	Date	17-06-2016

Course code	Course Title	L	T	P	J	C
SET 5001	SCIENCE, ENGINEERING AND TECHNOLOGY PROJECT– I	0	0	0	0	2

Pre-requisite		Syllabus Version
Anti-requisite		1.10

Course Objectives:

- To provide opportunity to involve in research related to science / engineering
- To inculcate research culture
- To enhance the rational and innovative thinking capabilities

Expected Course Outcome:

On completion of this course, the student should be able to:

1. Identify problems that have relevance to societal / industrial needs
2. Exhibit independent thinking and analysis skills
3. Demonstrate the application of relevant science / engineering principles

Modalities / Requirements

1. Individual or group projects can be taken up
2. Involve in literature survey in the chosen field
3. Use Science/Engineering principles to solve identified issues
4. Adopt relevant and well-defined / innovative methodologies to fulfill the specified objective
5. Submission of scientific report in a specified format (after plagiarism check)

Student Assessment : Periodical reviews, oral/poster presentation

Recommended by Board of Studies	17-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course Title	L	T	P	J	C
SET 5002	SCIENCE, ENGINEERING AND TECHNOLOGY PROJECT– II	0	0	0	0	2
Pre-requisite		Syllabus Version				
Anti-requisite		1.10				

Course Objectives:

1. To provide opportunity to involve in research related to science / engineering
2. To inculcate research culture
3. To enhance the rational and innovative thinking capabilities

Expected Course Outcome:

On completion of this course, the student should be able to:

1. Identify problems that have relevance to societal / industrial needs
2. Exhibit independent thinking and analysis skills
3. Demonstrate the application of relevant science / engineering principles

Modalities / Requirements

1. Individual or group projects can be taken up
2. Involve in literature survey in the chosen field
3. Use Science/Engineering principles to solve identified issues
4. Adopt relevant and well-defined / innovative methodologies to fulfill the specified objective
5. Submission of scientific report in a specified format (after plagiarism check)

Student Assessment : Periodical reviews, oral/poster presentation

Recommended by Board of Studies	17-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course Title	L	T	P	J	C
STS 5001	Essentials of Business Etiquette and problem solving	3	0	0	0	1
Pre-requisite	None	Syllabus version				

Course Objectives:

1. To develop the students' logical thinking skills
2. To learn the strategies of solving quantitative ability problems
3. To enrich the verbal ability of the students
4. To enhance critical thinking and innovative skills

Expected Course Outcome:

1. Enabling students to use relevant aptitude and appropriate language to express themselves
2. To communicate the message to the target audience clearly
3. The students will be able to be proficient in solving quantitative aptitude and verbal ability questions of various examinations effortlessly

Module:1	Business Etiquette: Social and Cultural Etiquette and Writing Company Blogs and Internal Communications and Planning and Writing press release and meeting notes	9 hours

Value, Manners, Customs, Language, Tradition, Building a blog, Developing brand message, FAQs', Assessing Competition, Open and objective Communication, Two way dialogue, Understanding the audience, Identifying, Gathering Information, Analysis, Determining, selecting plan, Progress check, Types of planning, Write a short, catchy headline, Get to the Point – summarize your subject in the first paragraph., Body – Make it relevant to your audience,

Module:2	Study skills – Time management skills	3 hours

Prioritization, Procrastination, Scheduling, Multitasking, Monitoring, working under pressure and adhering to deadlines

Module:3	Presentation skills – Preparing presentation and Organizing materials and Maintaining and preparing visual aids and Dealing with questions	7 hours

10 Tips to prepare PowerPoint presentation, Outlining the content, Passing the Elevator Test, Blue sky thinking, Introduction , body and conclusion, Use of Font, Use of Color, Strategic presentation, Importance and types of visual aids, Animation to captivate your audience, Design of posters, Setting out the ground rules, Dealing with interruptions, Staying in control of the questions, Handling difficult questions

Module:4	Quantitative Ability -L1 – Number properties and Averages and Progressions and Percentages and Ratios	11 hours

Number of factors, Factorials, Remainder Theorem, Unit digit position, Tens digit position, Averages, Weighted Average, Arithmetic Progression, Geometric Progression, Harmonic Progression, Increase & Decrease or successive increase, Types of ratios and proportions

Module:5	**Reasoning Ability-L1 – Analytical Reasoning**	**8 hours**
Data Arrangement (Linear and circular & Cross Variable Relationship), Blood Relations, Ordering/ranking/grouping, Puzzle test, Selection Decision table		
Module:6	**Verbal Ability-L1 – Vocabulary Building**	**7 hours**
Synonyms & Antonyms, One-word substitutes, Word Pairs, Spellings, Idioms, Sentence completion, Analogies		
	Total Lecture hours:	**45 hours**

Reference Books	
1.	Kerry Patterson, Joseph Grenny, Ron McMillan, Al Switzler (2001) Crucial Conversations: Tools for Talking When Stakes are High. Bangalore. McGraw-Hill Contemporary
2.	Dale Carnegie, (1936) How to Win Friends and Influence People. New York. Gallery Books
3.	Scott Peck. M (1978) Road Less Travelled. New York City. M. Scott Peck.
4.	FACE (2016) Aptipedia Aptitude Encyclopedia. Delhi. Wiley publications
5.	ETHNUS (2013) Aptimithra. Bangalore. McGraw-Hill Education Pvt. Ltd.
Websites:	
1.	www.chalkstreet.com
2.	www.skillsyouneed.com
3.	www.mindtools.com
4.	www.thebalance.com
5.	**www.eguru.ooo**

Mode of Evaluation: FAT, Assignments, Projects, Case studies, Role plays,
3 Assessments with Term End FAT (Computer Based Test)

Course code	Course Title	L	T	P	J	C
STS 5002	Preparing for Industry	3	0	0	0	1
Pre-requisite	None	Syllabus version				
		1				
Course Objectives:	1. To challenge students to explore their problem-solving skills 2. To develop essential skills to tackle advance quantitative and verbal ability questions 3. To have working knowledge of communicating in English					
Expected Course Outcome:	1. Enabling students to simplify, evaluate, analyze and use functions and expressions to simulate real situations to be industry ready. 2. The students will be able to interact confidently and use decision making models effectively 3. The students will be able to be proficient in solving quantitative aptitude and verbal ability questions of various examinations effortlessly					
Module:1	**Interview skills – Types of interview and Techniques to face remote interviews and Mock Interview**	**3 hours**				
Structured and unstructured interview orientation, Closed questions and hypothetical questions, Interviewers' perspective, Questions to ask/not ask during an interview, Video interview¸ Recorded feedback, Phone interview preparation, Tips to customize preparation for personal interview, Practice rounds						
Module:2	**Resume skills – Resume Template and Use of power verbs and Types of resume and Customizing resume**	**2 hours**				
Structure of a standard resume, Content, color, font, Introduction to Power verbs and Write up, Quiz on types of resume, Frequent mistakes in customizing resume, Layout - Understanding different company's requirement, Digitizing career portfolio						
Module:3	**Emotional Intelligence - L1 – Transactional Analysis and Brain storming and Psychometric Analysis and Rebus Puzzles/Problem Solving**	**12 hours**				
Introduction, Contracting, ego states, Life positions, Individual Brainstorming, Group Brainstorming, Stepladder Technique, Brain writing, Crawford's Slip writing approach, Reverse brainstorming, Star bursting, Charlette procedure, Round robin brainstorming, Skill Test, Personality Test, More than one answer, Unique ways						
Module:4	**Quantitative Ability-L3 – Permutation-Combinations and Probability and Geometry and mensuration and Trigonometry and Logarithms and Functions and Quadratic Equations and Set Theory**	**14 hours**				
Counting, Grouping, Linear Arrangement, Circular Arrangements, Conditional Probability, Independent and Dependent Events, Properties of Polygon, 2D & 3D Figures, Area & Volumes, Heights and distances, Simple trigonometric functions, Introduction to logarithms, Basic rules of						

logarithms, Introduction to functions, Basic rules of functions, Understanding Quadratic Equations, Rules & probabilities of Quadratic Equations, Basic concepts of Venn Diagram		
Module:5	**Reasoning ability-L3 – Logical reasoning and Data Analysis and Interpretation**	**7 hours**
Syllogisms, Binary logic, Sequential output tracing, Crypto arithmetic, Data Sufficiency, Data interpretation-Advanced, Interpretation tables, pie charts & bar chats		
Module:6	**Verbal Ability-L3 – Comprehension and Logic**	**7 hours**
Reading comprehension, Para Jumbles, Critical Reasoning (a) Premise and Conclusion, (b) Assumption & Inference, (c) Strengthening & Weakening an Argument		
Total Lecture hours:		**45 hours**
References	• Michael Farra and JIST Editors(2011) Quick Resume & Cover Letter Book: Write and Use an Effective Resume in Just One Day. Saint Paul, Minnesota. Jist Works • Daniel Flage Ph.D(2003) The Art of Questioning: An Introduction to Critical Thinking. London. Pearson • FACE(2016) Aptipedia Aptitude Encyclopedia.Delhi. Wiley publications	
Mode of Evaluation: FAT, Assignments, Projects, Case studies, Role plays, 3 Assessments with Term End FAT (Computer Based Test)		

Course Title	Course Title	L	T	P	J	C
ECE6099	Masters Thesis	0	0	0	0	16
Pre-requisite	As per the academic regulations	Syllabus version				
		1.0				

Course Objectives:

To provide sufficient hands-on learning experience related to the design, development and analysis of suitable product / process so as to enhance the technical skill sets in the chosen field.

Expected Course Outcome:

At the end of the course the student will be able to

1. Formulate specific problem statements for ill-defined real life problems with reasonable assumptions and constraints.
2. Perform literature search and / or patent search in the area of interest.
3. Conduct experiments / Design and Analysis / solution iterations and document the results.
4. Perform error analysis / benchmarking / costing
5. Synthesise the results and arrive at scientific conclusions / products / solution
6. Document the results in the form of technical report / presentation

Contents

Capstone Project may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, applied research and any other related activities.
Project should be for two semesters based on the completion of required number of credits as per the academic regulations.

Should be individual project.

In case of group projects, the individual project report of each student should specify the individual's contribution to the group project.

Carried out inside or outside the university, in any relevant industry or research institution.

Publications in the peer reviewed journals / International Conferences will be an added advantage

Mode of Evaluation: Periodic reviews, Presentation, Final oral viva, Poster submission

Recommended by Board of Studies	10-06-2015		
Approved by Academic Council	No. 37	Date	16-06-2015

Course Code	Course Title	L	T	P	J	C
ECE5031	QUANTUM PHYSICS FOR NANOSTRUCTURES	2	0	0	0	2
Pre-requisite	Nil					

Course Objective:

The course is aimed to

1. Educate various concepts of quantum theory and its importance.
2. Make them understand the different quantum nanostructures and their density of states.
3. Enable them to apply quantum theory to design nanoscale devices.

Expected Course Outcomes:

Students will be able to:

1. Gain the advanced concepts of quantum theory.
2. Understand the importance of Schrodinger wave equation & its applications.
3. Obtain the knowledge on quantum confinement effects.
4. Gain the knowledge in dispersion relation of electron in solids.
5. Understand the quantum nanostructures, such as quantum dots, nanowires and quantum wells and their density of states.
6. Understand the time-dependent perturbation and its applications.

Module :1	Introduction	4 hours

Importance of Quantum theory, Wave-particles duality, de-Broglie and Fermi Wavelengths, Wave function, Dynamical operators, Uncertainty principle, Quantum numbers and Hydrogen atom problem, Pauli exclusion principle.

Module:2	Schrodinger equations and their formulation	3 hours

Schrodinger time dependent and time independent wave equations - analytical solutions.

Module:3	Potential Well, Potential Barrier and Tunnelling	4 hours

One-Dimensional Potential well , Particle in 1D, 2D and 3D box, Rectangular Barrier, Concept of Tunneling, Reflectance, transmittance and tunnelling probability, Scanning tunnelling microscope

Module:4	Theory of conduction in solids	4 hours

Description of the theory of Conduction in Solids -Drude model, Nearly free electron model, Dispersion relation for electron.

Module:5	Electronic Band Structure	5 hours

Periodic lattice, Brillouine zones, Periodic potential, Bloch Theorem, Kronig-Penny Potential and Electronic energy bands, direct and indirect gap semiconductors.

Module:6	Quantum Confinement and Density of States	4 hours

Concept of Quantum Confinement, Quantum Dots, Quantum Well and Quantum Wires, Density of states in 3D, 2D, 1D and 0D solid, carrier concentration.

Module:7	Time-dependent perturbation and applications	4 hours

Time-dependent change in potential, First-order time-dependent perturbation, Fermi's golden rule, Photon emission due to electronic transitions, Fermi's golden rule for stimulated optical transitions, Semiconductor laser.

Module:8	Contemporary issues:	2 hours

	Total Lecture:			**30 hours**
Text Book(s)				
1	A. F. J. Levi, Applied Quantum Mechanics, Second edition, Cambridge University Press, 2006.			
2	Richard L. Liboff, Introductory Quantum Mechanics, Fourth edition, Pearson Education Inc, India, 2003.			
Reference Books				
1	Robert Eisberg and Robert Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, second Edition, John Wiley & Sons, Canada, 1985.			
2	A. Ghatak and S. Lokanathan, Quantum Mechanics–Theory & Applications, Macmillan India Limited, New Delhi, 2002.			
3	A. Beiser, Concepts of Modern Physics, Sixth edition, TataMcGraw- Hill Edition, New Delhi, 2003.			
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).				
Recommended by Board of Studies		13-12-2015		
Approved by Academic Council		No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5032	PHYSICS AND CHEMISTRY OF SOLIDS	2	0	0	0	2
Pre-requisite	Nil					

Course Objectives:

The course is aimed to:

1. Provide understanding of properties of materials from an atomistic view point, and to classify solids.
2. Outline the properties and structure of crystalline materials, various modes of bonding in solids with appropriate examples.
3. Render them about thermodynamics and statistical mechanics of solids.

Expected Course Outcomes:

Students will be able to:

1. Gain knowledge on crystal structure
2. Understand various types of atomic bonding in solids.
3. Classify the materials based on their properties.
4. Identify different imperfections in solids.
5. Understand thermodynamics and elementary statistical mechanics.
6. Apply Magnetic, Optical & Thermal properties of different material for potential applications.

Module 1	Structure of Matter	6 hours

Crystal structure & Bonding- Crystals, Polycrystals, Symmetry, Unit cells, Bravais lattices, Crystallographic directions, Crystallographic planes, Miller indices, Bragg's law, Single crystal and Powder X-ray diffraction.

Module 2	Chemical Bonding	3 hours

Atomic Bonding in solids - Types of bond: Metallic, Ionic, Covalent and van der Waals bond; Hybridization; H-bonding Molecular orbital theory for simple molecules such as diatomic molecule etc.

Module 3	Classification of Materials	2 hours

Different types of materials -Metals, Semiconductors, Composite materials, Ceramics, Alloys, and Polymers.

Module 4	Imperfections in solids	2 hours

Imperfections of crystal structure –point defects, Grain boundaries, phase boundaries, Dislocations Screw, Edge and Mixed Dislocations

Module 5	Introduction to Thermodynamics and Elementary Statistical Mechanics	6 hours

The first and second laws of thermodynamics, Thermodynamic functions, enthalpy, entropy and Microstates, Introduction to Ionic Conductivity, Gibb's freeenergy, Gibb'sparadox, Liouville's theorem, Classical Statistical systems, Boltzman statistics, quantum statistical systems, Fermi-Diracand Bose-Einstein Statistics and their applications.

Module 6	Phase Transformations	4 hours

Mechanisms of phase transformation; homogeneous and heterogeneous nucleation; spinodal

decomposition; order-disorder transformations; Martensitic transformation		
Module 7	**Magnetic, Optical & Thermal properties of solid**	**5 hours**
Magnetic properties- Different kind of magnetism in nature: Dia, Para, Ferro, Antiferro, Ferri, Superpara; Optical Properties- Photoconductivity, Opticalabsorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence; Thermal Properties- Concept of phonon, Thermal conductivity, Specific heat, Exothermic & endothermic processes.		
Module 8	**Contemporary issues:**	**2 hours**
	Total Lecture:	**30 hours**

Text Book(s)	
1	Charles Kittel, Introduction to Solid State Physics, 2012, eighth Edition, John Wiley & Sons
2	H. I bach and H. Lῦth, Solid-State Physics: An Introduction to Principles of Material Science 2009, fourth edition, Springer
Reference Books	
1	A.J. Dekker, Macmillan, Solid State Physics, 1969
2	L. H. Van Vlack, Elements of materials science, Pearson Education, 2002
3	Atkins Peter, Paula Julio, Physical Chemistry, Oxford University Press, 2008
4	K. Huang, Chapman and Hall, Introduction to Statistical Physics, CRC, 2009
5	Stephen Elliott & S. R. Elliott, The Physics and Chemistry of Solids, John Wiley & Sons, 1998.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5033	SYNTHESIS OF NANOMATERIALS AND THIN FILM DEPOSITION	2	0	2	4	4
Pre-requisite	Nil					

Course Objectives:

The course is aimed to :

1. Make them understand the fabrication of nanostructures for advanced devices.
2. Provide and train the students about nanomaterial synthesis and thin film deposition techniques.

Expected Course Outcomes::

At the end of the course students will be able to

1. Identify and understand various top-down and bottom-up approaches for nanomaterial synthesis.
2. Understand and apply vacuum technology for nanomaterial synthesis.
3. Know various deposition techniques at the atomic and molecular level.
4. Acquire knowledge about structure and properties of thin films.
5. Learn the advanced concepts in various vapour deposition techniques.
6. Synthesise and deposit nanomaterials by various methods.

Module 1	Nanomaterial Synthesis - Top-Down Approach	4 hours

Physical methods- Inert gas condensation, aerosol method, Arc discharge, RF-plasma, Plasma arc technique, laser ablation, Gas-phase synthesis, Spray Pyrolysis, Ball Milling, Combustion

Module 2	Nanomaterial Synthesis - Bottom-up approach	6 hours

Chemical Methods - Zero dimensional, one dimensional and two dimensional nanostructures, Nucleation theory, Homogeneous and heterogeneous nucleation, Metal nanocrystals by reduction, Solvothermal/Hydrothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Thermolysis routes, Sonochemical routes, Hybrid methods, Sol- gel, Micelles and microemulsions, Bio-Synthesis.

Module 3	Vacuum technology	3 hours

Concept of different vacuum pumps - rotary, diffusion, Turbo molecular pump, Cryogenic-pump, Ti-sublimation pump; Concept of different gauges - pirani, penning, Pressure control.

Module 4	Wafer Growth and Epitaxial Deposition	3 hours

Crystal Growth - CZ, Float zone technique; Basic Properties of different substrates (e.g. semiconductor, glass); Wafer cutting; Sources and related effects of various contamination; Wafer processing; Epitaxial growth- Growth kinetics of epitaxy, Doping, Growth modes.

Module 5	Structure and properties of thin films	4 hours

Definition of thin films- Environment (Gas phase and plasma) for thin film deposition, Deposition parameters and their effects on film growth; Physical parameters for evaluation of thin films- Surface roughness; Density; Stress in thin films; Adhesion; Stoichiometry.

Module 6	Physical vapor deposition (PVD) techniques	4 hours

Evaporation- Thermal evaporation, resistance evaporation, Electron beam evaporation, Ion vapor evaporation and Cathodic arc deposition; Molecular Beam Epitaxy; Sputtering- Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering; Atomic layer deposition (ALD)- Importance of ALD technique.		
Module 7	**Chemical vapor deposition techniques**	**4 hours**
Fundamentals, Advantages and limitations of Chemical vapor deposition (CVD) techniques; Different kinds of CVD techniques- Metallorganic (MO) CVD, Photoassisted CVD, Thermally activated CVD, Plasma enhanced (RF, µ-Wave) CVD, Low pressure (LP) CVD, Atmospheric pressure (AP) CVD etc,.		
Module 8	**Contemporary issues:**	**2 hours**
Advanced Topics		
	Total Lecture:	**30 hours**

Text Book(s)	
1.	Guozhong Cao. Ed Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, World Scientific Series in Nanoscience and Nanotechnology, 2011.
2.	G.A. Ozin and A.C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, Royal Society of Chemistry, 2009.
Reference Books	
1.	Bharat Bhushan, Handbook of Nanotechnology, Springer, 2005
2.	Hari Singh Nalwa, Handbook Of Nanostructured Biomaterials And Their Applications In Nanobiotechnology, Journal of Nanoscience and Nanotechnology, 2005.
3.	D.M. Hata, Introduction to Vacuum Technology, Prentice Hall New Jersey, 2007.
4.	K. Jousten, Handbook of Vacuum Technology, John Wiley and sons, Weinheim, 2008.
5.	S. Schmidt et.al., CFx thin films deposited by high power impulse magnetron sputtering: synthesis and characterization Surf.Coat.Technol. 2011, 206, pp. 646-653.
6.	J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).

Typical Projects

1. Green synthesis of nanoparticles and analysis using UV-Vis.
2. Kinetic analysis of growth of silver nanoparticles.
3. Demonstration of Electroless deposition process.
4. Growth of thin films by Electrodeposition technique.
5. Preparation and study of ferrofluids.
6. Hydrothermal synthesis of TiO2 nanoparticles and its optical study

Mode of Evaluation: Review I, II and III

List of Challenging Experiments (Indicative)

1.	Wet Chemical synthesis of Silver Quantum Dots - Effect of viscosity on the growth and its characterization by UV-Visible spectroscopy.	6 hours
2.	Synthesis of ZnO nanoparticles by wet chemical route and its optical band gap calculation.	6 hours
3.	Mie formalism of Optical absorption of Ag and Au nanoparticles for size estimation.	4 hours

4.	Calculation of d-spacing and crystallite size of Nanomaterials from X- ray diffraction data.	4 hours
5.	Thin film deposition using Electroplating technique and morphology characterization using Optical microscope.	3 hours
6.	Fabrication of thin films using Spin coating technique.	3 hours
7.	Fabrication of metal thin films on silicon/glass substrate using Metal evaporation Unit	4 hours
	Total Laboratory Hours	30 hours

Mode of Evaluation: Continuous assessment of challenging experiments /Final Assessment Test (FAT).			
Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5034	NANOMATERIAL CHARACTERIZATION TECHNIQUES	3	0	2	0	4

Pre-requisite	**Nil**

Course Objectives:

The course is aimed to :

1. Make them understand various Nanostructure characterization techniques.
2. Train the students on state-of-the-art metrology tools such as Scanning Probe Microscopes and optical spectroscopes.
3. Enable them to study the material's structure and properties that are probed and measured.

Expected Course Outcomes:

Students will be able to

1. Be conversant with conventional aspects of metrological tools.
2. Be aware of various morphological techniques and selecting appropriate tools for their future research.
3. Be familiar with various spectroscopic techniques.
4. Acquainted with the Scanning probe techniques for characterisation.
5. Learn advanced optical and magnetic characterization techniques.
6. Prepare, characterise and analyse the samples with suitable techniques.

Module 1	**Introduction to Metrology**	**4 hours**
Concepts of Metrology- Accuracy, precision and reliability; Types of Errors - Systematic Errors and Random Errors, Statistical analysis of errors.		
Module 2	**Microscopy Techniques**	**8 hours**
Optical microscopy; Electron microscopy- Scanning Electron Microscopy, EDX, WDX; Transmission Electron Microscopy; EELS; SPM.		
Module 3	**Spectroscopy Techniques**	**9 hours**
UV-Vis Spectroscopy; Ellipsometer; XPS; XAS; XRD; Raman Spectroscopy - Surface-enhanced Raman Spectroscopy.		
Module 4	**Scanning Tunneling Microscopy**	**8 hours**
Basic design of Scanning Probe Microscopes; Scanning Tunneling Microscope: Principles of operation, Quantum Mechanical Tunneling phenomenon in STM, Different modes of operation; STS - Principles of operation, applications.		
Module 5	**Atomic Force Microscopy**	**7 hours**
Atomic Force Microscope - Modes of operation of AFM, Advanced Modes of AFM - Force Modulation, Conductive AFM, EFM, MFM, SCM.		
Module 6	**Near Field Scanning Optical Microscopy**	**5 hours**
Principles of operation, Different modes of operation, Spectroscopic Applications of NSOM.		
Module 7	**Magnetic Characterization**	**2 hours**
Principles, Components of SQUID systems, Vibrating Sample Magnetometer (VSM)		
Module 8	**Contemporary issues:**	**2 hours**

Advanced Topics			
		Total	**45 Hours**
Text Book(s)			
1.	R.W. Cahn, E.M. Lifshitz, Concise Encyclopedia of Materials Characterization: Advances in Materials Sciences and Engineering,Elsevier, 2016.		
2.	Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods,John Wiley & Sons, 2013.		
Reference Books			
1	Richard Leach, Fundamental Principles of Engineering Nanometrology, Elsevier, 2014.		
2	Mauro Sardela, Practical Materials Characterization, Springer, 2014.		
3	Ewen Smith, Geoffrey Dent, Modern Raman Spectroscopy: A Practical Approach, John Wiley & Sons, 2013.		
4	Nikodem Tomczak, Kuan Eng Johnson Goh, Scanning Probe Microscopy, World Scientific, 2011.		
5	Ernst Meyer, Hans J. Hug, Roland Bennewitz, Scanning Probe Microscopy: The Lab on a Tip,Springer Science & Business Media, 2013.		
6	Vladimir V. Tsukruk, Srikanth Singamaneni, Scanning Probe Microscopy of Soft Matter: Fundamentals and Practices, John Wiley & Sons, 2012.		
7	H. Weinstock, SQUID Sensors: Fundamentals, Fabrication and Applications, Springer Science & Business Media, 2012.		
8	Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
List of challenging Experiments (Indicative)			
1.	STS analysis of CNT.		4 hours
2.	Analysis of magnetic nanoparticle with MFM		4 hours
3.	Application of Electrostatic Force Microscopy.		3 hours
4.	Characterization of Graphene with optical microscope.		4 hours
5.	Measure the blood glucose with electrochemical workstation		3 hours
6.	Study the band gap of semiconductor nanoparticle using UV-Vis spectroscopy		3 hours
7.	Measure the band gap and structure of crystal with XRD.		3 hours
8.	Elemental analysis using EDAX		3 hours
9.	Study the property of graphene using Raman Spectroscopy.		3 hours
		Total Laboratory Hours	30 hours
Mode of Evaluation: Continuous assessment of challenging experiments /Final Assessment Test (FAT).			
Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE6032	NANOELECTRONICS	2	0	2	4	4
Pre-requisite	ECE5031- Quantum Physics for Nanostructures					

Course Objectives:

The course is aimed to :

1. Make them understand various advanced concepts in nanoelectronics.
2. Explore the fundamentals on QED, SED, Molecular electronics and spintronics.
3. Train the students on state-of-the-art computational tools for modelling and simulation of nanoelectronics devices.

Expected Course Outcomes:

Student will be able to

1. Gain the concepts of nanoelectronics such as ballistic transport and quantum confinement.
2. Understand various nanostructures and its applications towards Quantum Electronic Devices.
3. Acquire the fundamentals of Molecular Electronics
4. Obtain the knowledge of Single Electron Devices and carbon based nanoelectronic devices.
5. Learn the fundamentals of Spintronics.
6. Design and simulate various advanced nanoelectronic devices.

Module 1	Introduction to Nanoelectronics	3 hours

Limitations of the conventional MOSFETs at Nanoscales, MOSFET Scaling & implications, Introductory concepts of Ballistic transport and Quantum confinement, Differences in Few Electron Devices (as analog version) and Single Electron Devices (as digital version) of Nanoelectronic devices

Module 2	Nanostructures and Quantum Electronic Devices	4 hours

Low-dimensional structures- Quantum wells, Quantum wires and Quantum dots; Density of states in low-dimensional structures; Quantum Interference Devices; Split –Gate Transistor; Electron – Wave Transistor; Resonant tunneling phenomena and its applications in diodes and transistors.

Module 3	Molecular Electronics	3 hours

Overview & Basics; Fabrication of molecular electronics-based transistor devices; Conductivity of organic polymers- Conduction mechanism in organic polymers; Polymer Electronics; Self-Assembling Circuits.

Module 4	Single Electron Devices	5 hours

Principle of operation- Single-Electron Effect, Coulomb Blockade Phenomenon; Theoretical Quantum Dot Transistor - Energy of Quantum Dot system, Single-Electron Quantum-Dot Transistor, Single transistors; Conductance Oscillation and Potential Fluctuation; Transport under Finite temperature and Finite Bias; Coulomb Blockade Devices.

Module 5	Carbon Nanoelectronics	4 hours

Carbon nanotubes - SWCNTs and MWCNTs; 1D quantization in nanotubes- van Hove singularities; Fabrication of CNTs; CNT FETs- Device characteristics, CNT-TUBFET, CNT-SET; and NanoWire FETs; Electronic structure of graphene; Graphene FETs- GNRFETs.

Module 6	Spintronics	2 hours

Fundamentals of spintronics; Spintronic devices- spin diodes and spin transistors

Module 7	Current Nanoelectronic Devices	7 hours
Quantum Effects in MOSFETs, Strained Silicon, Fully Depleted SOI-MOSFET, Double-Gate MOSFET, Multi-gate MOSFETs, FIN-FET, Electrically Induced Junctions for EJ-MOSFETs, Ballistic Transport, Conductance Quantization, Quantum Point Contact Devices.		
Module 8	**Contemporary issues:**	**2 hours**
	Total Lecture Hours	**30 hours**

Text Book(s)	
1.	Shunri Oda, David Ferry, Nanaoscale Silicon Devices, CRC Press, Taylor & Francis Group, 2015.
2.	K. Goser, P. Glosekotter, Nanoelectronics and Nanosystems, Springer, 2005.
Reference Books	
1.	Suprio Datta, Lessons from nanoelectronics, World Scientific publisher, 2015.
2.	Karl Goser, Peter Glosekotter, Jan Dienstuhl , Nanoelectronics and Nanosystems- From Transistors to Molecular and Quantum Devices, Springer-Verlag 2004.
3.	C.N.R. Rao and A. Govindaraj, Nanotubes and nanowires, RSC Publishing, 2005.
4.	Konstantin K. Likharev, Single Electron Devices and their Applications, IEEE proceedings, vol. 87, no. 4, April 1999.p 606- 632.
5.	Ziese and M. J. Thornton Spin Electronics, Springer-Verlag, 2001.
6.	Supriyo Datta, Quantum Transport-From Atom to Transistor, Cambridge University press, 2005.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).

Typical Projects

1. Design a Double gate MOSFET with 10nm-16nm channel dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.
2. Design a 2D SOI-MOSFET with 16nm technology node by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.
3. Design a gate around FINFET with 5nm fin length and 16nm channel length dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.
4. Solve relevant mathematical equations and plot band structure and DOS of various types of CNTs.
5. Solve relevant mathematical equations and plot band structure and DOS of various types of graphene nano ribbons(GNRs).
6. Solve NEGF equation for quantum transport of a 2D graphne FET and analyze its electrical characteristics.

Mode of Evaluation: Review I, II and III

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE6033	NANOPHOTONICS	3	0	0	0	3
Pre-requisite	ECE5031 - Quantum Physics for nanostructures					

Course Objectives:

The course is aimed to:

1. Expose them to the emerging area of nanophotonics and the phenomena involved in such devices.
2. Provide deep understandings of light – matter interaction at nanoscale.
3. Study different types of nanophotonic crystal based devices and systems.

Expected Course Outcomes:

At the end of course student will be able to

1. Gain the foundations of nanophotonics.
2. Understand the mathematical synthesis of Maxwell equations for Photonic systems.
3. Acquire the understanding and importance of confinement and propagation.
4. Obtain the knowledge of 1-D, 2-D and 3-D Photonic Crystals.
5. Gain the design and scope of nano-photonics applications.
6. Learn the foundation of plasmonics.

Module 1	**Foundations of Photonics**	**4 hours**

Photons and Electrons - Similarities and differences, Light Interaction with Matter, Complex refractive index and dielectric constant, Dispersion in Materials.

Module 2	**Maxwell equations for Photonic systems**	**6 hours**

Basic Maxwell equations and their interpretations, Master's Equation for dielectric medium and its analytical solution.

Module 3	**Confinement and Propagation**	**6 hours**

Confinement of Photons and Electrons, Co-operative effects for Photons and Electrons, Propagation through Classically Forbidden Zone- Tunneling, Concept of Near-Field phenomena in Photonic Crystals and Evanescent wave.

Module 4	**Photonic Crystals**	**8 hours**

1-D, 2-D and 3-D Photonic crystal, Theoretical and mathematical description of Photonic band gap, Features and fabrication of Photonic crystals.

Module 5	**Applications of Photonics**	**6 hours**

TE/TM Mode, Optical fiber, filters, switching devices, Kerr effect devices; Super Lenses – Micro and Nano Lenses, Prisms and Meta-materials, Graphene photonics.

Module 6	**Phosphor materials in Photonics**	**7 hours**

Flourescence, Phosphorescence, rare earth doped nanostructures, activator and sensitizer, energy transfer process, life time, down and up conversation, FRET.

Module 7	**Plasmonics**	**6 hours**

Fundamentals, wave equations, surface plasmon-polaritons, Plasmonics in gold and silver nanomaterials

Module 8	**Contemporary issues:**	**2 hours**

	Total Lecture:	**45 hours**

Text Book(s)	
1.	Paras Prasad, Nanophotonics, Wiley-Interscience, 2004.
2.	John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, Robert D. Meade, Photonic Crystals: Molding the Flow of Light, second Edition, Princeton University Press, 2008
Reference Books	
1.	Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui, Makoto Naruse, Principles of Nanophotonics, CRC Press, Taylor & Francis Group, 2008.
2.	Stefan A. Maier, Plasmonics: Fundamentals and Applications, Springer Science, 2007.
3.	J. R. Lakowicz, Principle of Fluorescence Spectroscopy, third Edition, Kluwer Academic Publisher, Newyork, 2007
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).	

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Programme Electives

Course Code	Course Title	L	T	P	J	C
ECE5035	SEMICONDUCTOR DEVICE PHYSICS AND TECHNOLOGY	2	0	0	4	3
Pre-requisite	Nil					

Course Objectives:

The course is aimed to:

1. Make them understand the physics of semiconductor materials and devices.
2. Educate the working mechanism and design of optoelectronic devices.
3. Train them to solve bandgap models and design different semiconductor devices.

Expected Course Outcomes:

Students will be able to

1. Gain in-depth knowledge in semiconductor physics
2. Acquire knowledge of mathematical model of various device fabrication processes
3. Gain in-depth knowledge of formation and properties of PN junctions
4. Obtain the fundamentals of metal-semiconductor junctions
5. Gain the physics of optoelectronic devices
6. Understand the fabrication and characteristics of nanoscale MOSFETs
7. Apply the concepts and techniques to solve bandgap model equations and design various semiconductor devices.

Module 1	Semiconductor Physics	6 hours

Energy Bands and Carrier Concentration in thermal Equilibrium: Semiconductor Materials, Basic Crystal Structure, Basic Crystal Growth Technique, Valence Bands, Energy Bands, Intrinsic Carrier Concentration, Donors and Acceptors. Carrier Transport Phenomena: Carrier Drift, Carrier Diffusion, Generation and Recombination Processes, Continuity Equation, Thermionic Emission Process, Tunneling Process, High-Field Effects.

Module 2	Device Process stages I	3 hours

Device Process stages I: Mathematical models relevant to thermal diffusion and ion implantation and Annealing. Pattern transfer; Optical lithography, Photoresists, Alignment and exposure, Etching.

Module 3	Device Process stages II	3 hours

Mathematical models relevant to Deposition; Physical and chemical vapor deposition, Epitaxy. Process Integration: Device isolation, contacts metallization.

Module 4	P-N Junction	5 hours

Diode fabrication, Device physics: Thermal equilibrium, Internal electro-static fields and potentials, Poisson's equation, continuity equations, drift-diffusion equations. I-V Characteristics: Forward bias, reverse bias, Diode equation. Capacitive effect: Junction and diffusion capacitance. DC, AC and transient analysis of Diodes.

Module 5	Metal-Semiconductor Contacts and Schottky Diodes	4 hours

Metal-Semiconductor Junction diode Fabrication, Device Physics: Ideal MS contacts, Schottky diode-Electrostatics,I-V characteristics, DC, AC and transient analysis. Metal-Semiconductor contacts: Ohmic contacts, Schottky contacts, Tunnel contacts and Annealed and alloyed contacts.		
Module 6	**Optoelectronic Diodes**	**3 hours**
Photodiode Fabrication**,** device Physics of pn Junction Photodiodes, p-i-n Photo diodes. Principle of operation and fabrication technologies of Solar cell, LED and LASER diodes.		
Module 7	**MOSFET**	**4 hours**
MOS capacitor, MOSFET device fabrication, MOSFET Physics: I-V characteristics, Sub-threshold region, Body effect, Capacitive effect, small and large signal model. MOSFET Short Channel effects: Punch through, DIBL, Hot electron effect, Velocity Saturation, Leakage current. MESFETs and MODFET analysis.		
Module 8	**Contemporary issues:**	**2 hours**
Advanced Topics		
	Total Lecture:	**30 Hours**
Text Books(s)		
1.	S. M. Sze and Ming-Kwei Lee, Semiconductor Devices Physics and technology, John Wiley & Sons, 2013.	
2.	Grundmann and Marius, Physics of Semiconductors, Springer, 2010	
Reference Books		
1.	Ben G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, Pearson Ed, 2014.	
2.	M. S. Tyagi, Introduction to semiconductor materials and devices, John Wiley & Sons, 2008.	
3.	Campbell, Stephan, Fabrication Engineering at the Micro and Nanoscale, Oxford University Press, 2008.	
4.	Robert F. Pierret, Semiconductor Device Fundamentals, Pearson Education, 2006.	
5.	Richard C. Jaeger, Introduction to Microelectronic Fabrication, Prentice Hall, 2001.	
Mode of Evaluation: Flipped Class Room, [Lecture to be videotaped], Use of physical and computer models to lecture, Visit to Industry, Min of 2 lectures by industry experts		
Typical Projects		
1. Solve relevant mathematical equations and plot band structure then extract effective mass of direct and indirect bandgap semiconductors. 2. Solve drift-diffusion equation for transport parameters (Drift velocity, mobility and conductivity) of direct and indirect band gap materials. 3. Design a P-N junction diode with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics. 4. Design a MOSFET with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators. 5. Design a MOSFET with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators. **6.** Design a LASER diode with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.		
Mode of Evaluation: Review I, II and III		

Course Code	Course Title	L	T	P	J	C
ECE5036	MEMS To NEMS	2	0	0	4	3
Pre-requisite	None					

Course Objectives:

The course is aimed to:

1. Make them to understand the technology of MEMS and NEMS.
2. Expose them about fabrication processes for development of MEMS/NEMS devices and systems.
3. Educate about the potential applications of NEMS.

Expected Course Outcomes:

At the end of course students will be able to

1. Acquire the knowledge of mechanisms in MESM/NEMS
2. Understand various engineering mechanics of microsystems
3. Gain the concept in finite element analysis of microsystems
4. Obtain the knowledge of MEMS fabrication
5. Acquire knowledge of quantum effects in MEMS/NEMS
6. Apply the knowledge of system integration in MEMS/NEMS
7. Design and simulate micro/nano sensors and actuators.

Module 1	Introduction	2 hours

Overview of MEMS / NEMS and various devices, Scaling geometry, Rigid Body Dynamics, Forces, Electron transfer, Fluid mechanics and Heat transfer.

Module 2	Engineering mechanics for Microsystems design	4 hours

Static Bending of Thin plates, Mechanical vibration, Resonant vibration, Design theory of Accelerometers, and Thermal analysis, Thermal effects on Mechanical strength of Materials, Creep formation.

Module 3	Finite Element Analysis	5 hours

Concept of FEA, Comparison with other methods, Formulation from the governing Differential equations, Formulation based on stationary total potential, 1-D and 2-D Finite Element Analysis, Examples.

Module 4	Overview of Micro - Scale fabrication	2 hours

Microsystem fabrication process-Lithography, Dry and wet etching, Thin film deposition-PVD,CVD,LIGA, Micromolding, Electro-deposition

Module 5	Quantum effects	6 hours

Casimir Force and its influence in MEMS and NEMS, control of casimir force, Nanotribology-experimental techniques for studying anotribology, phonic friction, electronic friction, static friction, frictional anisotropy, stick-slip dynamics

Module 6	NEMS	7 hours

Introduction to nanoscale engineering, theory and characteristics of NEMS**,** Design and simulation techniques of NEMS – molecular dynamics, Potential energy models, Integration algorithms

Molecular and Nanostructure Dynamics, Molecular Wires and Molecular Circuits		
Module 7	**System Integration**	**2 hours**
System Integration and reliability		
Module 8	**Contemporary issues:**	**2 hours**
Advanced Topics		
	Total Lecture:	**30 hours**

Text Books(s)

1.	Tai-ran Hsu, MEMS and microsystems design and manufacture, Nanoscale Engineering, TMGH, 2008
2.	Sergey Edward Lyshevski, MEMS and NEMS: Systems, Devices, and Structures, CRC, 2002

Reference Books

1.	P.Seshu, Text Book of Finite Element Analysis, PHI,2006
2.	Sergey Edward Lyshevski, Nano- and Micro-electromechanical Systems, CRC, Press, 2000
3.	Bharath Bhushan, Handbook of Micro/Nanotribology, CRC Press, 1999.
4.	Cornelius T. Leondes, MEMS/NEMS Handbook, Techniques and application, Springer, 2005.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).

Typical Projects

1. Design of capacitance based actuators.
2. Study of scaling effects in a magnetic systems
3. Simulation of peizo based cantilever beams
4. Molecular dynamics simulation
5. Accelerometer design
6. Design of capacitance based actuators.

Mode of Evaluation: Review I, II and III

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5037	NANOSENSORS	3	0	0	0	3
Pre-requisite	Nil					

Course Objectives:

The course is aimed to:

1. Offer an overview of basic nanosensor technology with examples drawn from existing products and literatures.
2. Enable them to identify suitable nanosensors and nanodevices for various potential applications.
3. Make them acquainted with various types of nanosensors and its potential applications.

Expected Course Outcomes:

At the end of this course students will be able to

1. Identify and understand various micro and nano-sensors and their working.
2. Learn material's properties used for the fabrication of nanosensors.
3. Gain the fundamentals of packaging and characterization of nanosensors.
4. Aware of various types of mechanical, chemical and optical nano-sensing systems.
5. Use nanostructured materials for developing nanobiosensors.

Module 1	Micro and nano-sensors	3 hours

Sensing principles, sensor types and classification – Mechanical, acoustic, magnetic, thermal, chemical, radiation; microsensors; sensors based on surface - acoustic wave devices, biosensor, microfluids

Module 2	Materials for Nanosensors	8 hours

Shape and size Dependence of Properties at Nanoscale, Surface Energy of a Solid, Core/Shell-Structured Nanoparticles, Metallic Nanoparticles and Plasmons Optical Properties of Bulk Metals and Metallic Nanoparticles, Quantum Dots, Carbon Nanotubes, Inorganic Nanowires, Nanoporous Materials.

Module 3	Packaging and characterization of sensors	4 hours

Design, fabrication and characterization, Method of packaging at dye level, zero level and first level.

Module 4	Mechanical Nanosensors	8 hours

Mass sensing- Nanogram Mass Sensing by Quartz Crystal Microbalance, MEMS/NEMS Resonators; Displacement sensor- Electron Tunneling Displacement Nanosensor, Coulomb Blockade Electrometer-Based Displacement Nanosensor, Nanometer-Scale Displacement Sensing by Single-Electron Transistor, Magnetomotive Displacement Nanosensor, Piezoresistive and Piezoelectric Displacement Nanosensors, Optical Displacement Nanosensor; Femtonewton Force Sensors- Doubly Clamped Suspended Carbon Nanotube Resonators, Suspended CNT Electromechanical Sensors for Displacement and Force, Membrane-Based CNT Electromechanical Pressure Sensor

Module 5	Chemical Nanosensors	8 hours

Gas Sensors Based on Metallic Nanoparticles, Metal Oxides, Carbon Nanotube, Porous Silicon; Thin Organic Polymer Film–Based Gas Sensors; Electrospun Polymer Nanofibers as Humidity Sensors; Nanoelectronic Nose; CNT, Nanowire, and Nanobelt-Based Chemical Nanosensors

Module 6	**Optical Nanosensors**	**6 hours**
Noble-Metal Nanoparticles with LSPR and UV–Visible Spectroscopy, Nanosensors Based on Surface-Enhanced Raman Scattering, Colloidal SPR Colorimetric Gold Nanoparticle Spectrophotometric Sensor, Fiber-Optic Nanosensors, Nanograting-Based Optical Accelerometer.		
Module 7	**Nanobiosensors**	**6 hours**
Nanoparticle-Based Electrochemical Biosensors, CNT-Based Electrochemical Biosensors, Functionalization of CNTs for Biosensor, Quantum Dot-Based Electrochemical Biosensors, Nanotube- and Nanowire-Based FET Nanobiosensors, Cantilever-Based Nanobiosensors, Optical Nanobiosensors, Biochips		
Module 8	**Contemporary issues:**	**2 hours**
Advanced Topics		
	Total Lecture:	**45 hours**

Text Book(s)	
1.	Peter Hauptmann and Tim Pownall, Sensors: Principles and Applications , Prentice Hall, 2003
2.	Vinod Kumar Khanna, Nanosensors: Physical, Chemical, and Biological, CRC, 2012
Reference Books	
1.	Kevin C. Honeychurch, Nanosensors for Chemical and Biological Applications: Sensing with Nanotubes, Nanowires and Nanoparticles, woodhead publishing, 2014
2.	Teik-Cheng Lim, Nanosensors: Theory and Applications in Industry, Healthcare and Defense, CRC, 2011

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5038	CARBON NANOMATERIALS	3	0	0	0	3
Pre-requisite	Nil					

Course Objectives:

The course is aimed to:

1. Make the students understand the importance of carbon based nanostructured materials.
2. Study various carbon allotropes, their types, structure, properties and applications.
3. Emphasize other carbon based nanostructured materials such as nanocones, nanofibers, nanodiscs and nanodiamonds.

Expected Course Outcomes:

At the end of course, students will be able to:

1. Understand the importance of carbon based nanomaterials.
2. Obtain the knowledge on synthesis, characterization and application of various carbon based nanomaterials such as fullerene, carbon nanotubes and graphene.
3. Understand the functionalization and applications of CNT & Graphene.
4. Gain knowledge in other carbon based nanomaterials such as nanocones, nanofibers, nanodiscs and nanodiamonds.

Module 1	Carbon Nanomaterials	2 hours

Introduction to Carbon Nanomaterials, Carbon allotropes and their bonding between carbon atoms.

Module 2	Fullerene	6 hours

Structure, Synthesis, Functionalization of fullerenes, Applications – Solar Cells, Hydrogen storage, Bio-applications.

Module 3	Carbon nanotubes	8 hours

Types ; Structure; Properties- Electrical, Optical, Mechanical, Vibrational properties; Nanotube synthesis - carbon arc discharge, Laser ablation, Chemical Vapor Deposition, High-pressure CO process, Purification techniques of carbon nanotube.

Module 4	Functionalization and Applications of CNTs	8 hours

Functionalization- Covalent, non-covalent, and biological; Applications - Energy storage: Batteries, Fuel Cells: H_2, Li storage, supercapacitors; Molecular electronics–Field emitting devices and Transistors, drug delivery, CNT based microscopy, Nanotube sensors.

Module 5	Graphene	7 hours

Electronic band structure, Properties of Graphene: chemical, mechanical, electronic and thermal. Synthesis of Graphene – Exfoliation, Epitaxial, CVD, Hummer Method; Graphene Nanoribbon-synthesis.

Module 6	Functionalization and Applications of Graphene	6 hours

Functionalization- Covalent, non-covalent Application of Graphene; Applications – Graphene MOSFET – Opening a Band gap, Spintronics, Solar cells, gas sensors, supercapacitors.

Module 7	**Other Carbon based materials**	**6 hours**
Carbon Nanocomposite, Nanocones, Nanofibers, Nanodiscs and Nanodiamonds.		
Module 8	**Contemporary issues:**	**2 hours**
	Total Lecture:	**45 Hours**

Text Book(s)	
1.	Peter. J.F Harris, Carbon Nanotube Science: Synthesis, Properties and Applications, Cambridge University Press, 2011
2.	Jamie H. Warner, Franziska Schaffel, Mark Rummeli, Alicja Bachmatiuk, Graphene: Fundamentals and Emergent Applications, Elseiver, 2013
Reference Books	
1.	Zhong Lin Wang, Nanowires and Nanobelts- Materials, Properties and Devices, Springer, 2006
2.	Thomas Webbester, Carbon Nanotube preparation and properties, CRC Press, 1997
3.	R Saito, G Dresselhaus, M S Dresselhaus, Physical Properties of Carbon Nanotubes, Imperial college press, 2004
4.	Yury Gogotsi, Volker Presser, Carbon nanomaterials, CRC Press, 2014
5.	CNR Rao and A Govindaraj, Nanotubes and Nanowires, RCS Nanoscience and Nanotechnology series, 2011
6.	Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC Taylor and Franci group, 2006.
7.	Mikhail I. Katsnelson, Graphene: Carbon in two dimensions, Cambridge University Press, 2012
8.	Fernando Langa, Jean-Francois Nierengarten, Fullerenes: Principles and Applications , RSC Publishing, 2007

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5039	LITHOGRAPHIC TECHNIQUES FOR DEVICE FABRICATION	3	0	0	0	3
Pre-requisite	Nil					

Course Objectives:

The course is aimed to:

1. Make conversant with conventional aspects of lithography, techniques related and their resolution aspects.
2. Introduce various existing Lithography techniques.
3. Study the principles, process steps and system components of the various lithographic techniques.

Expected Course Outcomes:

At the end of course students will be able to:

1. Obtain the in-depth knowledge in optical and electron beam lithography techniques.
2. Understand the conventional aspects of lithography, techniques related and their resolution aspects of X-ray, Ion, SPM based and soft lithography.
3. Learn and understand the importance of plasmonics in lithography

Module 1	Optical Lithography	9 hours

Process steps involved in the optical lithography; Types - Contact, proximity printing and Projection Printing; Resolution Enhancement techniques for projection systems; Deep Ultraviolet lithography; Extreme Ultraviolet lithography; Scanning Near Field Optical Lithography.

Module 2	Electron Beam Lithography	8 hours

Interaction of the electrons with the substrate; Electron Lithography System components; Raster scans and Vector scans; Electron resists and processing technique; Application of Electron Beam Lithography.

Module 3	X-ray Lithography	4 hours

X-ray lithography system components, Resolution enhancement, X-ray mask construction, X-ray sources, x-ray resists.

Module 4	Ion Lithography	3 hours

Ion lithography system components; Focused Ion Beam Lithography; Masked Ion Beam Lithography; Ion Projection Lithography.

Module 5	Scanning Probe Lithography	8 hours

Scratching Lithography; Anodic Oxidation- Mechanism of Nano-oxidation; Dip-Pen Nanolithography - Mechanism, DPN Types: Parallel DPN, Polymer DPN, Application of DPN; Nano-shaving.

Module 6	Soft Lithography	5 hours

Micro-contact printing, Solvent-Assisted Micromoulding, Micromoulding in capillaries, Patterning SAMs.

Module 7	**Plasmonic Nanolithography**	**6 hours**
Principle of Plasmonic Lithography, Plasmonic Mask, Near-field Plasmonic Lithography, Plasmonic Contact Lithography, Plasmonic direct write lithography.		
Module 8	**Contemporary issues:**	**2 hours**
	Total Lecture:	**45 hours**

Text Book(s)	
1.	M Feldman, Nanolithography: The Art of Fabricating Nanoelectronic and Nanophotonic Devices and Systems, Woodhead Publishing, 2014.
2.	Stefano Cabrini, Satoshi Kawata, Nanofabrication Handbook, CRC Press, 2012.
Reference Books	
1.	Bruce W. Smith, Kazuaki Suzuki, Microlithography: Science and Technology, Second Edition, CRC Press, 2007.
2.	D Bucknall, Nanolithography and Patterning Techniques in Microelectronics, Elsevier, 2005.
3.	Marc J. Madou, Manufacturing Techniques for Microfabrication and Nanotechnology, 3rd Edition, Vol II, CRC Press, 2011.
4.	Mark J. Jackson, Micro and Nanomanufacturing, Springer Science & Business Media, 2007.
5.	Ampere A. Tseng, Tip-Based Nanofabrication: Fundamentals and Applications, Springer Science & Business Media, 2011.
6.	Hyongsok T. Soh, Kathryn Wilder Guarini, Calvin F. Quate, Scanning Probe Lithography, Springer Science & Business Media, 2013.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE5040	PLASMONICS	2	0	0	4	3
Pre-requisite	Nil					

Course Objectives:

The course is aimed to:

1. Give a clear idea of changes in optical properties of nanostructures.
2. Enable to understand the fundamentals about surface plasmon polariton and plasmonic waveguides.
3. Make acquainted with various types of Spectroscopy and sensing techniques based on plasmonics.

Expected Course Outcomes:

At the end of course students will be able to:

1. Acquire the knowledge on electromagnetics of metallic nanoparticles.
2. Understand the fundamentals of surface plasmon polariton, and LSPR.
3. Understand the excitation dynamics at nanoscale.
4. Learn about nanocomposites and its application in the field of optoelectronics.
5. Familiar with nanostructured molecular architectures.
6. Obtain the basics on Surface-Plasmon-Polariton-Based Sensors.
7. Apply surface plasmon polariton, and LSPR concepts for designing nanophotonic devices.

Module 1	Electromagnetics of Metallic Nano-particles	5 hours

Metallic Nano-particles, Maxwell equation and Electromagnetic wave equation, dispersion of the free electron gas and volume plasmons, real metals and intraband transitions, Electromagentic field in metals, Local Field Enhancement, Sub-wavelength aperture plasmonics,

Module 2	Plasmonic waveguides	4 hours

Elements for surface plasmon polariton propagation, surface plasmon polariton band gap structures, metal nanowires for high confinement guiding and focusing, localized modes, metal nanoparticle waveguides

Module 3	Localized surface plasmons	4 hours

– Normal modes of sub-wavelength metal particles, Mie theory, Observations of particle plasmons, coupling between localized plasmons, void plasmons and metallic nanoshells

Module 4	Nanocontrol of Excitation Dynamics	4 hours

Nanostructure and excited states. Rare earth doped nanostructures Up-converting nanophores. Photon avalanche. Quantum cutting. Site isolating nanoparticles, prism and grating coupling, near field excitation.

Module 5	Nanocomposites	4 hours

Nanocomposites as photonic media. Nanocomposite waveguides. Random lasers. Local field enhancement. Multiphase nanocomposites. Nanocomposites for optoelectronics. Polymer dispersed liquid crystals. Nanocomposite metamaterials.

Module 6	Nanostructured Molecular Architectures	4 hours

Noncovalent interactions. Nanostructured polymeric media. Molecular machines. Dendrimers.

Supramolecular structures. Monolayer and multilayer molecular assemblies.		
Module 7	**Spectroscopy and sensing**	**3 hours**
Single-Particle Spectroscopy, Surface-Plasmon-Polariton-Based Sensors, Metamaterials and Negative Index at Optical Frequencies, The Perfect Lens, Imaging and Lithography		
Module 8	**Contemporary issues:**	**2 hours**
	Total Lecture:	**30 hours**

Text Book(s)	
1.	Stefan Alexender Maier, Plasmonics – Fundamental and Applications, Springer, 2007.
2.	Paras Prasad, Nanophotonics, Wiley-Interscience, 2004.
Reference Books	
1.	Mark L. Brongersma and Pieter G. Kik, Surface Plasmon Nanophotonics, Springer, 2007.
2.	Ralf B. Wehrspohn, Heinz-Siegfried Kitzerow, and Kurt Busch, Nanophotonic Materials: Photonic Crystals, Plasmonics, and Metamaterials, Wiley-VCH, 2008)
3.	Matthew Pelton, Garnett W. Bryant, Introduction to Metal–Nanoparticle Plasmonics, A Wiley–Science Wise Co–Publication, 2013

List of Projects (Indicative)

1. Electrodeposition of plasmonic nanomaterials
2. Electrochemical investigation of hot electron dynamics
3. Plasmonic simulations with light beams
4. Photonic spin Hall effect from single nanostructure
5. Fabrication and optical characterisation of metallic nanocubes
6. Localized surface plasmon resonance (LSPR) of Nobel metal nanoparticles

Mode of Evaluation: Review I, II and III

Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE6031	NANOMAGNETISM- FUNDAMENTALS AND APPLICATIONS	3	0	0	0	3
Pre-requisite	ECE5031- Quantum Physics for Nanostructures					

Course Objectives:

The course is aimed to:

1. Make them understand the fundamentals of nanomagnetism and their applications.
2. Study the magnetism at macro- and nanoscale and their potential effects.
3. Enable students to apply the concepts of magnetic nanomaterials in the field of energy storage, biomedicine and environmental applications.

Expected Course Outcomes:

At the end of course students will be able to:

1. Gain in-depth knowledge about the concepts of magnetism at macro and nanoscale.
2. Obtain the knowledge about magnetism of localized electrons on the atom.
3. Gain the fundamentals about ferromagnetism, antiferromagnetism and other magnetic order.
4. Identify and understand the concepts of micro- and nanoscale magnetism
5. Apply the concepts to the application of magnetic nanomaterials in the field of magnetic recording, energy storage, biomedicine and environmental applications.

Module 1	Magnetostatics	3 hours

Introduction - History - Magnetism and hysteresis, Magnetic dipole moment, Magnetic fields, Maxwell's equations, Magnetostatic energy and forces.

Module 2	Magnetism of electrons	8 hours

Orbital and spin moments, Magnetic field effects – Zeeman effect, Theory of electronic magnetism, Magnetism of electrons in solids

Module 3	Magnetism of localized electrons on the atom	8 hours

The hydrogenic atom and angular momentum, The many-electron atom, Paramagnetism, Ions in solids; crystal-field interactions.

Module 4	Ferromagnetism and Exchange	8 hours

Mean field theory, Exchange interactions, Band magnetism, Collective excitations, Anisotropy, Ferromagnetic phenomena

Module 5	Antiferromagnetism and other magnetic order	4 hours

Molecular field theory of antiferromagnetism, Ferrimagnets, Frustration, Amorphous magnets, Spin glasses, Magnetic models

Module 6	Micromagnetism and Nanoscale magnetism	7 hours

Micromagnetic energy, Domain theory, Reversal, Pinning and Nucleation, Characteristic length scales, Superparamagnetism, Thin films, Thin-film heterostructures, Wires and needles, Small particles, Bulk nanostructures, Novel methods for synthesis of magnetic nanoparticles, Magnetic interactions: a tool to modify the magnetic properties of materials based on nanoparticles.

Module 7	**Applications of nanomagnetism**	**5 hours**
Magnetic storage and recording, Magnetic resonance Imaging, Hyperthermia, Ferrofluid, Biosensors.		
Module 8	**Contemporary issues**	**2 hours**
	Total Lecture:	**45 hours**

Text Book(s)	
1.	J. M. D. Coey, Magnetism and Magnetic Materials, Pearson Education, 2010.
2.	B. D. Cullity, C. D. Graham, Introduction to Magnetic Materials, John Wiley & Sons, Inc, 2009.
Reference Books	
1.	R. C. O'Handley, Modern Magnetic Materials: Principles and Applications, John Wiley & Sons, Inc, 2000.
2.	C Binns, Nanomagnetism: Fundamentals and Applications, Elsevier, 2014.
3.	David Jiles, Introduction to Magnetism and Magnetic Materials, Chapman and Hall, 1991.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE 6034	ENERGY TECHNOLOGIES	3	0	0	0	3
Pre-requisite	ECE6034 - Physics and chemistry of solids					

Course Objectives:

1. To expose the students about various energy sources and the possibility of harvesting energy with nanomaterials

Expected Course Outcomes:

At the end of course the students will be able to:

1. Understand the various renewable energy sources.
2. Acquire the knowledge on different energy harvesting methods.
3. Understand thermodynamics and kinetics of fuel cell process with nanomaterials.
4. Explain and choose suitable nanomaterials and nanostructures for photovoltaics.
5. Distinguish different types and performance of solar collectors.
6. Acquire the knowledge of electrochemical energy storage systems.
7. Understand the process and design issues in magnetic energy storage systems.

Module 1	Renewable Energy Sources	2 hours

Basics and Types of Renewable energy sources.

Module 2	Energy Harvesting	7 hours

Sources, Types and mechanism – Solar, Thermoelectric, Piezoelectric; Electro dynamical and Biological; Energy harvesting devices and applications. Nanomaterials for energy harvesting.

Module 3	Energy Conversion I	7 hours

Energy conversion – Types and mechanism; Electrochemical energy conversion, thermodynamics; Hydrogen Technology; Fuel Cells - fundamentals, classifications, Operating principles and design considerations, thermodynamics and kinetics of fuel cell process, performance evaluation of fuel cell, Fuel cell applications. Nanomaterials as electrode materials for fuel cells.

Module 4	Energy Conversion II	7 hours

Solar energy: Photovoltaic fundamentals, Solar cell technologies, Types – Dye sensitized, Quantum dot, Copper indium gallium selenide (CIGS), Hybrid, Organic and Plasmonic solar cells etc,. Performance and parameter analysis of solar cells. Nanomaterials and Nanostructures for photovoltaics.

Module 5	Energy Conversion III	7 hours

Photothermal systems: Types and performance of solar collectors - Flat Plate, Hot Air, Evacuated Tube, Parabolic, Compound Parabolic and Fresnel Solar Concentrators, Thermal Analysis and performance of Solar Collectors, Current and future scope of solar energy.

Module 6	Energy storage I	7 hours

Electrochemical energy storage systems: Supercapacitors - Differences between capacitors, supercapacitors and batteries, classifications of supercapacitors. Batteries: Primary, Secondary, Lithium, Solid-state and molten solvent batteries; Lead acid batteries; Nickel Cadmium Batteries; Sodium ion and Aluminum Batteries. Nanostructured and Hybrid materials as electrodes for batteries and capacitors.

Module 7	**Energy storage II**	**6 hours**
Magnetic energy storage systems (SMES); Thermal energy storage systems - Thermal energy storage materials – Types, thermo physical properties, Phase change materials for heating and cooling applications. Heat transfer fluids – Properties and mechanism.		
Module 8	**Contemporary issues:**	**2 hours**
Advanced Topics		
	Total Lecture:	**45 hours**

Text Book(s)	
1	Chetan Singh Solanki, Solar Photovoltatics – Fundamentals, Technologies and Applications, PHI Learning Private limited, 2011
2	Ru-shiliu, Leizhang, Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2012
Reference Books	
1.	Caye M. Drapcho, Nghiem Phu Nhuan and Terry H. Walker, Biofuels Engineering, McGraw-Hill Companies, 2008
2.	Viswanathan, B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press ,2006
3.	Schaeffer, John, Real Goods Solar Living Sourcebook: The Complete Guide to Renewable Energy Technologies and Sustainable Living, Gaiam,2007
4.	Frank Kreith and D.Yogi Goswami, Handbook of Energy Efficiency and Renewable Energy, CRC Press, 2007
5.	John Twidell and Tony Weir, Renewable Energy Resources, Taylor & Francis, USA, 2006

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016

Course Code	Course Title	L	T	P	J	C
ECE6035	SPINTRONICS	2	0	0	4	3
Pre-requisite	ECE5031- Quantum Physics for Nanostructures					

Course Objectives :

The course aimed to:

1. Make them understand the spin based electronics.
2. Study the magnetic materials, Spintronic based devices and fabrication.

Expected Course Outcomes:

The student will be able to

1. Gain the knowledge about Paramagnetism & diamagnetism.
2. Acquire the understanding and importance of Micromagnetics.
3. Obtain the fundamental knowledge of Magnetic Materials
4. Understand the Electron Transport in Magnetic Systems
5. Study properties of magnetic materials using advanced characterization tools and techniques.
6. Obtain the design and scope of Spintronic Device fabrication Techniques

Module 1	Paramagnetism & diamagnetism	2 hours

Magnetically ordered state, Itinerant-electron magnetism, Localized Magnetic Systems.

Module 2	Micromagnetics	3 hours

Magnetism of single domain systems, Domain Walls, Exchange Bias and Magnetic Anisotropy.

Module 3	Magnetic Materials	3 hours

High-density recording materials, Soft Magnetic Materials (Ferrites), Magnetic Thin Films, Dilute Magnetic semiconductors, Hemsler Alloys, SQUID Magnetometer, Highly Spin Polarized Systems, Molecule-based magnets, Single-molecule magnets.

Module 4	Electron Transport in Magnetic Systems	5 hours

Degree of Spin Polarization, Idea of Tunneling, Magnetoresistance, Anisotropic Magnetoresistance (AMR), Hall Effect (Planar & Anomalous)and Spin Polarized states.

Module 5	Characterization of Magnetic Materials	6 hours

Magnetometry, SQUID, VSM, Torque, Faraday Balance, Kerr Effect, Magnetic Force Microscopy, Spin Polarized STM.

Module 6	Spintronic Devices	6 hours

Spintronics- Origins of Spin, Spin Mechanics, Origins of Spintronics, Spin current and Magnetoresistance, Giant Magnetoresistance (GMR), Colossal Magnetoresistance, Ballistic Magnetoresistance, Tunneling Magnetoresistance. Two-terminal devices-Spin valves, Tunneling MR devices, Magnetic Field sensors, Read- Heads, MRAMS, Three-terminal Devices- Spin FET, Spin SET, and Spin LED.

Module 7	Spintronic Device fabrication Techniques	3 hours

Advanced device fabrication methods-Growth of multilayer Structures, Lithography and Self-Assembly.

Module 8	Contemporary issues:	2 hours

	Total Lecture			**30 hours**
Text Book(s)				
1	Hirota, Sakakima, and Inomata, Giant Magneto-Resistive Devices, Springer Verlag 2002.			
2	D. Awschalom, D. Loss, and N.Samarth, Semiconductor Spintronics and Quantum Computation, Nano Science Technology series, Springer, 2002.			
Reference Books				
1	Stefan Visnovsky, Optics in Magnetic Multi-layers and Nanostructures, CRC Publishers, 2006.			
2	D.L. Mills, J. A.C. Brand Nanomagnetism, Elsevier Science and Technology, 2006.			
3	M. Ziese, M. J. Thornton Spin Electronics, Lecture Notes in Physics, Springer, 2001.			
4	Gersten and Smith, The Physics and Chemistry of Materials, Wiley, 2001.			
5	Buschow and De Boer, Physics of Magnetism and Magnetic Materials, Springer 2003.			
6	R. L. Carlin, Magnetochemistry, Springer-Verlag, Berlin, 1986.			
7	U. N.Hartmann, Magnetic Multi-layers and Giant Magnetoresistance: Fundamentals and Industrial Applications, Springer, 2000.			
8	M. Ziese, M. J. Thornton Spin Electronics, Lecture Notes in Physics, Springer, 2001.			
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).				
Typical Projects				
1. Fabrication of magnetic tunnel junctions (MTJ) with MgO or AlO insulating barriers 2. Spin pumping and high frequency spin dynamics in MTJs 3. MTJ sensors for biological applications 4. Theory of spin-polarized transport and pure spin currents 5. Topological insulator-based spintronic devices.				
Mode of Evaluation: Review I, II and III				
Recommended by Board of Studies	13-12-2015			
Approved by Academic Council	No. 40	Date	18-03-2016	

Course Code	Course Title	L	T	P	J	C
ECE6039	NANOELECTRONIC CIRCUIT DESIGN	3	0	0	0	3
Pre-requisite	ECE6032 - Nanoelectronics					

Course Objectives:

- To introduce students to the emerging design paradigms in various new nanotechnologies, for device and circuits.
- To bridge the existing gap between nanoelectronic device research and nanosystems design.

Expected Course Outcomes:

The student will be able to

1. Obtain the knowledge on advanced Nanoscale devices
2. Understand the operation and design FinFET based circuits.
3. Design reliable circuits using nanowire arrays and CNT interconnects.
4. Design logic circuits using quantum cellular automata.
5. Understand the design aspects of application specific Nanoscale ICs.
6. Model the circuits of Fin-FETs, CNT-FETs, GNR-FETs, RTDs and quantum dot devices using various SPICE versions.

Module 1	Introduction to advanced nanoelectronic devices	2 hours

New device structures for next generation nanotechnology - carbon nanotube field-effect transistors (CNFETs), FinFETs, nanowire FETs, III/V compound-based devices, graphene nanoribbon devices, resonant tunneling diodes and quantum dot devices.

Module 2	FinFET circuit and SRAM design	8 hours

Shorted-Gate and Independent-Gate FinFETs, Logic Design Using SG/IG-Mode FinFETs, Principle of TCMS, Logic Design Using TCMS, Latch Design Using SG/IG-Mode FinFETs, Precharge-Evaluate Logic Circuits, FinFET SRAM Design: Physics, Theory, and Modeling of FinFET Devices for SRAM Applications; Low-Power, High-Performance 90-nm DG-FinFET SRAM Design.

Module 3	Reliable Circuits Design with Nanowire Arrays and CNT Interconnects	7 hours

Nanowire Fabrication Techniques, Crossbar Technologies, Architecture of Nanowire Crossbars, Decoder Logic Design. Emerging interconnect technologies: Study of Performances of Low-k Cu, CNTs, and Optical Interconnects; Local Interconnects: CNT Bundles Versus Cu and Global and Semi-global Interconnects.

Module 4	Circuit Design with Quantum Cellular Automata	7 hours

QCA Fundamentals, Basic Logic Gates and Interconnect, Logic Design with QCA and Fabrication Technology and Challenges.

Module 5	Nanoscale Application-Specific Integrated Circuits	6 hours

NASIC Building Blocks: Nanowires and xnwFETs, NASIC Circuit Styles, NASIC Logic Styles, NASIC Architectures and manufacturing methods.

Module 6	Circuit Design with Carbon Nanotube FETs & Resonant Tunneling Diodes	8 hours

Mis-Positioned and Immune CNT Logic Design, Metallic-CNT-Immune CNFET Circuits.Metallic-CNT-Immune CNFET Circuits. Bistable Logic Using RTDs, Noise Margins of RTD–HBT Threshold Logic Gates, Monostable–Bistable Logic Elements and Circuit Examples for RTD-Based Devices.		
Module 7	**Circuit design with Graphene based Transistors**	**5 hours**
Recent developments in Graphene Transistors, Analog Circuits, Digital Circuits: GNRFET Digital Circuits, Ambipolar Logic Circuits.		
Module 8	**Contemporary issues:**	**2 hours**
Advanced Topics		
	Total Lecture:	**45 hours**

Text Book(s)	
1.	Niraj K. Jha and Deming Chen, Nanoelectronic Circuit Design, Springer publications, 2011.
2.	K. Goser, P. Glosekotter, Nanoelectronics and Nanosystems, Springer, 2015.
Reference Books	
1.	Yuan Taur and TakNing, Fundamentals of Modern VLSI Devices, Cambridge University Press, Newyark, 1998.
3.	Karl Goser, Peter Glosekotter, Jan Dienstuhl , Nanoelectronics and Nanosystems- From Transistors to Molecular and Quantum Devices, Springer-Verlag, 2004.
4.	John P. Uyemura, Introduction to VLSI Circuits and Systems, John Wiley & Sons, Inc, 2002.

Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies	13-12-2015		
Approved by Academic Council	No. 40	Date	18-03-2016