# Revised Model Curriculum for UG Degree Course in Electronics Engineering (VLSI Design and Technology)

## 2023


ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi 110070

www.aicte-india.org

# MODEL CURRICULUM

# Undergraduate Degree Course in Electronics Engineering (VLSI Design and Technology)

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# Preface

Developed under the auspices of the All India Council for Technical Education (AICTE), the VLSI Design and Technology Model Curriculum for Undergraduate Program is presented with tremendous enthusiasm and joy. This curriculum serves as evidence of our dedication to furnishing pupils with a thorough and industry-focused instruction in Very Large Scale Integration (VLSI) design, guaranteeing that they are exceptionally prepared to thrive in research and commercial environments.

The curriculum has been carefully crafted to provide students with a comprehensive education in VLSI, encompassing a diverse range of subjects that are vital for their success in this ever-evolving discipline. By incorporating group projects, program electives, open electives, internships, and core courses, the curriculum endeavors to offer students a well-rounded education. The foundational courses comprise the core of the curriculum, covering fundamental knowledge and abilities that are essential for the study of VLSI. (1) Semiconductor Devices and Fabrication; (2) Analog Mixed Signal and RF Circuits; (3) Digital Design and Systems; (4) Electronic Design Automation; (5) Display Technologies; and (6) Semiconductor Packaging comprise the thematic focal areas of these courses.

By requiring program electives to be designed and provided by professionals in the field, this policy guarantees that students are introduced to the most recent advancements and methodologies. The study materials utilized in these courses are accessible to the public, thereby encouraging the broad distribution of knowledge within universities and colleges that have implemented this curriculum. By allowing students to select courses from a variety of academic programs, open electives promote a multidisciplinary approach to education. Internships are considered essential components of the curriculum as they provide students with significant industry exposure. Problem statements derived from the industry ensure that the knowledge gained is applicable and practical.

Group projects are given significant importance in the curriculum, starting from the third semester. Acknowledging the criticality of collaborative abilities and peer learning within the VLSI sector, these initiatives strive to refine these fundamental aptitudes.

The creation of this curriculum was the result of a collaborative effort, with the guidance of eminent academics and professionals from around the world. The Curriculum Revision Committee, which was composed of esteemed professionals in the discipline, oversaw the curriculum's adherence to international and industry-required criteria. We would like to extend our sincere appreciation to the members of this committee for their indispensable contributions. We would like to extend our sincere appreciation to our Consultants and Industry Contributors for their invaluable real-world insights and perspectives. Their practical knowledge of the VLSI industry enhances the curriculum, serving as a link between academia and the constantly changing field.

It is our conviction that this curriculum will enable pupils to emerge as proficient VLSI professionals who are fully equipped to confront the obstacles of the field. We eagerly anticipate bearing witness to the triumphs that will inevitably ensue from the execution of this model curriculum.

Dr. Mamta Rani Agarwal

Advisor-I (AICTE)

# Curriculum Revision Committee

| S.No | Name | Designation | University / Workplace | Location | Profile Link |
|---|---|---|---|---|---|
| 1 | Alex James | Professor | Digital University | India | https://duk.ac.in/personnel/dr-a-p-james/ |
| 2 | Alon Ascoli | Faculty | Technische Universität Dresden | Dresden, Germany | https://ieeexplore.ieee.org/author/37270040800 |
| 3 | Garrett S. Rose | Professor | University of Tennessee | USA | http://web.eecs.utk.edu/~grose4/ |
| 4 | Bhasker Choubey | Professor | Siegen University | Germany | https://www.eti.uni-siegen.de/acis/departmentinfo/bhaskarchoubey/?lang=de |
| 5 | Hareesh Bhaskaran | Professor | Oxford University | United Kingdom | https://www.materials.ox.ac.uk/peoplepages/bhaskaran.html |
| 6 | Rajesh Zele | Professor | IIT Bombay | India | http://www.ee.iitb.ac.in/~zelerajesh/index.php |
| 7 | Ronald Tetzlaff | Professor | TU Dresden | Dresden, Germany | https://tu-dresden.de/tu-dresden/organisation/rektorat/co-technologietransfer-internationalisierung?set_language=en |
| 8 | Sreelal S | Scientist G | ISRO | India | https://ieeexplore.ieee.org/author/37088753219 |
| 9 | Sung Mo Kang | Professor | University of California, Santa Cruz | USA | https://en.wikipedia.org/wiki/Sung-Mo_Kang |
| 10 | Shahar Kvatinsky | Associate Professor | Israel Institute of Technology | Israel | https://kvatinsky.com/ |
| 11 | Vishal Saxena | Associate Professor | University of Delaware | United States | https://www.ece.udel.edu/people/faculty/vishal-saxena/ |

### Consultants and Industry Contributors

1. Apurva Varma, Arm
2. Sankalp Singh, Synopsys
3. Satya Gupta, VLSI society of India
4. Ashish Kumar, ST

# GENERAL COURSE STRUCTURE

## GENERAL COURSE STRUCTURE

### A. Definition of Credit:

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

### B. Range of Credits:

In the light of the fact that a typical Model Four-year Undergraduate degree program in Engineering has about 163 credits, the total number of credits proposed for the four- year B. Tech/B.E. in Electronics Engineering (VLSI Design and Technology) (Engineering & Technology) is kept as 164.

### C. Structure of UG Program in VLSI Design and Technology:

The structure of UG program in Electronics Engineering (VLSI Design and Technology) shall have essentially the following categories of courses with the breakup of credits as given:

| S.No | Category | Credit Breakup for VLSI Design & Tech |
|---|---|---|
| 1 | Humanities and Social Sciences including Management courses | 15 |
| 2 | Basic Science courses | 23 |
| 3 | Engineering Science courses including workshop, drawing, basics of electronics/electrical/mechanical/computer etc. | 17 |
| 4 | Common Basic Core | 21 |
| 5 | Professional core courses | 41 |
| 6 | Professional Elective courses relevant to chosen specialization/branch | 08 |
| 7 | Open subjects – Electives from other technical and /or emerging subjects | 08 |
| 8 | Project work, seminar and internship in industry or elsewhere | 29 |
| 9 | Mandatory Courses<br>[Environmental Sciences, Induction Program, Indian Constitution, Essence of Indian Knowledge Tradition] | (non-credit) |
| | **Total** | **164*** |

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

## D. Course code and definition:

| Course code | Definitions |
|---|---|
| L | Lecture |
| T | Tutorial |
| P | Practical |
| C | Credits |
| BSC | Basic Science Courses |
| ESC | Engineering Science Courses |
| HSMC | Humanities and Social Sciences including Management courses |
| PCC | Professional core courses |
| SCC | Subject Common Core |
| PEC | Professional Elective courses |
| OEC | Open Elective courses |
| LC | Laboratory course |
| MC | Mandatory courses |
| PRC | Project or Research |

**Pedagogical Approach for VLSI Design and Technology program**

VLSI is a discipline that is heavily influenced by practical applications and industrial demands. Hence, it is crucial for students to acquire experience and practical abilities in order to thrive in this domain. Internships or co-op programs provide students with an opportunity to get this experience.

The overall structure of the program is developed in the following manner:

**Core Courses** - these courses provide foundational knowledge and board knowledge required to carry out study in VLSI. These courses are arranged in several thematic areas, namely,

(1) **Focus area #1:** Semiconductor Devices and Fabrication,
(2) **Focus area #2:** Analog Mixed Signal and RF Circuits,
(3) **Focus area #3:** Digital Design and Systems,
(4) **Focus area #4:** Electronic Design Automation,
(5) **Focus area #5:** Display Technologies, and
**(6) Focus area #6:** Semiconductor Packaging.

**Program Electives** - this curricula mandate that these courses are offered by industry and developed from industry. The study materials for these courses are publicly made available for those universities or colleges where this curriculum is adopted.

**Open Electives** - these are those courses that students can take across various programs, and can be also those courses that are listed as program electives.

**Internships** - we expect every student in the program undergoes some form of internship, either in the final year or while taking up group projects. The problem statements are expected to be provided by the industry.

**Group Projects** - peer learning and teamwork are essential skills in VLSI. Hence, the program puts special emphasis on group projects starting from 3rd semester.

**Class Projects** - along with laboratories in most of the core courses, it's also expected that students perform small projects as part of the course activities. Practice led exploratory learning is encouraged.

Project-based learning is a highly successful approach for students to acquire expertise and practical skills in the field of VLSI. Through engagement in practical projects, students may effectively utilize their academic knowledge to address real-life challenges and cultivate a more profound comprehension of the field. Research and inquiry-based learning is a crucial approach for students to acquire expertise and hands-on abilities in the VLSI domain. The courses incorporate the following aspects:

**Active Learning and Hands-On Experience**

Implement a hands-on approach with laboratory exercises, projects, and assignments. Use software tools for simulation and layout design to allow students to apply theoretical knowledge in practical scenarios. One of the key reasons why a hands-on approach is important in learning VLSI is that it allows students to apply theoretical knowledge to real-world scenarios. By working on laboratory exercises, projects, and assignments, students can gain practical skills and develop a deeper understanding of the subject. Additionally, the use of software tools in VLSI learning enhances the overall learning experience by providing students with a platform to design, simulate, and analyze complex circuits. For example, in a VLSI course, students may be given a project to design and implement a digital circuit using software tools such as Cadence or Xilinx. This hands-on experience will require the students to apply their theoretical knowledge of logic gates, Boolean algebra, and circuit design principles to create a functional circuit. Through this project, students not only gain practical skills in designing circuits but also learn about the challenges and limitations faced in real-world VLSI design.

**Guest Lectures and Industry Connections**

Invite industry experts for guest lectures to expose students to real-world applications and trends in VLSI. Encourage internships and collaboration with local VLSI companies to gain practical experience. For example, students could apply their theoretical knowledge by designing a digital thermometer circuit using logic gates and Boolean algebra through internships. They would need to understand how to convert analog signals from a temperature sensor into digital information, and then use circuit design principles to create a functional thermometer circuit. This project would not only enhance their practical skills but also expose them to the challenges of designing accurate and reliable circuits for real-world applications. To further enrich their learning experience, inviting industry experts for guest lectures would provide students with insights into the

**Project-Based Learning**

Divide the course into smaller projects that build on each other. Start with simple designs and gradually move to more complex projects. This helps students apply concepts progressively. By dividing the course into smaller projects that build on each other, students are able to apply the concepts they have learned progressively and gain a deeper understanding of circuit design. Starting with simple designs allows them to grasp the basics and build a strong foundation, while gradually moving to more complex projects challenges them to think critically and problem-solve. This approach not only enhances their practical skills, but also prepares them for the challenges and limitations they may face in real-world VLSI design. For example, in a circuit design course, students may begin by learning about basic logic gates and how to combine them to create simple circuits like adders or multiplexers. They can then progress to more complex projects such as designing a microprocessor or a memory unit, where they have to consider factors like power consumption, timing constraints, and chip area. By gradually increasing the complexity of the projects, students gain hands-on experience in tackling real-world challenges and develop the critical thinking skills necessary for successful engineering careers. Additionally, these projects allow students to understand the importance of optimization and trade-offs in circuit design. They learn to balance performance requirements with the limitations of available resources, ultimately leading to more efficient and cost-effective designs. Furthermore, the experience gained from working on these projects can serve as a strong foundation for students pursuing advanced studies or careers in fields such as computer engineering or integrated circuit design. Overall, these hands-on projects not only foster technical skills but also instill a problem-solving mindset, preparing students for the challenges they may encounter in the engineering industry.

**Design Methodologies**

Teach popular design methodologies such as RTL design, synchronous design, and hierarchical design. Explain how these methodologies are applied in industry. By integrating software in laboratory exercises, projects, and assignments, educators can provide students with practical experience in applying popular design methodologies such as RTL design, synchronous design, and hierarchical design. This hands-on approach allows students to understand how these methodologies are actually used in industry, enhancing their understanding of the subject matter. Therefore, it is crucial for educators to implement these strategies in their teaching, as they provide numerous benefits such as improved problem-solving skills, better retention of knowledge, and preparation for real-world scenarios. For example, in a digital systems design course, students can be given a project where they are tasked with designing a simple processor. They would first start with RTL design, where they define the behavior of each individual component and how they interact with each other. Then, they would use synchronous design to ensure that all components operate on the same clock cycle, avoiding any timing issues. Finally, hierarchical design would be employed to break down the complex processor into smaller modules, making it easier to understand and debug.

**Cross-Disciplinary Learning**

Connect VLSI with other relevant fields like computer architecture, digital signal processing, and embedded systems. This helps students understand the broader context of VLSI. By integrating software in laboratory exercises, projects, and assignments, educators can provide students with a hands-on approach to learning VLSI. This approach allows students to not only gain theoretical knowledge but also apply it in practical settings. Furthermore, connecting VLSI with other relevant fields like computer architecture, digital signal processing, and embedded systems helps students understand the broader context of VLSI and its applications in various industries. Therefore, it is highly encouraged for educators to implement these strategies in their teaching to enhance the learning experience for students. For example, in a VLSI course, students may be given a project to design and implement a small-scale integrated circuit using CAD tools. This hands-on experience allows students to apply their theoretical knowledge of VLSI design principles and techniques in a real-world setting. Adding VLSI to computer architecture and other related fields can also help students understand how important VLSI is to the creation of modern computer systems like microprocessors and digital signal processors.

**Group Work**

Encourage collaborative learning by assigning group projects. VLSI design often involves teamwork, and this approach simulates real-world scenarios. Collaborative learning not only enhances students' technical skills but also improves their ability to work effectively in a team. Group projects allow students to share their knowledge and experiences, fostering a deeper understanding of the subject matter. By implementing this strategy, educators can prepare students for the collaborative nature of the industry and equip them with valuable teamwork skills.

The benefits of collaborative learning in VLSI design: Expanding on how teamwork can enhance students' technical skills and their ability to work effectively as part of a team. Collaborative learning in VLSI design can enhance students' technical skills by providing them with the opportunity to learn from their peers. Through group projects, students can share their technical expertise, brainstorm solutions, and tackle complex problems together. This not only deepens their understanding of VLSI design principles but also strengthens their ability to work effectively as part of a team, a skill that is highly valued in the industry. For example, in a collaborative VLSI design project, students can divide the workload based on their individual strengths and interests. One student may excel at circuit design while another may have expertise in layout and fabrication. By leveraging their skills in a team setting, they can collectively design and implement a more efficient and optimized VLSI chip. Additionally, through discussions and debates within the team, students can gain exposure to different perspectives and approaches, leading to innovative solutions that they may not have discovered on their own. Furthermore, collaborating in a team setting fosters a sense of camaraderie and encourages the sharing of knowledge and ideas. Students can learn from one another's experiences and build upon each other's strengths, ultimately pushing the boundaries of what they can achieve. This collaborative approach also prepares students for real-world situations where interdisciplinary teamwork is essential for success. Overall, working in a team allows for the creation of a well-rounded and innovative VLSI chip that combines the best of each team member's expertise.

Exploring the real-world simulations in VLSI design: Discussing how this approach mirrors the collaborative nature of the industry, providing students with practical experience. Through exploring real-world simulations in VLSI design, students are able to gain a deeper understanding of the collaborative nature of the industry. This practical experience prepares them to effectively work in interdisciplinary teams, just like they would in the professional world. By delving into these simulations, students can develop innovative solutions and enhance their problem-solving skills, positioning them for success in the field of VLSI chip design. For example, during a VLSI design project, students may be tasked with designing a high-performance microprocessor chip. Through the simulation process, they would need to collaborate with electrical engineers to optimize the chip's power consumption, mechanical engineers to ensure proper heat dissipation, and software engineers to develop efficient algorithms. This interdisciplinary teamwork not only helps students gain practical knowledge but also exposes them to different perspectives and fosters creativity in finding innovative solutions.

The impact of group projects on knowledge sharing: Detailing how group projects enable students to exchange their knowledge and experiences, leading to a deeper understanding of the subject matter. By working collaboratively, students are able to learn from each other's strengths and weaknesses, expanding their own knowledge base in the process. Group projects also create opportunities for students to engage in discussions and debates, challenging and refining their ideas. Through this knowledge sharing, students develop critical thinking skills and a more comprehensive understanding of the topic at hand. For example, in a group project focused on environmental sustainability, students with backgrounds in science may contribute their knowledge of renewable energy sources and the impact of pollution on ecosystems. Meanwhile, students with backgrounds in social sciences may provide insights into the economic and social implications of sustainable practices. By working together, these students can gain a holistic understanding of the topic and develop innovative solutions that consider multiple perspectives.

**Assessment and Feedback**

Implement continuous assessment through quizzes, exams, and regular feedback. This helps students track their progress and areas that need improvement. Continuous assessment through quizzes, exams, and regular feedback is crucial in ensuring that students stay engaged and motivated in their learning. It allows them to track their progress and identify areas where they need improvement, enabling them to take necessary steps to enhance their understanding. Moreover, continuous assessment also provides teachers with valuable insights into the effectiveness of their teaching methods and allows for timely interventions to better support student learning. Overall, implementing continuous assessment practices fosters a supportive and collaborative learning environment that promotes student success. In addition, continuous assessment encourages students to take ownership of their learning by actively engaging in the evaluation process. This helps them develop important skills such as self-reflection and goal setting, which are essential for lifelong learning. Furthermore, the regular feedback provided through continuous assessment allows students to make adjustments and improvements in real-time, leading to more meaningful and effective learning experiences.

**Use of Open Educational Resources (OER)**

Leverage open-source resources and materials for VLSI, as this can provide students with additional learning materials and give wider options for learning. Furthermore, utilizing open-source resources and materials for Very Large Scale Integration (VLSI) can also foster collaboration among students. By sharing knowledge and ideas through these platforms, students can access a vast array of resources, enhancing their understanding and expanding their options for learning. This approach encourages creativity and innovation, as students can explore different methodologies and techniques, ultimately leading to the development of cutting-edge solutions in the field of VLSI. For example, a group of students working on a VLSI project can collaborate online using open-source resources to access design templates, reference materials, and simulation tools. They can exchange ideas and troubleshoot problems together, accelerating their learning process and enabling them to tackle complex design challenges more effectively.

### Case Studies and Industry Trends

Present case studies of successful VLSI projects and discuss current industry trends. This keeps the course relevant and demonstrates the real-world impact of VLSI. Additionally, by examining successful VLSI projects, students can gain practical insights and learn from real-world experiences. They can also analyze current industry trends to stay updated with the latest developments and opportunities in the field. This not only enhances their knowledge but also prepares them for future careers in VLSI design and engineering. Ultimately, incorporating case studies and industry discussions into the curriculum helps students see the tangible results and potential impact of their work in the VLSI industry. For example, in a VLSI design course, students may be assigned a case study where they have to design and optimize a microprocessor for a specific application. Through this project, they will gain hands-on experience in designing complex circuits and understanding the trade-offs involved in terms of power consumption and performance. Additionally, by discussing current industry trends and challenges with professionals in the field, students can learn about emerging technologies like artificial intelligence and internet of things that are shaping the future of VLSI engineering.

### Ethics and Social Responsibility

Include discussions on the ethical considerations in VLSI, such as intellectual property, environmental impact, and societal responsibilities. By considering ethical considerations in VLSI, students can ensure that their innovations do not infringe upon intellectual property rights of others and uphold the principles of fair competition. Moreover, they can develop environmentally conscious solutions that minimize the negative environmental impact of VLSI technology, such as reducing energy consumption and waste generation. Additionally, students can explore how VLSI technology can be used responsibly to address societal challenges, such as improving healthcare, enhancing communication systems, and promoting inclusivity. By addressing these ethical considerations, students can contribute to a more sustainable and socially responsible VLSI industry.

### Mentorship and Office Hours

Offer regular mentorship and office hours to provide students with individualized support and guidance. This personalized attention ensures that students can address any challenges or questions they may have and receive the necessary guidance to excel in their studies. Additionally, mentorship and office hours can also foster a sense of community and camaraderie among students, as they have the opportunity to connect with their peers and mentors on a more personal level. Ultimately, this support system plays a crucial role in helping students navigate their academic journey and achieve their full potential.

**Capstone or Final Year Project**

Conclude the program with a capstone project that allows students to showcase their VLSI design skills. This project should be challenging and demonstrate a comprehensive understanding of VLSI concepts. It should also give students the opportunity to apply their knowledge and creativity to solve a real-world problem. Additionally, the capstone project can serve as a valuable addition to students' portfolios, showcasing their abilities to potential employers or graduate schools. Overall, by engaging in collaborative learning and completing a challenging capstone project, students in this program will be well-prepared to make meaningful contributions to the field of VLSI design. For example, a group of students in a VLSI program may choose to design and implement a high-performance processor for mobile devices. They can apply their knowledge of VLSI concepts such as circuit design, power optimization, and layout techniques to create a processor that meets the strict power and performance requirements of mobile devices. This project would not only demonstrate their technical skills but also showcase their ability to solve a real-world problem by designing an efficient and compact processor for mobile devices. Such an accomplishment would greatly benefit the mobile industry, as it would allow for faster and more efficient processing in smartphones and tablets. Additionally, it would enhance the user experience by enabling smoother multitasking, faster app response times, and improved battery life. This high-performance processor could potentially revolutionize the mobile market and set new standards for mobile device performance, making it a highly sought-after product by manufacturers and consumers alike.

**Continuous Improvement**

Gather feedback from students and adapt your teaching approach to improve the course continually. This feedback loop ensures that the course remains relevant and engaging for students, allowing them to better understand and apply the concepts they have learned. Additionally, by adapting the teaching approach, instructors can cater to the diverse learning styles and needs of the students, fostering a more inclusive and effective learning environment. This continuous improvement process benefits both the students and the instructors, enhancing the overall educational experience. For example, in a computer programming course, the instructor may gather feedback from students through surveys or discussions to identify areas where the material may need clarification or additional examples. Based on this feedback, the instructor can modify their teaching approach by providing more hands-on coding exercises or incorporating real-world case studies to help students better grasp the concepts. This iterative process of gathering feedback and adapting the teaching approach ensures that the course content remains relevant and engaging for students, ultimately improving their understanding and application of programming concepts. This iterative process also allows the instructor to identify any gaps in students' understanding and address them promptly. Additionally, incorporating real-world case studies helps students see how programming concepts are applied in practical scenarios, making the learning experience more meaningful. By continuously seeking feedback and making adjustments, the instructor can create a dynamic and effective learning environment that fosters growth and mastery of programming skills.

# Overall Structure

The overall structure of the program is listed below:

<table>
<tr><td>Common Core<br>21 credits</td><td colspan="6">Control Systems, Analog and Digital Signal Processing and Communication, Hardware Systems Engineering, Computer and Processor Architecture, Operating Systems, Circuit and Network Theory, Digital Electronics, Data Structures, Linux and Scripting</td></tr>
<tr><td>Program Core<br>41 credits</td><td colspan="6">Electronic Devices 1, Electronic Devices 2, Microfabrication and Semiconductor materials, Analog Circuits, Linear Integrated Circuits, RF and HF Circuits, CMOS Integrated Circuits, Electronic System Design, Embedded Systems, CAD for VLSI, SOC Design 1: Design & Verification, SOC Design 2: Chip Implementation with Physical Design leading to Tape-Out, Optoelectronics, IC Packaging</td></tr>
<tr><td rowspan="3">Program Electives'<br>8 credits<br><br>Open Electives'<br>8 credits</td><td>Specialization #1a/1b</td><td>Specialization #2</td><td>Specialization #3</td><td>Specialization #4</td><td>Specialization #5</td><td>Specialization #6</td></tr>
<tr><td>Semiconductor Devices /Manufacturing</td><td>Analog Mixed Signal and RF Circuits</td><td>Digital Design and Systems</td><td>Electronic Design Automation</td><td>Display Technologies</td><td>Semiconductor Packaging</td></tr>
<tr><td>Advanced Semiconductor Manufacturing<br>Compound Semiconductors<br>Semiconductor Instruments<br>Emerging Memory Devices</td><td>Mixed Signal Circuits<br>Low Power Circuit Designs<br>MEMS<br>High Power Circuit Designs<br>AI circuits</td><td>Design for Testability<br>FPGA Programing<br>Verification Tools and Techniques<br>On-Chip Interfaces<br>Memory Design</td><td>Logic Synthesis<br>Device Modelling<br>AI and ML for VLSI<br>CAD<br>Formal Methods</td><td>Thin Film Transistors<br>OLEDs and LCDs<br>Principles of Nanomaterials and Quantum Dots<br>Display Systems Design<br>Light Management Films<br>Color Science<br>Touch Panel Technology<br>Display Testing & Characterization</td><td>Materials for Semiconductor Packaging<br>Advanced Packaging Technologies<br>Package Design and Simulation Tools<br>EMC and Signal Integrity</td></tr>
<tr><td>Group Projects<br>8 credits</td><td colspan="6">Group Project 1/ Research Project 1; Group Project 2 / Research Project 2; Group Project 3/ Research Project 3; Group Project 4 / Research Project 4</td></tr>
<tr><td>Internship/Final year<br>21 credits</td><td colspan="6">Foundry or Semiconductor Cleanroom Visit/Internship/Final year project</td></tr>
</table>

## Specialization options:

**General specialization** - Students can select any elective across any specialization. In such cases no major or minor specialization will be listed.

**Minors** - Students complete at least 4 credits of courses within a specialization elective. Multiple minors possible.

**Major** - Students complete at least 8 credits of courses within a specialization elective

# INDUCTION PROGRAM

The Essence and Details of Induction program can also be understood from the 'Detailed Guide on Student Induction program', as available on AICTE Portal, (Link:https://www.aicteindia.org/sites/default/files/Detailed%20Guide%20on%20Student%20Induction%20program.pdf). For more, Refer **Appendix II.**

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

## A. Mandatory Visits/ Workshop/Expert Lectures:

- It is mandatory to arrange one industrial visit every semester for the students of each branch.
- It is mandatory to conduct a One-week workshop during the winter break after fifth semester on professional/ industry/ entrepreneurial orientation.
- It is mandatory to organize at least one expert lecture per semester for each branch by inviting resource persons from domain specific industry.

## B. Evaluation Scheme (Suggestive only):

a. **For Theory Courses:**

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

b. **For Practical Courses:**

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

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

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

## C. Mapping of Marks to Grades

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

| Range of Marks | Assigned Grade |
|---|---|
| 91-100 | AA/A+ |
| 81-90 | AB/A |
| 71-80 | BB/B+ |
| 61-70 | BC/B |
| 51-60 | CC/C+ |
| 46-50 | CD/C |
| 40-45 | DD/D |
| < 40 | FF/F (Fail due to less marks) |
| - | FR (Fail due to shortage of attendance and therefore, to repeat the course) |

*******

# SEMESTER WISE STRUCTURE

## SEMESTER 1

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| | 3 WEEKS COMPULSORY INDUCTION PROGRAM (UHV-I) | | | | | |
| 1 | BS-01 | Physics | 3 | 1 | 2 | 5 |
| 2 | BS-02 | Mathematics-I | 3 | 1 | 0 | 4 |
| 3 | ES-01 | Basic Electrical Engineering | 2 | 1 | 2 | 4 |
| 4 | ES-02 | Engineering Graphics & Design | 1 | 0 | 4 | 3 |
| 5 | HSM-01 | English for Technical Writing | 2 | 0 | 2 | 3 |
| 6 | ES-03 | Design Thinking | 0 | 0 | 2 | 1 |
| 7 | AU-01^ | IDEA Lab Workshop/ Maker Space 1 | 2 | 0 | 4 | 0 |
| **TOTAL** | | | **13** | **3** | **16** | **20** |

^ represent “Audit Course”, i.e. compulsory course but non- credit course

## SEMESTER 2

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | BS-03 | Chemistry | 3 | 0 | 2 | 4 |
| 2 | BS-04 | Mathematics-II | 3 | 1 | 0 | 4 |
| 3 | ES-04 | Programming for Problem Solving | 2 | 0 | 4 | 4 |
| 4 | SCC-10 | Linux and Scripting | 2 | 0 | 0 | 2 |
| 5 | BS-05 | Biology for Engineers | 3 | 0 | 0 | 3 |
| 6 | ES-05 | Digital Fabrication / Workshop/Manufacturing Practices /Maker Space 2 | 0 | 0 | 4 | 2 |
| 7 | HSM-02 | Universal Human Values | 2 | 1 | 0 | 3 |
| 8 | AU-02^ | Sports and Yoga or NSS/NCC | 2 | 0 | 0 | 0 |
| **TOTAL** | | | **15** | **2** | **10** | **22** |

^ represent “Audit Course”.

## SEMESTER 3

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | SCC-01 | Control Systems | 2 | 0 | 0 | 2 |
| 2 | SCC-02 | Analog and Digital Signal Processing and Communications | 2 | 0 | 2 | 3 |
| 4 | SCC-09 | Data Structures | 2 | 0 | 0 | 2 |
| 5 | PCC-01 | Electronic Devices 1 | 2 | 0 | 2 | 3 |
| 6 | SCC-06 | Circuit and Network Theory | 3 | 0 | 0 | 3 |
| 7 | SCC-07 | Digital Electronics | 2 | 0 | 0 | 2 |
| 8 | PRC-01 | Group Project 1/ Research Project 1 | 0 | 0 | 4 | 2 |
| 9 | BS-06 | Slot for BS Course | | | | 3 |
| 10 | ML-01 | Slot for Mandatory Learning Course (Audit Course) | | | | 0 |
| **TOTAL** | | | | | | **20** |

## SEMESTER 4

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | SCC-04 | Computer and Processor Architecture | 2 | 0 | 2 | 3 |
| 2 | SCC-05 | Operating Systems | 2 | 0 | 0 | 2 |
| 3 | SCC-03 | Hardware Systems Engineering | 2 | 0 | 0 | 2 |
| 4 | PCC-02 | Electronic Devices 2 | 2 | 0 | 2 | 3 |
| 5 | PCC-03 | Microfabrication and Semiconductor materials | 2 | 0 | 0 | 2 |
| 6 | PCC-04 | Analog Circuits | 2 | 0 | 2 | 3 |
| 7 | PRC-02 | Group Project 2/ Research Project 2 | 0 | 0 | 4 | 2 |
| 8 | ES-06 | Numerical Techniques | 2 | 0 | 2 | 3 |
| 9 | HSM-03 | Slot for HM Course | | | | 3 |
| 10 | ML-02 | Slot for Mandatory Learning Course (Audit Course) | | | | 0 |
| **TOTAL** | | | | | | **23** |

# SEMESTER 5

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | PCC-05 | Linear Integrated Circuits | 2 | 0 | 2 | 3 |
| 2 | PCC-06 | RF and HF Circuits | 2 | 0 | 2 | 3 |
| 3 | PCC-07 | CMOS Integrated Circuits | 2 | 0 | 2 | 3 |
| 4 | PCC-08 | Electronic System Design | 1 | 0 | 4 | 3 |
| 5 | PCC-09 | Embedded Systems | 2 | 0 | 2 | 3 |
| 6 | PCC-11 | SOC Design 1: Design & Verification | 2 | 0 | 2 | 3 |
| 7 | PRC-03 | Group Project 3/ Research Project 3 | 0 | 0 | 4 | 2 |
| 8 | HSM-04 | Slot for HM Course | | | | 3 |
| 9 | ML-03 | Slot for Mandatory Learning Course (Audit Course) | | | | 0 |
| **TOTAL** | | | | | | **23** |

# SEMESTER 6

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | PCC-10 | CAD for VLSI | 3 | 0 | 0 | 3 |
| 2 | PCC-12 | SOC Design 2: Chip Implementation with Physical Design leading to Tape-Out | 2 | 0 | 2 | 3 |
| 3 | PCC-13 | Optoelectronics | 3 | 0 | 0 | 3 |
| 4 | PCC-14 | IC Packaging | 3 | 0 | 0 | 3 |
| 5 | PRC-04 | Group Project 4/ Research Project 4 | 0 | 0 | 4 | 2 |
| 6 | OE-01 | Open Elective-01 | 2 | 0 | 0 | 2 |
| 7 | OE-02 | Open Elective-02 | 2 | 0 | 0 | 2 |
| 8 | OE-03 | Open Elective-03 | 2 | 0 | 0 | 2 |
| **TOTAL** | | | | | | **20** |

## SEMESTER 7

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | PE-01 | Program Elective-01 | 2 | 0 | 0 | 2 |
| 2 | PE-02 | Program Elective-02 | 2 | 0 | 0 | 2 |
| 3 | PE-03 | Program Elective-03 | 2 | 0 | 0 | 2 |
| 4 | PE-04 | Program Elective-04 | 2 | 0 | 0 | 2 |
| 5 | OE-04 | Open Elective-04 | 2 | 0 | 0 | 2 |
| 6 | HSM-5 | Slot for HSM Course | 3 | 0 | 0 | 3 |
| 7 | XC-28 | Internship/Foundry visits | 0 | 0 | 10 | 1 |
| 8 | XC-29 | Final Year Project Phase -1 | 0 | 0 | 4 | 2 |
| **TOTAL** | | | | | | **16** |

## SEMESTER 8

| S. No. | Course Code | Course Title | L | T | P | Credit |
|---|---|---|---|---|---|---|
| 1 | XC-P3 | Final Year Project Phase 2 | 0 | 0 | 40 | 20 |
| **TOTAL** | | | | | | **20** |

# CREDIT DISTRIBUTION

## Course List and Credit Distribution

| Course type | Course code | Course Name | Credit split (L-T-P) | Total credits |
|---|---|---|---|---|
| Humanities and Social Sc. | HSM-01 | English for Technical Writing | 2-0-2 | 3 |
| Humanities and Social Sc. | HSM-02 | Universal Human Values- II: Understanding Harmony And Ethical Human Conduct | 2-1-0 | 3 |
| Humanities and Social Sc. | HSM-03 | Management-I (Organizational Behaviour)/ Finance & Accounting | 3-0-0 | 3 |
| Humanities and Social Sc. | HSM-04 | Humanities – I | 3-0-0 | 3 |
| Humanities and Social Sc. | HSM-05 | Humanities – II | 3-0-0 | 3 |
| Basic Science | BS-01 | Physics-I | 3-1-2 | 5 |
| Basic Science | BS-02 | Mathematics-I (Calculus and Linear Algebra) | 1-0-4 | 3 |
| Basic Science | BS-03 | Chemistry-I | 0-0-2 | 1 |
| Basic Science | BS-04 | Mathematics-II (Probability and Statistics) | 2-0-4 | 4 |
| Basic Science | BS-05 | Biology for Engineers | 0-0-4 | 2 |
| Basic Science | BS-05 | Slot for BS | 2-0-2 | 3 |
| Engineering Science | ES-01 | Basic Electrical Engineering | 2-1-2 | 4 |
| Engineering Science | ES-02 | Engineering Graphics & Design | 1-0-4 | 3 |
| Engineering Science | ES-03 | Design Thinking | 0-0-2 | 1 |
| Engineering Science | ES-04 | Programming for Problem Solving | 2-0-4 | 4 |

| | | | | |
|---|---|---|---|---|
| Engineering Science | ES-05 | Digital Fabrication / Workshop/Manufacturing Practices | 0-0-4 | 2 |
| Engineering Science | ES-06 | Numerical Techniques | 2-0-2 | 3 |
| Common core | SCC-01 | Control Systems | 2-0-0 | 2 |
| Common core | SCC-02 | Analog and Digital Signal Processing and Communication | 2-0-2 | 3 |
| Common core | SCC-03 | Hardware Systems Engineering | 2-0-0 | 2 |
| Common core | SCC-04 | Computer and Processor Architecture | 2-0-2 | 3 |
| Common core | SCC-05 | Operating Systems | 2-0-0 | 2 |
| Common core | SCC-06 | Circuit and Network Theory | 3-0-0 | 3 |
| Common core | SCC-07 | Digital Electronics | 2-0-0 | 2 |
| Common core | SCC-09 | Data Structures | 2-0-0 | 2 |
| Common core | SCC-10 | Linux and Scripting | 2-0-0 | 2 |
| Program core | PCC-01 | Electronic Devices 1 | 2-0-2 | 3 |
| Program core | PCC-02 | Electronic Devices 2 | 2-0-2 | 3 |
| Program core | PCC-03 | Microfabrication and Semiconductor materials | 2-0-0 | 2 |
| Program core | PCC-04 | Analog Circuits | 2-0-2 | 3 |
| Program core | PCC-05 | Linear Integrated Circuits | 2-0-2 | 3 |
| Program core | PCC-06 | RF and HF Circuits | 2-0-2 | 3 |
| Program core | PCC-07 | CMOS Integrated Circuits | 2-0-2 | 3 |
| Program core | PCC-08 | Electronic System Design | 1-0-4 | 3 |
| Program core | PCC-09 | Embedded Systems | 2-0-2 | 3 |
| Program core | PCC-10 | CAD for VLSI | 3-0-0 | 3 |

| | | | | |
|---|---|---|---|---|
| Program core | PCC-11 | SOC Design 1: Design & Verification | 2-0-2 | 3 |
| Program core | PCC-12 | SOC Design 2: Chip Implementation with Physical Design leading to Tape-Out | 2-0-2 | 3 |
| Program core | PCC-13 | Optoelectronics | 3-0-0 | 3 |
| Program core | PCC-14 | IC Packaging | 3-0-0 | 3 |
| **Semiconductor Devices /Manufacturing** | | | | |
| Program Elective | PEC-01 | Advanced Semiconductor Manufacturing | 1-0-2 | 2 |
| Program Elective | PEC-02 | Compound Semiconductors | 2-0-0 | 2 |
| Program Elective | PEC-03 | Semiconductor Instruments | 2-0-0 | 2 |
| Program Elective | PEC-04 | Emerging Memory Devices | 2-0-0 | 2 |
| **Analog Mixed Signal and RF Circuits** | | | | |
| Program Elective | PEC-05 | Mixed Signal Circuits | 2-0-0 | 2 |
| Program Elective | PEC-07 | Low Power Circuit Designs | 2-0-0 | 2 |
| Program Elective | PEC-08 | MEMS | 2-0-0 | 2 |
| Program Elective | PEC-09 | High Power Circuit Designs | 2-0-0 | 2 |
| Program Elective | PEC-10 | AI circuits | 2-0-0 | 2 |
| **Digital Design and Systems** | | | | |
| Program Elective | PEC-11 | Design for Testability | 2-0-0 | 2 |
| Program Elective | PEC-12 | FPGA Programing | 1-0-2 | 2 |

| | | | | |
|---|---|---|---|---|
| Program Elective | PEC-13 | Verification Tools and Techniques | 1-0-2 | 2 |
| Program Elective | PEC-14 | On-Chip Interfaces | 2-0-0 | 2 |
| Program Elective | PEC-15 | Memory Design | 2-0-0 | 2 |
| **Electronic Design Automation** | | | | |
| Program Elective | PEC-16 | Logic Synthesis | 2-0-0 | 2 |
| Program Elective | PEC-17 | Device Modelling | 1-0-2 | 2 |
| Program Elective | PEC-18 | AI and ML for VLSI CAD | 2-0-0 | 2 |
| Program Elective | PEC-19 | Formal Methods | 2-0-0 | 2 |
| **Display Technologies** | | | | |
| Program Elective | PEC-20 | Thin Film Transistors | 2-0-0 | 2 |
| Program Elective | PEC-21 | OLEDs and LCDs | 2-0-0 | 2 |
| Program Elective | PEC-22 | Principles of Nanomaterials and Quantum Dots | 2-0-0 | 2 |
| Program Elective | PEC-23 | Display Systems Design | 2-0-0 | 2 |
| Program Elective | PEC-24 | Light Management Films | 2-0-0 | 2 |
| Program Elective | PEC-25 | Color Science | 2-0-0 | 2 |
| Program Elective | PEC-26 | Touch Panel Technology | 2-0-0 | 2 |

| | | | | |
|---|---|---|---|---|
| Program Elective | PEC-27 | Display Testing & Characterization | 2-0-0 | 2 |
| **Semiconductor Packaging** | | | | |
| Program Elective | PEC-28 | Materials for Semiconductor Packaging | 2-0-0 | 2 |
| Program Elective | PEC-29 | Advanced Packaging Technologies | 2-0-0 | 2 |
| Program Elective | PEC-30 | Package Design and Simulation Tools | 1-0-2 | 2 |
| Program Elective | PEC-31 | EMC and Signal Integrity | 2-0-0 | 2 |

# Industry Course Electives for Program and Open Electives

To provide students with rich industry experience, it is recommended to make use of the industry courses in online or offline mode. Below is a sample collection of industry supported courses that the students are encouraged to take, as part of Program/Open Elective or Core Courses in online or offline mode. Universities and colleges are encouraged to fill the gaps through extensively using NPTEL and other MOOC platforms in delivering the Program Elective or Course Elective Program Elective or Course Elective to enrich the students' learning experience.

## Courses supported by Arm

1. Computer Architecture
   https://www.arm.com/resources/education/education-kits/computer-architecture

2. System on Chip
   https://www.arm.com/resources/education/online-courses/introduction-to-soc

3. Advanced System on Chip
   https://www.arm.com/resources/education/online-courses/advanced-soc

4. Embedded Linux
   https://www.arm.com/resources/education/online-courses/embedded-linux

5. Digital Signal Processing
   https://www.arm.com/resources/education/online-courses/digital-signal-processing

6. IP access
   https://www.arm.com/resources/research/enablement/academic-access

7. **NPTEL-NIELIT**

| Arm-NPTEL-NIELIT Lab Workshops on VLSI & EMBEDDED Systems | | |
|---|---|---|
| **S.No** | **Name of Workshop** | **NIELIT Workshop Link** |
| 1. | Embedded C and Arm Cortex Microcontrollers | https://www.nielit.gov.in/calicut/content/lab-workshop-arm-cortex |
| 2. | VLSI Fundamentals | https://www.nielit.gov.in/calicut/content/lab-workshop-vlsi-fundamentals |
| 3. | FPGA Architecture and Programming using Verilog HDL | https://nielit.gov.in/calicut/content/fpga-architecture-and-programming-using-verilog-hdl |

| | | |
|---|---|---|
| 4. | Arm -based SoC Design | https://nielit.gov.in/calicut/content/arm-based-soc-design |
| 5. | Advanced Arm SoCs Design | https://www.nielit.gov.in/calicut/content/lab-workshop-advanced-arm |
| 6. | SoC Verification | https://www.nielit.gov.in/calicut/content/lab-workshop-soc-verification |
| 7. | Embedded RTOS | https://www.nielit.gov.in/calicut/content/lab-workshop-embedded-rtos |
| 8. | Scripting Tool and GUI Design for Industrial Application | https://www.nielit.gov.in/calicut/content/lab-workshop-scripting-tool-gui |
| 9. | Industrial Product Design-B1 | https://www.nielit.gov.in/calicut/content/lab-workshop-industrial-product-design |
| 10. | Embedded Linux | https://www.nielit.gov.in/calicut/content/lab-workshop-embedded-linux |
| 11. | Internet of Things | https://www.nielit.gov.in/calicut/content/lab-workshop-internet-things |

## Courses supported by Synopsys

1. **Advanced Methods in Logic Synthesis and Equivalence Checking - March 2020**
   The goal of the course is to study logic synthesis problem, logic optimization as well as advanced methods in synthesis. The course also focuses on logic design components and combinational and sequential equivalent checking.

2. **Algorithms and Structural Programming - December 2018**
   The goal of the course is to get introduced to the principles of building algorithms, estimation of their complexity, more applied basic algorithms as well as the principles of structural programming.
   > Syllabus
   > Lectures
   > Labs
   > Project
   > Homework & Exams

3. **Analog and Mixed-Signal IC Physical Design - December 2018**
   This course covers the basics of IC design, custom design flows. The course mainly focuses on data of analog and mixed-signal IC physical design.
   > Syllabus
   > Lectures
   > Labs
   > Homework & Exams

4. **Analog Integrated Circuits - October 2021**
   The goal of the course is to study principles of design, analysis and simulation of analog integrated circuits. The course also focuses on variants, parameter improvement methods, parameters analysis of different basic analog circuits: differential and operational amplifiers, switched capacitor circuits, oscillators, phase looked loops, data converters, secondary power sources, etc.
   > Syllabus
   > Lectures
   > Labs
   > Project
   > Homework & Exams

5. **Analog Modeling with Verilog-A - July 2020**
   The goal of the course is to teach to write behavioral models of analog circuits using correct Verilog-A language and syntax, edit and simulate a variety of analog models written in the Verilog-A language, verify the functionality and performance of Verilog-A models.
   > Syllabus
   > Lectures
   > Homework & Exams

6. **Applied Probability - May 2020**
   The main objective of the course is the study of applied probability theory.
   > Syllabus

> Lectures
> Homework & Exams

7. **Arm Processor-Based Embedded Programming - July 2020**
The goal of the course is to study the architecture of controllers, their memory mapping, general purpose registers, instruction sets and so on. The course also focuses on automation by using Arm microcontrollers with practical work. Students will learn how to solve automation problems, how to explore product datasheets, how to debug and program IC devices.

> Syllabus
> Lectures
> Homework & Exams

8. **Big Data - October 2021**
The goal of the course is to study Relational Databases, Big Data File Format, NoSQL Databases, Data Preparation. The course also focuses on Supervised Learning, Unsupervised Learning, Streaming Data, Hadoop, Resource Management in Big Data Processing Systems, MapReduce.

> Syllabus
> Lectures

9. **Compilers Design - July 2022 - Updated!**
The goal of the course is to study Finite State Machines together with their implementation. Pushdown automaton as well as context-free grammars are also introduced. The course also focuses on top-down methods of processing for attribute grammars as well as syntactically controlled processes of language processing.

> Syllabus
> Lectures
> Labs
> Homework & Exams

10. **Complex Functions - July 2022 - Updated!**
The goal of the course is to teach the characteristics of complex variable functions.

> Syllabus
> Lectures
> Homework & Exams

11. **Computational Geometry - February 2018**
The goal of the course is to get introduced to computational geometry, geometrical search and convex hull. The course also focuses on proximity problems and tasks of computational geometry in IC design.

> Syllabus (80 KB)
> Lectures (2 MB)
> Homework & Exams (329 KB)

12. **Computer Architecture and Engineering - July 2017**
The main objectives of the course are organization of modern computers; Virtual memory (paged and segmented) and multilevel cache memory organization; organization of instruction pipelining. The course also focuses on the study of methods input/output organization.

> Syllabus

> Lectures
> Labs
> Labs & Project
> Homework & Exams

**13. Computer Language Engineering - July 2018**

The goal of the course is to be able to build a compiler for a simplified programming language. Know how to use compiler construction tools, such as generators of scanners and parsers. Be familiar with assembly code and virtual machines, such as the JVM, and bytecode. Be able to define LL(1), LR(1), and LALR(1) grammars. Be familiar with compiler analysis and optimization techniques. Learn how to work on a larger software project.

> Syllabus
> Lectures
> Homework & Exams

**14. Contemporary Software Development Kits - October 2018**

The main objectives of the course are:the study of programming with Qt; the study of programming with Boost library; understanding of multithreading programming; understanding the sockets and inter-process communication.

> Syllabus
> Lectures
> Labs
> Project
> Homework & Exams

**15. Crosstalk and Noise - July 2022 - Updated!**

The goal of the course is to study the transmission line theory as well as crosstalk and noise basics.

> Syllabus
> Lectures
> Labs
> Homework & Exams

**16. Data Structures - August 2022 - Updated!**

The main objective of the course is to study elementary data structures (stacks, queues, trees, etc).

> Syllabus
> Lectures
> Labs
> Homework & Exams

**17. Database Management System - May 2018**

The main objective of the course is to study the relational models of data, theoretical languages of inquiries and SQL.

> Syllabus
> Lectures
> Homework & Exams

18. **Databases - February 2016**
The main objective of the course is to study the relational models of data, theoretical languages of inquiries and SQL.
> Syllabus
> Lectures
> Labs
> Homework & Exams

19. **Design for Test - August 2022 - Updated!**
The goal of the course is to study the theory of design for testability for integrated circuits and systems, basics of IC design with embedded test circuits. The course also focuses on the study of principles of design, analysis and simulation of self-testable digital ICs.

20. **Design of Embedded Systems - December 2021**
The goal of the course is to study the development of embedded systems, specifics of HW/SW co-design and co- verification, embedded cores, core reusability criteria, core generators, verification and integrations of reusable cores in embedded system, logic design of embedded cores.

21. **Design of Programming Languages - October 2018**
To teach the principles of object oriented design, object oriented design in C++, use of STL library. The course also focuses on the study of deep level of object oriented programming, detailed study of design patterns, cooperating with Standard Template Library and Boost Library.

22. **Digital ASIC Design (NCSU)**
This course focuses on how to design and synthesize a complex digital functional block. It discusses the issues involved in ASIC design and the ways to optimize the performance, area and power of a complex digital functional block. Some of the main topics covered in the class are: introduction to ASIC design, timing design, design of complex systems, design for test, low power design. Note: This course can be used with permission from the 3rd party owner.

23. **Digital Integrated Circuits - December 2021**
The goal of the course is to study the principles of design, analysis and simulation of digital integrated circuits. The course also focuses on the basics of design; analysis and Spice simulation of CMOS and bipolar combinational and sequential digital logic circuits, input/output circuits as well as semiconductor memories.

24. **Digital Signal Processing - June 2022 - Updated!**
The goal of the course is to study theoretical bases of digital signal processing, with the methods of description of discrete and digital signals and systems in the domain, z - and transform domain including discrete and fast Fourier transforms. The course also focuses on methods of design of digital filters.

25. **Digital VLSI Design (SFSU)**

The goal of the course is to teach students the analysis and design of Very Large Scale Integrated Circuits (VLSI). The skills learned in this course will prepare students to do real-world design tasks or do research in various areas of VLSI and circuit design. Synopsys tools are used to perform project. Some of the main topics covered in this class are: interconnects, combinational logic gates in CMOS, design of sequential logic circuits, arithmetic building blocks, memory design. Note: This course can be used with permission from the 3rd party owner.

26. **Discrete Mathematics and Probability - August 2022 - Updated!**

The main objective of the course is the study of set theory, Boolean functions, elements of mathematical logic as well as graph theory. The course also focuses on probability theory and mathematical statistics basics.

27. **EDA Introduction - March 2020**

The main objectives of the course are to get acquainted with levels of design process, phases and their capabilities. The course also focuses on IC design data formats and tools. In the process of laboratory works presentation of Synopsys design and verification platforms structure is implemented and practical skills of using basic tools are gained.

28. **EDA Mathematical Methods - July 2022 - Updated!**

The goal of this course is to study the basic mathematical methods and principles in EDA. The course also focuses on basic mathematical methods and principles in EDA; errors theory; correlation and regression; theory of design of experiments; theorem of pattern recognition; elements of fuzzy logic theory and computational graphics.

29. **EDA Tools - August 2022 - Updated!**

The goal of the course is to teach the fundamentals of EDA tools, their goals, algorithms, design flows, and data management. As examples of tools at different abstraction levels, the basic overview of Synopsys EDA tools is shown.

30. **Electrotechnical Bases of Electronic Circuits - December 2021**

The goal of the course is to study key concepts of atom physics, key concepts of electricity: charge, current, potential, voltage, power as well as basic electronic components: resistor, voltage and current sources, inductor, transistor, diode, FInFET transistor, etc. The course also focuses on the analysis of simplest resistive circuits, Kirchhoff's laws, methods for calculating electrical circuits, and different simplest circuits.

31. **Embedded Systems Design (CWRU)**

This course helps to understand methodologies for systematic design of embedded systems, Architecture Modeling, DSP systems, Hardware Software Codesign, RTOS and applications in compression and wireless mobile systems. Synopsys tools are used to perform project work. Some of the main topics covered in this class are: audio compression, software defined radio (SDR), image compression based on JPEG techniques, digital signal processors, and frequency multiplexing. Note: This course can be used with permission from the 3rd party owner.

32. **Fourier Transformations - September 2020**

The goal of the course is to teach the Fourier transform methods, its properties and algorithms. The course also focuses on the study of basics of Fourier transform methods.

33. **FPGA Prototyping - November 2021**

The goal of the course is to study the basic principles and methods of FPGA prototyping. The course also focuses on the study of principles of IC prototyping; hardware and software; design strategies and methods.

34. **Fundamentals of Telecommunications - December 2021**
The goal of the course is to study principles of signal transmission. The course also focuses on signal properties, coding and modulation, analysis of different components of communication systems, particularly transmitters, receivers. Basic introduction to modern high- speed IC communication systems and system level components like PLL, ESD protection circuits, IO devices.

35. **Fuzzy Logic - October 2018**
The goal of the course is to basics of fuzzy logic theory. The course also focuses on fuzzy numbers and operations, fuzzy logic calculus as well as linguistic fuzzy logic.

36. **Hardware Description Languages - November 2021**
The goal of the course is to study hardware description languages and describe their role in the electronic design automation environment. The course also focuses on System Verilog basics, SystemC basics, Verilog basics and VHDL basics.

> Syllabus
> Lectures
> Labs
> Homework & Exams

37. **High Speed SerDes Design - February 2022**
The course covers the necessity of High Speed SerDes, Serial Links, Channel, Transmitter. It also focuses on Clock Recovery, Receiver, Equalization with DSP, Microcontroller and FirmWare.

> Syllabus
> Lectures
> Labs

38. **I/O Design - August 2022 - Updated!**
The goal of the course is to study the principles of design, as well as analysis and simulation of I/Os. The course also focuses on the study of Spice simulation basics.

> Syllabus
> Lectures
> Labs
> Homework & Exams

39. **IC Design Algorithms - October 2021**
The goal of the course is to teach methods and algorithms of IC design automation. The course also focuses on the study of algorithms of high-level and logic synthesis, floorplanning, placement and partitioning, routing and layout compaction.

> Syllabus
> Lectures
> Homework & Exams

40. **IC Design Flow - June 2019**
The goal of the course is to get acquainted with the levels of design process, phases and their automation capabilities as well as study the IC design basics, levels, strategies, options, methods, styles, challenges, economics and trends.

> Syllabus

> Lectures
> Labs
> Homework & Exams
> Files

**41. IC Design for Thermal Issues - May 2018**

The goal of the course is to get introduced to thermal issues in ICs, design principles of electro-thermal models of devices, electro-thermal and simultaneous electro-thermal simulation methods, as well as methods of thermal design of ICs.

> Syllabus
> Lectures
> Labs
> Homework

**42. IC Design Introduction - December 2021**

The main objectives of the course are: to study the IC structure, components, types, fabrication process, packaging techniques, history of IC evolution; to study the basics of IC design, levels, strategies, options, methods, styles, challenges, and trends, custom and automated design flows, peculiarities of digital standard cell library and I/O cell design, specifications, design steps, deliverable files; to study Synopsys EDA tools used at various design steps.

> Syllabus
> Lectures
> Homework & Exams

**43. IC Physical Design - July 2022 - New!**

The course focuses on Physical design, Semiconductor Technology, Technology nodes differences, Physical Design side effects. It also describes Logic Library Physical Design, Analog and mixed signal physical design basics, Layout improvements.

> Lectures

**44. IC Physical Design Algorithms - August 2021**

The goal of the course is to study floorplanning and pin assignment, global and detailed routing, cell routing via minimization and clock and power routing algorithms.

> Syllabus
> Lectures
> Homework & Exams

**45. IC Reliability - May 2022**

The main objectives of the course are the study of main concepts of reliability. The course focuses on crosstalk, power integrity, aging, self-heating, radiation effects, ESD and latch up, process variability and metastability.

> Syllabus
> Lectures
> Labs

**46. IC Schematic Design Algorithms - August 2022 - Updated!**

The goal of the course is to teach high-level, logic-level and transistor-level design and simulation algorithms. At the practice classes practical skills of analysis and synthesis of algorithms of IC schematic design automation are gained.

> Syllabus

> Lectures

> Homework & Exams

**47. IC Synthesis and Optimization - September 2021**

The main objectives of the course are the study of logic synthesis, timing and area constraints, Design for Test as well as physical design data. The course also focuses on design planning, CTS, placement, routing, power optimization. Issues of OCV, physical verification and sign- off are also discussed.

> Syllabus

> Lectures

> Labs

> Homework & Exams

> Files

48. **IC Synthesis and Optimization with Fusion Compiler - May 2022 - Updated!** The main objective of the course is to study how to use Fusion Compiler to perform complete RTL-to-GDSII flow, which is the unification of traditional Logic Synthesis and Physical Synthesis functionality.

> Syllabus

> Lectures

> Labs

> Files

**49. IC Testing - December 2021**

The course goals are to study the basics of fault analysis and simulation, diagnostic test generation for combinational and sequential digital logic circuits, as well as for semiconductor memories. To study the principles of design, analysis and simulation of self-testable digital ICs.

> Syllabus

> Lectures

> Labs

> Homework & Exams

**50. IC Verification Algorithms - August 2022 - Updated!**

The goal of the course is to study methods and algorithms of IC design verification. The course also focuses on the study of pre-layout and post layout verification algorithms.

> Syllabus

> Lectures

> Homework & Exams

**51. Introduction to Algorithms - March 2018**

The goal of the course is to teach the basic algorithms and implementations of some algorithms.

> Syllabus

> Lectures

> Homework & Exams

52. **Introduction to Circuits - August 2022 - Updated!**
The main objectives of the course are: to revise the fundamentals of electrical engineering, study the principles of operations of microelectronic circuit elements (resistor, capacitor, inductor, diode, MOSFET, simple logic cells), their basic characteristics and simple cells, composed of them.

53. **Introduction to Digital and Analog Integrated Circuit Design - February 2022**
The main objectives of the course are to study the IC structure, components, types, fabrication process, packaging techniques, history of IC evolution; to study the basics of IC design, levels, strategies, options, methods, styles, challenges, and trends. Custom and automated design flows, peculiarities of digital standard cell library and I/O cell design. Specifications, design steps, deliverable files as well as to study Synopsys EDA tools used at various design steps.

54. **Introduction to Logic Design (Syracuse)**
This is a digital design course which will help students to understand the basic concepts of high level digital design using hardware description languages and Synopsys tools. Some of the topics include: number systems and codes, digital electronics, combination logic design principles and practices, introduction to sequential logic design, and high level digital design using design automation tools. Note: This course can be used with permission from the 3rd party owner. All rights reserved.

55. **Introduction to Semiconductor Devices - July 2022 - Updated!**
The goal of the course is to teach the principles of operation, design, and construction of contemporary semiconductor devices created on the basis of solid state physical effects as well as instrumental software. The course also focuses on the study of all types of semiconductor devices used in the VLSI, their structure, operation principles, characteristics and computer models.

56. **Introduction to VLSI Design (UT)**
This course covers all the aspects of design and synthesis of Very Large Scale Integrated (VLSI) chips using CMOS technology. Some of the main topics covered in this class are: switches, logic, interconnects, and circuit families. Note: This course can be used with permission from the 3rd party owner. All rights reserved.

57. **Linear Algebra - April 2018**
The main objectives of the course are: to develop methods of linear system solutions, make operations with matrices, reduce matrices to Jordan normal form and use special cases of this normal form for different kinds of linear transformations.

58. **Logic Design - August 2020**
The goal of the course is to teach the principles of design, analysis and simulation of digital circuits. Some of the main topics covered in this class are: Boolean functions, basic combinational circuits, finite states machines, synthesis of synchronous FSM, programmable logical integrated circuits (PLDs).

59. **Low Power Design - January 2019**
The goal of the course is toTo teach the principles of design, analysis, modeling and optimization of low power ICs. The course also focuses on the study of FinFET low power IC design, modeling and optimization basics.

60. **Low Power Design with SAED 14nm EDK - March 2020**
The goal of the course is to teach the principles of design, analysis, modeling and optimization of low power ICs. The course focuses on contemporary low power design techniques, their peculiarities,

requirements and application. Also, this course highlights the features of SAED 14nm Educational Design Kit (EDK) as a solution to low power design and other modern IC design challenges. The course includes a laboratory work covering application of low power design along with Synopsys EDA tools and Synopsys UPF solutions by the help of SAED 14nm EDK.

61. **Low Power Methodology Manual (SVTI)**
The goal of the course is to teach about various practical design methodologies for improving the power performance of SoC products. Some of the main topics covered in this class are: standard low power methods, multi-voltage design, designing power gating, physical libraries, IP design for low power. Note: This course can be used with permission from the 3rd party owner. All rights reserved.

62. **Memory Schematic Design Basics - April 2018**
The main objectives of the course are: to introduce students to the schematic design of memory circuits, sense amplifiers and peripheral circuits. Students should have thorough understanding of the ground up structure of memory circuits.

63. **Microprocessor Systems - July 2018**
The main objectives of the course are to study the introduction, microprocessor architecture, microcontroller architecture, microcontroller modules, serial interfaces, analog interfaces, organization communications, serviced microcontrollers systems.

64. **Mixed-Signal IC Design - August 2022 - Updated!**
The goal of the course is to study the characteristics, principles and methods of contemporary mixed-signal IC design and analysis. The course also focuses on the study of different types of mixed signal ICs and design procedures with methods applied in different design stages.

65. **Modeling and Optimization of IC Interconnects - November 2017**
The main objectives of the course are: to study IC interconnects design, modeling and optimization basics; to study the influence of interconnects parasitic parameters on the circuits performance.

66. **Nanoscale Circuits and Systems (SFSU)**
This course introduces advanced topics in nano-scale VLSI device and circuit design. High-performance and low-power design issues in modern and future nano-scale CMOS technologies are discussed in detail. Students will learn low power design approaches and techniques at different levels of abstraction. New design techniques will be introduced to deal with nano circuit designs under excessive leakage and process variations. Several non-classical CMOS devices for circuit design in such technologies will be explored. Note: This course can be used with permission from the 3rd party owner.

67. **Numerical and Logic Bases of Digital Circuits - February 2022**
The goal of the course is to study basics of Boolean algebra, logic cells, analysis of digital circuits. The course also focuses on synthesis of digital circuits, optimization of digital circuits as well as typical digital circuits and parameters of digital circuits.

68. **Numerical Methods - August 2022 - Updated!**
The goal of the course is to teach the methods of interpolation, approximation as well as for solving system of algebraic and differential equations. The course also focuses on the study of numerical methods basics.

69. **Object-Oriented Programming - August 2022 - Updated!**
The goal of the course is to teach the principles of object oriented programming, object oriented programming in C++, use of STL library. The main objectives of the course are: the study of basics of object oriented programming; detailed study of C++ as an object oriented language; study of Standard Template Library and Boost Library.

70. **Operating Systems and System Programming - February 2018**
The goal of the course is to study the basics of operating systems and system programming. The course also focuses on memory management, Simplified Instructional Computer (SIC), assemblers, loaders and linkers, macro processors, static and dynamic shared libraries.

71. **Operational Calculus - August 2022 - Updated!**
The goal of the course is to study of basic methods and principles of operational research, partial fraction expansion. The course also focuses on integration of systems of linear differential equations as well as solution of integral equations.

72. **Operational Research - August 2022 - Updated!**
The goal of the course is the study of classical optimization methods, linear programming, dynamic programming. The course also focuses on network models operational research as well as advanced methods of operational research.

73. **Probability Theory and Mathematical Statistics - July 2022 - Updated!**
The main objective of the course is the study of probability theory and mathematical statistics basics.

74. **Programming C++ - May 2017**
The goal of the course is to study the C++ programming language, use of STL library. The course also focuses on the creation of effective programs on C++, object-oriented programming in C++ and study of Standard Template Library.

75. **Programming Languages and Compilers - April 2017**
The goal of the course is to teach the future EDA tool developers the C++ programming language as well as use of STL library. The course also focuses on the detailed study of C++, creation of effective programs on C++, object-oriented programming in C++ and study of Standard Template Library. In the process of laboratory works programs in C++ are designed and implemented.

76. **Rad-hard IC Design - June 2017**
This course is aimed at studying different radiation effects on ICs, TID and SEE effects as well as basics of hardening methods. The course also focuses on the study of rad-hard layout, special circuits and systems architectures.

77. **RF IC Design - May 2022**
The goal of course is to teach RF IC design principles, noises and distortions; low-noise and resonant amplifiers; nonlinear circuits; schemes of RF modulators, demodulators and oscillators; phase-locked loops; multiple access techniques; transmitters and receivers.

78. **Scripting Languages for Beginners - July 2022 - Updated!**
The goal of the course is the study of scripting languages such as PERL, TCL/TK and BASH. The

main objectives of the course are: creation of programs in the Linux environment, the study of the principles of scripting languages and the study of usage of scripting languages in IC design flow. This course is anticipated for the beginners.

79. **Semiconductor Technology - August 2022 - Updated!**
The main objectives of the course are: to study all types of semiconductor devices used in the IC, their structures, operation principles, characteristics and computer models as well as acquaintance with the peculiarities of models introduction in EDA and application of semiconductor devices; to study the basics of semiconductor processing technology and process flows both for bipolar and MOS integrated circuits.

80. **Signal Processing and Systems Theory - March 2022 - New!**
The goal of the course is to make students familiar with the most important methods in signal processing, including: transform-domain processing, focus will be on Fourier Transform, Laplace Transform, Z Transform, and their properties; filter design, while focusing on design process and considerations; introduction to equalizers and their design methodologies.

81. **Soft IP Development - March 2022 - New!**
The goal of the course is to study the steps of Soft IP Development. The course also focuses on the separate steps of the Soft IP development processes: RTL design, verification, validation.

82. **Software Development Technology - June 2018**
The goal of the course is to study the development technology and project management, rational unified process as well as the agile development process.

83. **Static Timing Analysis - June 2017**
The goal of the course is to study STA concepts, Delay Modeling, Interconnect Parasitics and Delay Calculation. The course also focuses on configuring the STA Environment, Timing Checks and Crosstalk and Noise.

84. **Synopsys EDA Tool Flow for Back-End Digital IC Design-April 2020-Updated!**
The goal of the course is to cover back-end digital IC design flow and specifics. The course also covers Synopsys EDA tools for back-end digital IC design.

85. **Synopsys EDA Tool Flow for Front-End Digital IC Design - February 2018**
The goal of the course is to study details of Front-End EDA Tools for digital IC design. It covers steps from logic simulation to static timing analysis.

86. **System-on-Chip Architecture Design**
The goal of this course is to understand system architecture and design and outlines the steps to create a SoC. Issues from concept to mask layer implementations are highlighted. Some of the main topics covered in this class are: delay, delay estimation, pipe-lining, floating point arithmetic, buses and bridges.

87. **SystemVerilog - May 2020 - New!**
The goal of the course is to teach to write a behavioral description of digital circuits by using SystemVerilog language, understand the difference between synthesizable and non-synthesizable descriptions. Get acquainted with different components of the testbench, create a reusable test environment by using the OOP features of SystemVerilog language. >Lectures (2.37 MB)

88. **Technical Writing - April 2018**
The goal of the course is to teach technical and business writing, including skills for IC design documentation creation.

89. **Theory of Algorithms - June 2020 - Updated!**
The main objectives of the course are: the study of various formal definitions, concepts of algorithms, interrelation among themselves and with modern theories of formal languages and programming; learn a variety of important algorithms; understand various ways to analyze the complexity of algorithms; become acquainted with the issues related to NP-completeness.

90. **Thermal and Electro-Thermal Simulation: Achievements and Trends - July 2017**
The goal of the course is to get introduced to thermal issues in ICs, design principles of electro-thermal models of devices, electro-thermal and simultaneous electro-thermal simulation methods, as well as design techniques of electro-thermal simulation tools.

91. **Unix System Administration - April 2017**
The goal of the course is to get introduced to peculiarities and capabilities of Unix system administration.

92. **VLSI Design Verification & Testing**
The course goal is to study the introduction to the concepts and techniques of VLSI (Very Large Scale Integration) design verification and testing, details of test economy, fault modeling and simulation, defects, Automatic Test Pattern Generation (ATPG), design for testability, Scan and Boundary scan architectures, built-in self-test (BIST) and current-based testing.

# Short Lectures/Labs:

93. **Basic Perl Programming**
This lecture highlights the core basics of the Perl language with a focus on how it is used by chip designers. It helps people just starting out in EDA to learn what Perl is and how it can help them. It will also give an overview about what Perl is and what areas to focus to get the most out of Perl as a scripting tool.

94. **Characterization with SiliconSmart - July 2018**
The goal of the laboratory course is to learn standard cell characterization with SiliconSmart.

95. **Circuit Simulation: Transient Analysis (IITB)**
This lecture highlights the general problem of numerical solution of ordinary differential equations and shows the stability of numerical methods. It also covers the adaptive step size and a few miscellaneous topics relevant to transient analysis in the context of circuit simulation. Note: This course can be used with permission from the 3rd party owner.

96. **Compiler Optimization and Code Generation - October 2018**
The main objective of the course is to study compiler optimization and code generation basics, get deep knowledge about main phases of intermediate and machine level code generation as well as study main principles of both machine independent and machine dependent code optimizations.

97. **Computer Networks - October 2018**
The goal of the course is to study how to design computer networks which includes important topics as communication media, network programming, scale, network topology, views of networks, etc.

98. **Digital Design with Verilog**
This course teaches the Verilog language from a design prospective.
Several examples are analyzed during the course to show the best way to translate a design into Verilog, so synthesis tools such as design Compiler, can generate a good netlist.

> Lectures

99. **Digital System Design and Simulation with VHDL (SU)**
Basic digital logic circuit design and implementation. Structural and RTL description of digital system using VHDL. Simulation and verification of combinational and sequential logic. Note: This course can be used with permission from the 3rd party owner. 

100. **Embedded Systems Design (CWRU)**
This lecture serves to introduce and expose the student to methodologies for systematic design of embedded systems. The topics include, but are not limited to, system specification, architecture modeling, DSP systems, hardware software codesign, RTOS, and applications in compression and wireless mobile systems. Note: This course can be used with permission from the 3rd party owner. 
> Lectures

101. **How to Create an Interoperable PDK - November 2018**
This presentation highlights PDK requirements for custom analog design flow and walks through the steps of creation of an interoperable PDK library and all the relevant models and technology files.
> Lectures

102. **IC Fabrication - August 2022 - Updated!**
To study the basics of IC fabrication technology and to study the interface between designer and process engineer.

103. **IC Simulation Theory - July 2020**
The main objectives of the course are: to familiarize the future designers of microelectronic circuits and systems with IC simulation tool design principles, models, simulation methods, peculiarities of model and method program realization; to help use simulators more effectively by providing in-depth look at concepts and principles, practical implementation issues, constructing a better simulator.

104. **Introduction to RF Communication - August 2022 - Updated!**
The goal of course is to teach the necessary knowledge of RF communication, principles of RF circuits analysis and design. The course also focuses on RF signals and noises, principles of operation, functional and electrical circuits of RF systems and their basic parameters.

> Syllabus

> Lectures

> Homework & Exams

105. **Introduction to Verilog HDL**
This course provides an introduction to Verilog HDL, describing the synthesizable subset, and some

basic simulation constructs to easily simulate and verify the functionality of a small design. It also shows some general and FSM coding guidelines.

> Lectures

**106. LINUX System and Network Administration - April 2022**

This course is aimed at engineers with no background or novice level knowledge of Linux. After completion of the course the engineer will be able to perform basic operations in Linux and cover every day needs during the working process, including: History of UNIX, Linux file system, access file or directory permissions Basic shell functions, command structure, basic commands, file management and viewing, control operators Use CUT command, use all options of CUT command Use grep command, majority of widely used options.

> Syllabus

> Lectures

> Exams

**107. Low Power Methodology Manual for 14nm - March 2020**

The aim of these laboratory works is to accompany Low Power Methodology Manual with hands-on examples based on Synopsys 14nm library and UPF. It includes all necessary input data for practical implementation of all main low power design techniques: clock gating, multi voltage, power gating and multi voltage with power gating. This tutorial is intended for anyone interested in or responsible for low power implementation.

> Labs

> Labs & Homework

**108. Optimization Methods - August 2022 - Updated!**

The main objective of the course is to study mathematical aspects and algorithms of optimization: mathematical programming, calculus of variations, minimization technique of functions. The course also focuses on classical, 1D, mathematical pogramming, simulated and applied optimization methods.

> Syllabus

> Homework & Exams

**109. Physical Verification Runset Development - May 2018**

The goal of the course is to teach basic understanding and concepts of physical verification using Synopsys' IC Validator tool.

> Lectures

**110. Power-Performance Optimization of Digital Circuits and Systems (UCLA)**

This lecture addresses the sensitivity-based methodology for power performance optimization of digital circuits and systems. The application of the methodology to complex designs puts new requirements on digital standard-cell libraries which include special cells. This consists of characterization of custom macros, ability to include third-party macros/IP, usage of a SRAM generator and creation of an I/O library customized for low power. A 90nm generic library from Synopsys which meets the mentioned requirements and is compatible with Universal Power Format (UPF) is also presented in the tutorial. The use of the library will be exemplified on different circuit designs. Note: This course can be used with permission from the 3rd party owner. All rights reserved.

> Lectures

> Lecture & Material

**111. Process Variation Aware Design**

This lecture highlights the different sources of variations and their impact on circuit performance. It also covers few of the existing design methodologies and solutions for addressing pernicious sources of variability. Due to the significant impact of variations on memories, a detailed analysis on the SRAM bit cells is provided. Note: This course can be used with permission from the 3rd party owner. 

> Lectures

**112. RF Circuits - May 2022**

The goal of course is to teach RF circuits principles analysis and design. The course also focuses on RF signals, RF circuits structure, principles of operation, functional and electrical circuits of RF systems and their basic parameters as well as the study of RF circuits.

> Syllabus

> Lectures

> Homework & Exams

**113. Scripting Languages - April 2017**

The goal of the course is the study of scripting languages such as PERL, TCL/TK and BASH. The main objectives of the course are: creating programs in the Linux environment; studying the principles of scripting languages; studying the usage of scripting languages in IC design flow.

> Syllabus

> Homework & Exams

**114. Sequential Elements**

Provides a description how sequential elements works and their timing parameters, also include timing analysis for sequential designs.

> Lectures

115. **Signal and Power Integrity: Current State and New Approaches - June 2017**

The goal of this lecture is to cover signal and power integrity issues including crosstalk, IR drop and electro migration, and the definitions and challenges in 90nm and below technologies. Traditional SI and PI fixing methods together with new methods are also presented.

> Lectures

**116. Statistical Techniques for Timing Analysis: Current State and Trends-July 2018**

This lecture covers static timing analysis (STA) basics, on- chip variation issues and the necessity for usage of variation-aware analysis instead of traditional corner-based analysis. Principles and techniques of statistical static timing analysis (SSTA) are covered and compared with STA and Monte-Carlo methods.

> Lectures

**117. Subthreshold Design and Implementation (RIT)**

Subthreshold circuit design offers an ultra-low power alternative to standard superthreshold digital CMOS circuits. In this short lecture, the performance specifications of a subthreshold standard cell library for commercial 65nm models are presented. Multiple performance enhancements to the

standard cell library are also analyzed, along with a cell placement optimization algorithm. The lecture concludes with sample applications of subthreshold circuits. Note: This course can be used with permission from the 3rd party owner. 
> Lectures

**118. Techniques for Circuit Simulation**

This lecture is an overview of the need for circuit simulation with the help of examples and the Newton-Raphson method for solving non-linear problems.
It also covers transient simulations and the steady state waveform. Note: This course can be used with permission from the 3rd party owner. 

> Lectures

**119. Tool Command Language (TCL) - May 2021 - New!**

This course focuses on TCL language. TCL basics are studied.

> Syllabus

**120. User Interface Design - December 2018**

To study how to design good user interfaces which include design principles, prototyping techniques, evaluation techniques, and implementation of graphical user.

> Syllabus

> Lectures

> Labs

> Project

> Homework & Exams

**121. Verification Methodologies for Low Power - April 2018**

The main objectives of the course are: to teach the introduction to system level design, verification with System Verilog and low power verification with system Verilog.

> Syllabus

> Lectures

> Labs

**122. Verification Methodology Manual for Low Power**

This lecture covers all aspects of a successful low power verification methodology. It elaborates on the causes of low power bugs, how to detect and avoid them, enumerate the dos and don'ts of low power verification and give advice on creating the right verification plan. The lecture concludes with an introduction to the newly developed base classes that make the methodology reusable and scalable. This tutorial is intended for anyone interested in or responsible for low power implementation and verification.
> Lectures

**123. Verilog - June 2022 - New!**

The goal of the course is to study Verilog basics, simulation using EDA tools. > >Lectures

# SEMESTER – I

# SEMESTER I

| | | |
|---|---|---|
| Course Code | : | MT-101 |
| Course Title | : | Physics- I |
| Number of Credits | : | 5 (L: 3, T: 1, P: 2) |
| Course Category | : | MT |
| Course Contents in Physics **(Any One)** | : | **Anyone from the below options**<br>i. Introduction to Electromagnetic Theory<br>ii. Introduction to Mechanics<br>iii. Quantum Mechanics for Engineers<br>iv. Oscillation, Waves and Optics |

**Course Objectives:** To enhance the fundamental knowledge in Physics and its applications relevant to various streams of Engineering and Technology.

| **Introduction to Electromagnetic Theory** |
|---|
| Pre-requisites (if any): Mathematics course with vector calculus |

**Module I: Electrostatics in vacuum**
Calculation of electric field and electrostatic potential for a charge distribution; Divergence and curl of electrostatic field; Laplace's and Poisson's equations for electrostatic potential and uniqueness of their solution and connection with steady state diffusion and thermal conduction; Practical examples like Faraday's cage and coffee-ring effect; Boundary conditions of electric field and electrostatic potential; method of images; energy of a charge distribution and its expression in terms of electric field.

**Module II: Electrostatics in a linear dielectric medium**
Electrostatic field and potential of a dipole. Bound charges due to electric polarization; Electric displacement; boundary conditions on displacement; Solving simple electrostatics problems in presence of dielectrics – Point charge at the centre of a dielectric sphere, charge in front of a dielectric slab, dielectric slab and dielectric sphere in uniform electric field.

**Module III: Magnetostatics**
Bio-Savart law, Divergence and curl of static magnetic field; vector potential and calculating it for a given magnetic field using Stokes' theorem; the equation for the vector potential and its solution for given current densities.

**Module IV: Magnetostatics in a linear magnetic medium**
Magnetization and associated bound currents; auxiliary magnetic field H; Boundary conditions on B and H. Solving for magnetic field due to simple magnets like a bar magnet; magnetic susceptibility and ferromagnetic, paramagnetic and diamagnetic materials; Qualitative discussion of magnetic field in presence of magnetic materials.

**Module V: Faraday's law**

Faraday's law in terms of EMF produced by changing magnetic flux; equivalence of Faraday's law and motional EMF; Lenz's law; Electromagnetic breaking and its applications; Differential form of Faraday's law expressing curl of electric field in terms of time-derivative of magnetic field and calculating electric field due to changing magnetic fields in quasi-static approximation; energy stored in a magnetic field.

**Module VI: Displacement current, Magnetic field due to time-dependent electric field and Maxwell's equations**

Continuity equation for current densities; Modifying equation for the curl of magnetic field to satisfy continuity equation; displace current and magnetic field arising from time dependent electric field; calculating magnetic field due to changing electric fields in quasistatic approximation. Maxwell's equation in vacuum and non-conducting medium; Energy in an electromagnetic field; Flow of energy and Pointing vector with examples. Qualitative discussion of momentum in electromagnetic fields.

**Module VII: Electromagnetic waves**

The wave equation; Plane electromagnetic waves in vacuum, their transverse nature and polarization; relation between electric and magnetic fields of an electromagnetic wave; energy carried by electromagnetic waves and examples. Momentum carried by electromagnetic waves and resultant pressure. Reflection and transmission of electromagnetic waves from a non-conducting medium-vacuum interface for normal incidence.

**Laboratory - Introduction to Electromagnetic Theory**

Choice of experiments from the following:

- Experiments on electromagnetic induction and electromagnetic braking;
- LC circuit and LCR circuit;
- Resonance phenomena in LCR circuits;
- Magnetic field from Helmholtz coil;
- Measurement of Lorentz force in a vacuum tube.

**TEXTBOOKS/REFERENCES:**


1. David Griffiths, Introduction to Electrodynamics
2. Halliday and Resnick, Physics
3. W. Saslow, Electricity, magnetism and light


**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | INTRODUCTION TO ELECTROMAGNETIC THEORY | PROF. MANOJ HARBOLA | IIT KANPUR |

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | LC circuit and LCR circuit; | 1. http://vlab.amrita.edu/?sub=1&brch=75&sim=326&cnt=1<br>2. http://vlab.amrita.edu/?sub=1&brch=75&sim=330&cnt=1<br>3. http://vlab.amrita.edu/?sub=1&brch=75&sim=318&cnt=1<br>4. http://vlab.amrita.edu/?sub=1&brch=75&sim=325&cnt=1<br>5. http://vlabs.iitkgp.ernet.in/asnm/exp12/index.htm |
| 2 | Resonance phenomena in LCR circuits | http://vlab.amrita.edu/?sub=1&brch=75&sim=325&cnt=1 |

*****

| Introduction to Mechanics |
|---|
| Pre-requisites (if any): High School Education |

**Module I**

Transformation of scalars and vectors under Rotation transformation; Forces in Nature; Newton's laws and its completeness in describing particle motion; Form invariance of Newton's Second Law; Solving Newton's equations of motion in polar coordinates; Problems including constraints and friction; Extension to cylindrical and spherical coordinates.

**Module II**

Potential energy function; F = - Grad V, equipotential surfaces and meaning of gradient; Conservative and non-conservative forces, curl of a force field; Central forces; Conservation of Angular Momentum; Energy equation and energy diagrams; Elliptical, parabolic and hyperbolic orbits; Kepler problem; Application: Satellite manoeuvres;

**Module III**

Non-inertial frames of reference; Rotating coordinate system: Five-term acceleration formula. Centripetal and Coriolis accelerations; Applications: Weather systems, Foucault pendulum;

**Module IV**

Harmonic oscillator; Damped harmonic motion – over-damped, critically damped and lightly-damped oscillators; Forced oscillations and resonance.

**Module V**

Definition and motion of a rigid body in the plane; Rotation in the plane; Kinematics in a coordinate system rotating and translating in the plane; Angular momentum about a point of a rigid body in planar motion; Euler's laws of motion, their independence from Newton's laws, and their necessity in describing rigid body motion; Examples.

**Module VI**

Introduction to three-dimensional rigid body motion — only need to highlight the distinction from two-dimensional motion in terms of (a) Angular velocity vector, and its rate of change and (b) Moment of inertia tensor; Three-dimensional motion of a rigid body wherein all points move in a coplanar manner: e.g. Rod executing conical motion with center of mass fixed — only need to show that this motion looks two-dimensional but is three-dimensional, and two-dimensional formulation fails.

**Laboratory - Introduction to Mechanics**

1. Suggested list of experiments from the following:
2. Coupled oscillators;
3. Experiments on an air-track;
4. Experiment on moment of inertia measurement,
5. Experiments with gyroscope;
6. Resonance phenomena in mechanical oscillators.

**TEXTBOOKS/REFERENCES:**


1. Engineering Mechanics, 2nd ed. — MK Harbola
2. Introduction to Mechanics — MK Verma
3. An Introduction to Mechanics — D Kleppner & R Kolenkow
4. Principles of Mechanics — JL Synge & BA Griffiths
5. Mechanics — JP Den Hartog
6. Engineering Mechanics - Dynamics, 7th ed. - JL Meriam
7. Mechanical Vibrations — JP Den Hartog
8. Theory of Vibrations with Applications — WT Thomson


**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | ENGINEERING MECHANICS | PROF. MANOJ HARBOLA | IIT KANPUR |

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | Experiment on moment of inertia measurement. | https://vlab.amrita.edu/?sub=1&brch=74&sim=571&cnt=1 |

*****

| Quantum Mechanics for Engineers |
|---|
| Pre-requisites (if any): Mathematics Course on Differential equations & linear algebra |

**Module I: Wave nature of particles and the Schrodinger equation**

Introduction to Quantum mechanics, Wave nature of Particles, Time-dependent and time independent Schrodinger equation for wave function, Born interpretation, probability current, Expectation values, Free-particle wave function and wave-packets, Uncertainty principle.

**Module II: Mathematical Preliminaries for quantum mechanics**

Complex numbers, Linear vector spaces, inner product, operators, eigenvalue problems, Hermitian operators, Hermite polynomials, Legendre's equation, spherical harmonics.

**Module III: Applying the Schrodinger equation**

Solution of stationary-state Schrodinger equation for one dimensional problems– particle in a box, particle in attractive delta-function potential, square-well potential, linear harmonic oscillator. Numerical solution of stationary-state Schrodinger equation for one dimensional problems for different potentials Scattering from a potential barrier and tunneling; related examples like alpha-decay, fieldionization and scanning tunneling microscope Three-dimensional problems: particle in three dimensional box and related examples, Angular momentum operator, Rigid Rotor, Hydrogen atom ground-state, orbitals, interaction with magnetic field, spin, Numerical solution stationary-state radial Schrodinger equation for spherically symmetric potentials.

**Module IV: Introduction to molecular bonding**

Particle in double delta-function potential, Molecules (hydrogen molecule, valence bond and molecular orbitals picture), singlet/triplet states, chemical bonding, hybridization.

**Module V: Introduction to solids**

Free electron theory of metals, Fermi level, density of states, Application to white dwarfs and neutron stars, Bloch's theorem for particles in a periodic potential, Kronig-Penney model and origin of energy bands Numerical solution for energy in one-dimensional periodic lattice by mixing plane waves.

**Laboratory - Quantum Mechanics for Engineers**

**Suggested list of experiments**: Frank-Hertz experiment; photoelectric effect experiment; recording hydrogen atom spectrum.

**TEXTBOOKS/REFERENCES:**


1. Eisberg and Resnick, Introduction to Quantum Physics
2. D. J. Griffiths, Quantum mechanics
3. Richard Robinett, Quantum Mechanics
4. Daniel McQuarrie, Quantum Chemistry

**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | INTRODUCTION TO ELECTROMAGNETIC THEORY | PROF. MANOJ HARBOLA | IIT KANPUR |
| 2 | QUANTUM MECHANICS I | PROF. P. RAMADEVI | IIT BOMBAY |

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | Photoelectric effect experiment. | http://mpv-au.vlabs.ac.in/modern-physics/Photo_Electric_Effect/ |

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| Oscillations, waves and optics |
|---|
| Pre-requisites (if any): Mathematics Course on Differential equations |

**Module I: Simple harmonic motion, damped and forced simple harmonic oscillator**
Mechanical and electrical simple harmonic oscillators, complex number notation and phasor representation of simple harmonic motion, damped harmonic oscillator – heavy, critical and light damping, energy decay in a damped harmonic oscillator, quality factor, forced mechanical and electrical oscillators, electrical and mechanical impedance, steady state motion of forced damped harmonic oscillator, power absorbed by oscillator.

**Module II: Non-dispersive transverse and longitudinal waves in one dimension and introduction to dispersion**
Transverse wave on a string, the wave equation on a string, Harmonic waves, reflection and transmission of waves at a boundary, impedance matching, standing waves and their Eigen frequencies, longitudinal waves and the wave equation for them, acoustics waves and speed of sound, standing sound waves. Waves with dispersion, water waves, superposition of waves and Fourier method, wave groups and group velocity.

**Module III: The propagation of light and geometric optics**
Fermat's principle of stationary time and its applications e.g. in explaining mirage effect, laws of reflection and refraction, Light as an electromagnetic wave and Fresnel equations, reflectance and transmittance, Brewster's angle, total internal reflection, and evanescent wave. Mirrors and lenses and optical instruments based on them, transfer formula and the matrix method.

**Module IV: Wave optics**

Huygens' principle, superposition of waves and interference of light by wave front splitting and amplitude splitting; Young's double slit experiment, Newton's rings, Michelson interferometer, Mach-Zehnder interferometer.

Farunhofer diffraction from a single slit and a circular aperture, the Rayleigh criterion for limit of resolution and its application to vision; Diffraction gratings and their resolving power.

**Module V: Lasers**

Einstein's theory of matter radiation interaction and A and B coefficients; amplification of light by population inversion, different types of lasers: gas lasers (He-Ne, CO2), solid-state lasers (ruby, Neodymium), dye lasers; Properties of laser beams: mono-chromaticity, coherence, directionality and brightness, laser speckles, applications of lasers in science, engineering and medicine.

**Laboratory - Oscillations, waves and optics**

Suggested list of experiments from the following:

- Diffraction and interference experiments (from ordinary light or laser pointers); measurement of speed of light on a table top using modulation; minimum deviation from a prism.

**TEXTBOOKS/REFERENCES:**

1. Ian G. Main, Oscillations and waves in physics
2. H.J. Pain, The physics of vibrations and waves
3. E. Hecht, Optics
4. A. Ghatak, Optics
5. O. Svelto, Principles of Lasers

**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | WAVES AND OSCILLATIONS | PROF. M. S. SANTHANAM | IISER PUNE |

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | Diffraction and interference experiments (from ordinary light or laser pointers). | http://ov-au.vlabs.ac.in/optics/Diffraction_Grating/ |
| 2 | Minimum deviation from a prism. | http://ov-au.vlabs.ac.in/optics/Spectrometer_i_d_Curve/ |

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|---|---|---|
| **Course Code** | : | **BS-02** |
| **Course Title** | **:** | **Mathematics- I** |
| **Number of Credits** | **:** | **4 (L: 3, T: 1, P: 0)** |
| **Course Category** | **:** | **Basic Science Courses** |

**Course Objectives:** The goal of this course is to achieve conceptual understanding and to retain the best traditions of traditional calculus. The syllabus is designed to provide the basic tools of calculus mainly for the purpose of modelling the engineering problems mathematically and obtaining solutions. This is a foundation course which mainly deals with topics such as single variable and multivariable calculus and plays an important role in the understanding of science, engineering, economics and computer science, among other disciplines.

**Course Contents:**

**Module 1: Basic Calculus:** (6 hours)
Curvature, evolutes and involutes; Evaluation of definite and improper integrals; Beta and Gamma functions and their properties; Applications of definite integrals to evaluate surface areas and volumes of revolutions.

**Module 2: Single-variable Calculus (Differentiation):** (6 hours)
Rolle's Theorem, Mean value theorems and applications; Extreme values of functions; Linear approximation; Indeterminate forms and L'Hospital's rule.

**Module 3: Sequences and series:** (10 hours)
Limits of sequence of numbers, Calculation of limits, Infinite series; Tests for convergence; Power series, Taylor and Maclaurin series; Taylor theorem, convergence of Taylor series, error estimates.

**Module 4: Multivariable Calculus (Differentiation):** (8 hours)
Limit, continuity and partial derivatives, directional derivatives, gradient, total derivative; Tangent plane and normal line; Maxima, minima and saddle points; Method of Lagrange multipliers.

**Module 5**: **Multivariable Calculus (Integration):** (10 hours)
Multiple Integration: Double integrals (Cartesian), change of order of integration in double integrals, Change of variables (Cartesian to polar), Applications: areas and volumes, Center of mass and Gravity (constant and variable densities); Triple integrals (Cartesian), orthogonal curvilinear coordinates, Simple applications involving cubes, sphere and rectangular parallelepipeds; Scalar line integrals, vector line integrals, scalar surface integrals, vector surface integrals, Gradient, curl and divergence, Theorems of Green, Gauss and Stokes.

**TEXTBOOKS/REFERENCES:**


1. **AICTE's Prescribed Textbook: Mathematics-I (Calculus & Linear Algebra), Khanna Book Publishing Co.**
2. Reena Garg, Engineering Mathematics, Khanna Book Publishing Company, 2022.
3. Reena Garg, Advanced Engineering Mathematics, Khanna Book Publishing Company, 2021.

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

**Note:** The modules have been prepared keeping the following from the Textbooks/References in mind:

(1) Module 1: The relevant sections from Chapters 2, 6 and 11 of [3].
(2) Module 2: Sections 3.1, 3.2, 3.3, 3.7 & 6.6 of [1].
(3) Module 3: Sections 8.1-8.6, 8.8-8.10 of [1].
(4) Module 4: Sections 12.1-12.5, 12.7-12.9 of [1].
(1) Module 5: Sections 13.1 – 13.7, 14.1 – 14.8 of [1].

**Course outcomes:** The objective of this course is to familiarize the prospective engineers with techniques in calculus, multivariate differentiation and integration. It aims to equip the students with standard concepts and tools at an intermediate to advanced level that will serve them well towards tackling more advanced level of mathematics and applications that they would find useful in their disciplines.

The students will learn

- To apply differential and integral calculus to notions of curvature and to improper integrals. Apart from some other applications they will have a basic understanding of Beta and Gamma functions.
- The fallouts of Rolle's Theorem that is fundamental to application of analysis to Engineering problems.
- The tool of power series and Fourier series for learning advanced Engineering Mathematics.
- To deal with functions of several variables that are essential in most branches of engineering.
- To acquaint the student with mathematical tools needed in evaluating multiple integrals and their usage.

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|---|---|---|
| **Course Code** | : | **ES-01** |
| **Course Title** | : | **Basic Electrical Engineering** |
| **Number of Credits** | : | **4 (L: 2, T: 1, P: 2)** |
| **Course Category** | : | **Engineering Science Courses** |

**Course Objective:** The objective of this Course is to provide the students with an introductory and broad treatment of the field of Electrical Engineering.

**Course Contents:**

**Module I:** D. C. Circuits covering, Ohm's Law and Kirchhoff's Laws; Analysis of series, parallel and series-parallel circuits excited by independent voltage sources; Power and energy; Electromagnetism covering, Faradays Laws, Lenz's Law, Fleming's Rules, Statically and dynamically induced EMF; Concepts of self-inductance, mutual inductance and coefficient of coupling; Energy stored in magnetic fields;

**Module II:** Single Phase A.C. Circuits covering, Generation of sinusoidal voltage- definition of average value, root mean square value, form factor and peak factor of sinusoidal voltage and current and phasor representation of alternating quantities; Analysis with phasor diagrams of R, L, C, RL, RC and RLC circuits; Real power, reactive power, apparent power and power factor, series, parallel and series- parallel circuits; Three Phase A.C. Circuits covering, Necessity and Advantages of three phase systems, Generation of three phase power, definition of Phase sequence, balanced supply and balanced load; Relationship between line and phase values of balanced star and delta connections; Power in balanced three phase circuits, measurement of power by two wattmeter method;

**Module III:** Transformers covering, Principle of operation and construction of single phase transformers (core and shell types). EMF equation, losses, efficiency and voltage regulation; Synchronous Generators covering, Principle of operation; Types and constructional features; EMF equation;

**Module IV:** DC Machines covering, working principle of DC machine as a generator and a motor; Types and constructional features; EMF equation of generator, relation between EMF induced and terminal voltage enumerating the brush drop and drop due to armature reaction; DC motor working principle; Back EMF and its significance, torque equation; Types of D.C. motors, characteristics and applications; Necessity of a starter for DC motor;

**Module V:** Three Phase Induction Motors covering; Concept of rotating magnetic field; Principle of operation, types and constructional features; Slip and its significance; Applications of squirrel cage and slip ring motors; Necessity of a starter, star-delta starter.

**Module VI:** Sources of Electrical Power covering, Introduction to Wind, Solar, Fuel cell, Tidal, Geo-thermal, Hydroelectric, Thermal-steam, diesel, gas, nuclear power plants; Concept of cogeneration, and distributed generation;

**TEXT/REFERENCS BOOKS:**

1. **AICTE's Prescribed Textbook: Basic Electrical Engineering, Khanna Book Publishing.**
2. Ritu Sahdev (2022), Basic Electrical Engineering, Khanna Book Publishing.
3. Nagrath I.J. and D. P. Kothari (2001), Basic Electrical Engineering, Tata McGraw Hill.
4. Hayt and Kimberly, Engineering Circuit Analysis, Tata McGraw Hill.
5. Kulshreshtha D.C. (2009), Basic Electrical Engineering, Tata McGraw Hill.
6. Rajendra Prasad (2009), Fundamentals of Electrical Engineering, Prentice Hall, India Hughes, E. 2005)

**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | BASIC ELECTRIC CIRCUITS | PROF. ANKUSH SHARMA | IIT KANPUR |
| 2 | BASIC ELECTRICAL CIRCUITS | PROF. NAGENDRA KRISHNAPURA | IITM |
| 3 | FUNDAMENTALS OF ELECTRICAL ENGINEERING | PROF. DEBAPRIYA DAS | IIT KGP |

**COURSE OUTCOMES:**

The students will learn:

1. To explain strong basics of Electrical Engineering and practical implementation of Electrical fundamentals.
2. To identify different applications of commonly used electrical machinery.

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|---|---|---|
| **Course Code** | **:** | **ES-02** |
| **Course Title** | **:** | **Engineering Graphics & Design** |
| **Number of Credits** | **:** | **3 (L: 1, T: 0, P: 4)** |
| **Course Category** | **:** | **Engineering Science Courses** |

**COURSE OBJECTIVE(S):**

The objective of this Course is to provide the basic knowledge about Engineering Drawing. Detailed concepts are given in projections, technical drawing, dimensioning and specifications, so useful for a student in preparing for an engineering career.

**COURSE CONTENTS:**

**Traditional Engineering Graphics:** Principles of Engineering Graphics; Orthographic Projection; Descriptive Geometry; Drawing Principles; Isometric Projection; Surface Development; Perspective; Reading a Drawing; Sectional Views; Dimensioning & Tolerances; True Length, Angle; intersection, Shortest Distance.

**Computer Graphics: Engineering Graphics** Software; -Spatial Transformations; Orthographic Projections; Model Viewing; Co-ordinate Systems; Multi-view Projection; Exploded Assembly; Model Viewing; Animation; Spatial Manipulation; Surface Modelling; Solid Modelling; Introduction to Building Information Modelling (BIM).

***(Except the basic essential concepts, most of the teaching part can happen concurrently in the laboratory)***

**Module I: Introduction to Engineering Drawing**
Principles of Engineering Graphics and their significance, usage of Drawing instruments, lettering, Conic sections including the Rectangular Hyperbola (General method only); Cycloid, Epicycloid, Hypocycloid and Involute; Scales – Plain, Diagonal and Vernier Scales;

**Module II: Orthographic Projections**
Principles of Orthographic Projections-Conventions - Projections of Points and lines inclined to both planes; Projections of planes inclined Planes - Auxiliary Planes;

**Module III: Projections of Regular Solids**
Covering those inclined to both the Planes- Auxiliary Views; Draw simple annotation, dimensioning and scale. Floor plans that include: windows, doors, and fixtures such as WC, bath, sink, shower, etc.

**Module IV: Sections and Sectional Views of Right Angular Solids**
Prism, Cylinder, Pyramid, Cone – Auxiliary Views; Development of surfaces of Right Regular Solids - Prism, Pyramid, Cylinder and Cone; Draw the sectional orthographic views of geometrical solids, objects from industry and dwellings (foundation to slab only).

**Module V: Isometric Projections**
Principles of Isometric projection – Isometric Scale, Isometric Views, Conventions; Isometric Views of lines, Planes, Simple and compound Solids; Conversion of Isometric Views to Orthographic Views and Vice-versa, Conventions;

**Module VI: Overview of Computer Graphics**
Listing the computer technologies that impact on graphical communication, Demonstrating knowledge of the theory of CAD software [such as: The Menu System, Toolbars (Standard, Object Properties, Draw, Modify and Dimension), Drawing Area (Background, Crosshairs, Coordinate System), Dialog boxes and windows, Shortcut menus (Button Bars), The Command Line (where applicable), The Status Bar, Different methods of zoom as used in CAD, Select and erase objects.; Isometric Views of lines, Planes, Simple and compound Solids];

**Module VII: Customisation & CAD Drawing**
Consisting of set up of the drawing page and the printer, including scale settings, setting up of Modules and drawing limits; ISO and ANSI standards for coordinate dimensioning and tolerancing; Orthographic constraints, Snap to objects manually and automatically; Producing drawings by using various coordinate input entry methods to draw straight lines, Applying various ways of drawing circles;

**Module VIII: Annotations, layering & other functions**
Covering applying dimensions to objects, applying annotations to drawings; Setting up and use of Layers, layers to create drawings, Create, edit and use customized layers; Changing line lengths through modifying existing lines (extend/lengthen); Printing documents to paper using the print command; orthographic projection techniques; Drawing sectional views of composite right regular geometric solids and project the true shape of the sectioned surface; Drawing annotation, Computer-aided design (CAD) software modeling of parts and assemblies. Parametric and non-parametric solid, surface, and wireframe models. Part editing and two-dimensional documentation of models. Planar

projection theory, including sketching of perspective, isometric, multiview, auxiliary, and section views. Spatial visualization exercises. Dimensioning guidelines, tolerancing techniques; dimensioning and scale multi views of dwelling;

**Module IX: Demonstration of a simple team design project that illustrates**
Geometry and topology of engineered components: creation of engineering models and their presentation in standard 2D blueprint form and as 3D wire-frame and shaded solids; meshed topologies for engineering analysis and tool-path generation for component manufacture; geometric dimensioning and tolerancing; Use of solid-modeling software for creating associative models at the component and assembly levels; floor plans that include: windows, doors, and fixtures such as WC, bath, sink, shower, etc. Applying colour coding according to building drawing practice; Drawing sectional elevation showing foundation to ceiling; Introduction to Building Information Modelling (BIM).

**Text/Reference Books:**


1. **AICTE's Prescribed Textbook: Engineering Graphics & Design Khanna Book Publishing.**
2. Jain, Maheshwari, Gautam (2021), Engineering Graphics & Design, Khanna Book Publishing.
3. Bhatt N.D., Panchal V.M. & Ingle P.R., (2014), Engineering Drawing, Charotar Publishing House.
4. Shah, M.B. & Rana B.C. (2008), Engineering Drawing and Computer Graphics, Pearson Education.
5. Agrawal B. & Agrawal C. M. (2012), Engineering Graphics, TMH Publication
6. Narayana, K.L. & P Kannaiah (2008), Text book on Engineering Drawing, Scitech Publishers.
7. (Corresponding set of) CAD Software Theory and User Manuals.


**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | PROF. RAJARAM LAKKARAJU | IIT KGP | ENGINEERING DRAWING AND COMPUTER GRAPHICS |
| 2 | PROF. NIHAR RANJAN PATRA | IIT KANPUR | ENGINEERING GRAPHICS |

**Course Outcomes:**
All phases of manufacturing or construction require the conversion of new ideas and design concepts into the basic line language of graphics. Therefore, there are many areas (civil, mechanical, electrical, architectural and industrial) in which the skills of the CAD technicians play major roles in the design and development of new products or construction. Students prepare for actual work situations through practical training in a new state-of-the-art computer designed CAD laboratory using engineering software. This course is designed to address:

- to prepare you to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- to prepare you to communicate effectively
- to prepare you to use the techniques, skills, and modern engineering tools necessary for engineering practice

The students will learn:

- To describe engineering design and its place in society.
- To discuss the visual aspects of engineering design.
- To use engineering graphics standards.
- To illustrate solid modelling.
- To use computer-aided geometric design.
- To design creating working drawings.
- To inspect engineering communication.

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|---|---|---|
| **Course Code** | **:** | **HSM-01** |
| **Course Title** | **:** | **English for Technical Writing** |
| **Number of Credits** | **:** | **3 (L: 2, T: 0, P: 2)** |
| **Course Category** | **:** | **Humanities & Social Science Courses** |

**Course Objective:**

- To provide learning environment to practice listening, speaking, reading and writing skills.
- To assist the students to carry on the tasks and activities through guided instructions and materials.
- To effectively integrate English language learning with employability skills and training.
- To provide hands-on experience through case-studies, mini-projects, group and individual presentations.

**Course Content:**

**Module I**: Vocabulary Building

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

**Module II:** Basic Writing Skills

1.1. Sentence Structures
1.2. Use of phrases and clauses in sentences
1.3. Importance of proper punctuation
1.4. Creating coherence
1.5. Organizing principles of paragraphs in documents
1.6. Techniques for writing precisely

**Module III**: Identifying Common Errors in Writing

1.1. Subject-verb agreement
1.2. Noun-pronoun agreement
1.3. Misplaced modifiers
1.4. Articles
1.5. Prepositions

1.6. Redundancies
1.7. Clichés

**Module IV**: Nature and Style of sensible Writing
1.1. Describing
1.2. Defining
1.3. Classifying
1.4. Providing examples or evidence
1.5. Writing introduction and conclusion

**Module V**: Writing Practices
1.1. Comprehension
1.2. Précis Writing
1.3. Essay Writing

**Module VI**: Oral Communication
(This Module involves interactive practice sessions in Language Lab)
- Listening Comprehension
- Pronunciation, Intonation, Stress and Rhythm
- Common Everyday Situations: Conversations and Dialogues
- Communication at Workplace
- Interviews
- Formal Presentations

**Text/Reference Books:**


1. AICTE's Prescribed Textbook: English (with Lab Manual), Khanna Book Publishing Co.
2. Effective Communication Skills. Kul Bhushan Kumar, Khanna Book Publishing, 2022.
3. Practical English Usage. Michael Swan. OUP. 1995.
4. Remedial English Grammar. F.T. Wood. Macmillan.2007
5. On Writing Well. William Zinsser. Harper Resource Book. 2001
6. Study Writing. Liz Hamp-Lyons and Ben Heasly. Cambridge University Press. 2006.
7. Communication Skills. Sanjay Kumar and PushpLata. Oxford University Press. 2011.
8. Exercises in Spoken English. Parts. I-III. CIEFL, Hyderabad. Oxford University Press.


**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | ENGLISH LANGUAGE FOR COMPETITIVE EXAMS | PROF. AYSHA IQBAL | IIT MADRAS |
| 2. | TECHNICAL ENGLISH FOR ENGINEERS | PROF. AYSHA IQBAL | IITM |

**Course Outcomes:** The student will acquire basic proficiency in English including reading and listening comprehension, writing and speaking skills.

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|---|---|---|
| **Course Code** | **:** | **ES-03** |
| **Course Title** | **:** | **Design Thinking** |
| **Number of Credits** | **:** | **1 (L: 0, T: 0, P: 2)** |
| **Course Category** | **:** | **Engineering Science Courses** |

**COURSE OBJECTIVE(S):**

The objective of this Course is to provide the new ways of creative thinking and Learn the innovation cycle of Design Thinking process for developing innovative products which useful for a student in preparing for an engineering career.

**COURSE CONTENTS:**

**Unit 1**: An Insight to Learning

Understanding the Learning Process, Kolb's Learning Styles, Assessing and Interpreting

**Unit 2**: Remembering Memory

Understanding the Memory process, Problems in retention, Memory enhancement techniques

**Unit 3**: Emotions: Experience & Expression

Understanding Emotions: Experience & Expression, Assessing Empathy, Application with Peers

**Unit 4**: Basics of Design Thinking

Definition of Design Thinking, Need for Design Thinking, Objective of Design Thinking, Concepts & Brainstorming, Stages of Design Thinking Process (explain with examples) – **Empathize, Define, Ideate, Prototype, Test**

**Unit 5**: Being Ingenious & Fixing Problem

Understanding Creative thinking process, Understanding Problem Solving, Testing Creative Problem Solving

**Unit 6**: Process of Product Design

Process of Engineering Product Design, Design Thinking Approach, Stages of Product Design, Examples of best product designs and functions, **Assignment – Engineering Product Design**

**Unit 7**: Prototyping & Testing

What is Prototype? Why Prototype? Rapid Prototype Development process, Testing, **Sample Example**, Test Group Marketing

**Unit 8**: Celebrating the Difference

Understanding Individual differences & Uniqueness, Group Discussion and Activities to encourage the understanding, acceptance and appreciation of Individual differences

**Unit 9**: Design Thinking & Customer Centricity

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

**Unit 10**: Feedback, Re-Design & Re-Create

Feedback loop, Focus on User Experience, Address "ergonomic challenges, User focused design, rapid prototyping & testing, final product, Final Presentation – **"Solving Practical Engineering Problem through Innovative Product Design & Creative Solution".**

**Course Outcomes (CO):**

Student will able to

1. Compare and classify the various learning styles and memory techniques and Apply them in their engineering education
2. Analyze emotional experience and Inspect emotional expressions to better understand users while designing innovative products
3. Develop new ways of creative thinking and Learn the innovation cycle of Design Thinking process for developing innovative products
4. Propose real-time innovative engineering product designs and Choose appropriate frameworks, strategies, techniques during prototype development
5. Perceive individual differences and its impact on everyday decisions and further Create a better customer experience

**Text/Reference Books:**

1. E Balaguruswamy (2022), Developing Thinking Skills (The way to Success), Khanna Book Publishing Company.

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|---|---|---|
| **Course Code** | **:** | **AU-01** |
| **Course Title** | **:** | ***IDEA Lab Workshop*** |
| **Number of Credits** | **:** | **0 (L: 2, T: 0, P: 4)** |
| **Course Category** | **:** | **AU-101** |
| **Prerequisites** | **:** | **None** |

**Course Objectives:**

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

**Course Contents:**

| Unit # | Topics | |
|---|---|---|
| 1 | Electronic component familiarization, Understanding electronic system design flow. Schematic design and PCB layout and Gerber creation using EagleCAD. Documentation using Doxygen, Google Docs, Overleaf. Version control tools - GIT and GitHub.<br>Basic 2D and 3D designing using CAD tools such as FreeCAD, Sketchup, Prusa Slicer, FlatCAM, Inkspace, OpenBSP and VeriCUT. | Introduction to basic hand tools - Tape measure, combination square, Vernier calliper, hammers, fasteners, wrenches, pliers, saws, tube cutter, chisels, vice and clamps, tapping and threading. Adhesives<br><br>Introduction to Power tools: Power saws, band saw, jigsaw, angle grinder, belt sander, bench grinder, rotary tools. Various types of drill bits, |
| 2 | Familiarization and use of basic measurement instruments - DSO including various triggering modes, DSO probes, DMM, LCR bridge, Signal and function generator. Logic analyzer and MSO. Bench power supply (with 4-wire output)<br>Circuit prototyping using (a) breadboard, (b) Zero PCB (c) 'Manhattan' style and (d) custom PCB. Single, double and multilayer PCBs. Single and double-sided PCB prototype fabrication in the lab. Soldering using soldering iron/station. Soldering using a temperature controlled reflow oven. Automated circuit assembly and soldering using pick and place machines. | Mechanical cutting processes - 3-axis CNC routing, basic turning, milling, drilling and grinding operations, Laser cutting, Laser engraving etc.<br>Basic welding and brazing and other joining techniques for assembly.<br>Concept of Lab aboard a Box. |

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|---|---|---|
| 3. | Electronic circuit building blocks including common sensors. Arduino and Raspberry Pi programming and use. Digital Input and output. Measuring time and events. PWM. Serial communication. Analog input. Interrupts programming. Power Supply design (Linear and Switching types), Wireless power supply, USB PD, Solar panels, Battery types and charging | 3D printing and prototyping technology – 3D printing using FDM, SLS and SLA. Basics of 3D scanning, point cloud data generation for reverse engineering.<br><br>Prototyping using subtractive cutting processes. 2D and 3D Structures for prototype building using Laser cutter and CNC routers.<br><br>Basics of IPR and patents; Accessing and utilizing patent information in IDEA Lab |
| 4. | Discussion and implementation of a mini project. | |
| 5. | Documentation of the mini project (Report and video). | |

Laboratory Activities:

| S. No. | List of Lab activities and experiments |
|---|---|
| 1. | Schematic and PCB layout design of a suitable circuit, fabrication and testing of the circuit. |
| 2. | Machining of 3D geometry on soft material such as soft wood or modelling wax. |
| 3. | 3D scanning of computer mouse geometry surface. 3D printing of scanned geometry using FDM or SLA printer. |
| 4. | 2D profile cutting of press fit box/casing in acrylic (3 or 6 mm thickness)/cardboard, MDF (2 mm) board using laser cutter & engraver. |
| 5. | 2D profile cutting on plywood /MDF (6-12 mm) for press fit designs. |
| 6. | Familiarity and use of welding equipment. |
| 7. | Familiarity and use of normal and wood lathe. |
| 8. | Embedded programming using Arduino and/or Raspberry Pi. |
| 9. | Design and implementation of a capstone project involving embedded hardware, software and machined or 3D printed enclosure. |

Reference Books:

| S. No. | Title |
|---|---|
| 1. | **AICTE's Prescribed Textbook: Workshop / Manufacturing Practices (with Lab Manual), Khanna Book Publishing.** |

| | |
|---|---|
| 2. | All-in-One Electronics Simplified, A.K. Maini; 2021. ISBN-13: 978-9386173393, Khanna Book Publishing Company, New Delhi. |
| 3. | Simplified Q&A - Data Science with Artificial Intelligence, Machine Learning and Deep Learning, Rajiv Chopra, ISBN: 978-9355380821, Khanna Book Publishing Company, New Delhi. |
| 4. | 3D Printing & Design, Dr. Sabrie Soloman, ISBN: 978-9386173768, Khanna Book Publishing Company, New Delhi. |
| 5. | The Big Book of Maker Skills: Tools & Techniques for Building Great Tech Projects. Chris Hackett. Weldon Owen; 2018. ISBN-13: 978-1681884325. |
| 6. | The Total Inventors Manual (Popular Science): Transform Your Idea into a Top-Selling Product. Sean Michael Ragan (Author). Weldon Owen; 2017. ISBN-13: 978-1681881584. |
| 7. | Make: Tools: How They Work and How to Use Them. Platt, Charles. Shroff/Maker Media. 2018. ISBN-13: 978-9352137374 |
| 8. | The Art of Electronics. 3rd edition. Paul Horowitz and Winfield Hill. Cambridge University Press. ISBN: 9780521809269 |
| 9. | Practical Electronics for Inventors. 4th edition. Paul Sherz and Simon Monk. McGraw Hill. ISBN-13: 978-1259587542 |
| 10. | Encyclopedia of Electronic Components (Volume 1, 2 and 3). Charles Platt. Shroff Publishers. ISBN-13: 978-9352131945, 978-9352131952, 978-9352133703 |
| 11. | Building Scientific Apparatus. 4th edition. John H. Moore, Christopher C. Davis, Michael A. Coplan and Sandra C. Greer. Cambridge University Press. ISBN-13: 978-0521878586 |
| 12. | Programming Arduino: Getting Started with Sketches. 2nd edition. Simon Monk. McGraw Hill. ISBN-13: 978-1259641633 |
| 13. | Make Your Own PCBs with EAGLE: From Schematic Designs to Finished Boards. Simon Monk and Duncan Amos. McGraw Hill Education. ISBN-13 : 978-1260019193. |
| 14. | Pro GIT. 2nd edition. Scott Chacon and Ben Straub. A press. ISBN-13 : 978-1484200773 |
| 15. | Venuvinod, PK., MA. W., Rapid Prototyping – Laser Based and Other Technologies, Kluwer. |
| 16. | Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing", Springer, 2010 |
| 17. | Chapman W.A.J, "Workshop Technology", Volume I, II, III, CBS Publishers and distributors, 5th Edition,2002. |


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# SEMESTER – II

## SEMESTER II

| | | |
|---|---|---|
| **Course Code** | **:** | **BS-03** |
| **Course Title** | **:** | **Chemistry- I** |
| **Number of Credits** | **:** | **4 (L: 3, T: 0, P: 2)** |
| **Course Category** | **:** | **Basic Science Course** |

**Course Objective:**

The objective of the Chemistry I is to acquaint the students with the basic phenomenon/concepts of chemistry, the student faces during course of their study in the industry and Engineering field. The student with the knowledge of the basic chemistry, will understand and explain scientifically the various chemistry related problems in the industry/engineering field. The student will able to understand the new developments and breakthroughs efficiently in engineering and technology. The introduction of the latest (R&D oriented) topics will make the engineering student upgraded with the new technologies.

**Course Content:**

**Module I: Atomic and Molecular Structure**
Schrodinger equation. Particle in a box solutions and their applications for conjugated molecules and nanoparticles. Forms of the hydrogen atom wave functions and the plots of these functions to explore their spatial variations. Molecular orbitals of diatomic molecules and plots of the multicentre orbitals. Equations for atomic and molecular orbitals. Energy level diagrams of diatomic. Pi-molecular orbitals of butadiene and benzene and aromaticity. Crystal field theory and the energy level diagrams for transition metal ions and their magnetic properties. Band structure of solids and the role of doping on band structures.

**Module II: Spectroscopic techniques and applications**
Principles of spectroscopy and selection rules. Electronic spectroscopy. Fluorescence and its applications in medicine. Vibrational and rotational spectroscopy of diatomic molecules. Applications. Nuclear magnetic resonance and magnetic resonance imaging, surface characterization techniques. Diffraction and scattering.

**Module III: Intermolecular forces and potential energy surfaces**
Ionic, dipolar and van Der Waals interactions. Equations of state of real gases and critical phenomena. Potential energy surfaces of H3, H2F and HCN and trajectories on these surfaces.

**Module IV: Use of free energy in chemical equilibria (6 lectures)**
Thermodynamic functions: energy, entropy and free energy. Estimations of entropy and free energies. Free energy and emf. Cell potentials, the Nernst equation and applications. Acid base, oxidation reduction and solubility equilibria. Water chemistry. Corrosion. Use of free energy considerations in metallurgy through Ellingham diagrams.

**Module V: Periodic properties**
Effective nuclear charge, penetration of orbitals, variations of s, p, d and f orbital energies of atoms in the periodic table, electronic configurations, atomic and ionic sizes, ionization energies, electron affinity and electronegativity, polarizability, oxidation states, coordination numbers and geometries, hard soft acids and bases, molecular geometries.

**Module VI: Stereochemistry**
Representations of 3 dimensional structures, structural isomers and stereoisomers, configurations and symmetry and chirality, enantiomers, diastereomers, optical activity, absolute configurations and conformational analysis. Isomerism in transitional metal compounds.

**Module VII: Organic reactions and synthesis of a drug molecule**
Introduction to reactions involving substitution, addition, elimination, oxidation, reduction, cyclization and ring openings. Synthesis of a commonly used drug molecule.

**LABORATORY**
Choice of 10-12 experiments from the following:
1. Determination of surface tension and viscosity.
2. Thin layer chromatography.
3. Ion exchange column for removal of hardness of water.
4. Determination of chloride content of water.
5. Colligative properties using freezing point depression.
6. Determination of the rate constant of a reaction.
7. Determination of cell constant and conductance of solutions.
8. Potentiometry - determination of redox potentials and emfs.
9. Synthesis of a polymer/drug.
10. Saponification/acid value of an oil.
11. Chemical analysis of a salt.
12. Lattice structures and packing of spheres.
13. Models of potential energy surfaces.
14. Chemical oscillations- Iodine clock reaction.
15. Determination of the partition coefficient of a substance between two immiscible liquids.
16. Adsorption of acetic acid by charcoal.
17. Use of the capillary viscosimeters to the demonstrate of the isoelectric point as the pH of minimum viscosity for gelatin sols and/or coagulation of the white part of egg.

**Text/Reference Books:**

1. **AICTE's Prescribed Textbook: Chemistry – I with Lab Manual, Khanna Book Publishing.**
2. Engineering Chemistry, by Manisha Agrawal.
3. University chemistry, by B. H. Mahan
4. Chemistry: Principles and Applications, by M. J. Sienko and R. A. Plane
5. Fundamentals of Molecular Spectroscopy, by C. N. Banwell
6. Engineering Chemistry (NPTEL Web-book), by B. L. Tembe, Kamaluddin and M. S. Krishnan
7. Physical Chemistry, by P. W. Atkins
8. Organic Chemistry: Structure and Function by K. P. C. Volhardt and N. E. Schore, 5th Edition http://bcs.whfreeman.com/vollhardtschore5e/default.asp


**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | CHEMISTRY - I | PROF. MANGALA SUNDER KRISHNAN | IITM |

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | Determination of surface tension and viscosity. | http://pcv-au.vlabs.ac.in/physical-chemistry/Determination_of_Viscosity_of_Organic_Solvents/ |
| 2 | Ion exchange column for removal of hardness of water. | http://icv-au.vlabs.ac.in/inorganic-chemistry/Water_Analysis_Determination_of_Chemical_Parameters/ |
| 3 | Determination of chloride content of water. | http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk_labs/Environmental_Engineering_1/experiments/determination-of-chloride-nitk/simulation.html |
| 4 | Colligative properties using freezing point depression. | http://pcv-au.vlabs.ac.in/physical-chemistry/Cryoscopy/ |
| 5 | Determination of the rate constant of a reaction. | http://pcv-au.vlabs.ac.in/physical-chemistry/EMF_Measurement/ |
| 6 | Determination of cell constant and conductance of solutions. | http://icv-au.vlabs.ac.in/inorganic-chemistry/Water_Analysis_Determination_of_Physical_Parameters/ |
| 7 | Potentiometry - determination of redox potentials and emfs. | http://pcv-au.vlabs.ac.in/physical-chemistry/EMF_Measurement/ |
| 8 | Saponification/acid value of an oil. | http://biotech01.vlabs.ac.in/bio-chemistry/Estimation_of_Saponification_Value_of_Fats_or_Oils/ |
| 9 | Lattice structures and packing of spheres. | https://vlab.amrita.edu/?sub=1&brch=282&sim=370&cnt=1 |

**Course Outcomes:** The concepts developed in this course will aid in quantification of several concepts in chemistry that have been introduced at the 10+2 levels in schools. Technology is being increasingly based on the electronic, atomic and molecular level modifications. Quantum theory is more than 100 years old and to understand phenomena at nanometre levels, one has to base the description of all chemical processes at molecular levels. The course will enable the students:

- To analyse microscopic chemistry in terms of atomic and molecular orbitals and intermolecular forces.
- To rationalise bulk properties and processes using thermodynamic considerations.
- To distinguish the ranges of the electromagnetic spectrum used for exciting different molecular energy levels in various spectroscopic techniques
- To rationalise periodic properties such as ionization potential, electronegativity, oxidation states and electronegativity.

- To list major chemical reactions that are used in the synthesis of molecules.

**Laboratory Outcomes:** The chemistry laboratory course will consist of experiments illustrating the principles of chemistry relevant to the study of science and engineering. The students will learn:

- To estimate rate constants of reactions from concentration of reactants/products as a function of time.
- To measure molecular/system properties such as surface tension, viscosity, conductance of solutions, redox potentials, chloride content of water, etc.
- To synthesize a small drug molecule and analyze a salt sample.

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| **Course Code** | **:** | **BS-04** |
| **Course Title** | **:** | **Mathematics- II** |
| **Number of Credits** | **:** | **4 (L: 3, T: 1, P: 0)** |
| **Course Category** | **:** | **Basic Science Course** |

**Course Objective:** Mathematics fundamental necessary to formulate, solve and analyze engineering problems.

**Course Content:**

**Module 1: Matrices** (10 hours)
Linear Systems of Equations; Linear Independence; Rank of a Matrix; Determinant, Inverse of a matrix, rank-nullity theorem; System of linear equations; Symmetric, skew-symmetric and orthogonal matrices; Determinants; Eigenvalues and eigenvectors; Orthogonal transformation; Diagonalization of matrices; Cayley-Hamilton Theorem.

**Module 2: First order ordinary differential equations:** (6 hours)
Exact, linear and Bernoulli's equations. Equations not of first degree: equations solvable for p, equations solvable for y, equations solvable for x and Clairaut's type.

**Module 3: Ordinary differential equations of higher orders:** (8 hours)
Second order linear differential equations with variable coefficients: Euler-Cauchy equations, solution by variation of parameters; Power series solutions: Legendre's equations and Legendre polynomials, Frobenius method, Bessel's equation and Bessel's functions of the first kind and their properties.

**Module 4: Complex Variable – Differentiation:** (8 hours):
Differentiation, Cauchy-Riemann equations, analytic functions, harmonic functions, finding harmonic conjugate; elementary analytic functions (exponential, trigonometric, logarithm) and their properties; Conformal mappings, Mobius transformations and their properties.

**Module 5: Complex Variable – Integration:** (8 hours):
Contour integrals, Cauchy-Goursat theorem (without proof), Cauchy Integral formula (without proof), Liouville's theorem and Maximum-Modulus theorem (without proof); Taylor's series, zeros of analytic functions, singularities, Laurent's series; Residues, Cauchy Residue theorem (without proof), Evaluation

of definite integral involving sine and cosine, Evaluation of certain improper integrals using the Bromwich contour.

**TEXTBOOKS/REFERENCES:**


1. **AICTE's Prescribed Textbook: Mathematics-II (Calculus, Ordinary Differential Equations and Complex Variable), Khanna Book Publishing Co.**
2. Reena Garg, Engineering Mathematics, Khanna Book Publishing Company, 2022.
3. Reena Garg, Advanced Engineering Mathematics, Khanna Book Publishing Company, 2021.
4. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Edition, John Wiley & Sons, 2006.
5. Veerarajan T., Engineering Mathematics for first year, Tata McGraw-Hill, New Delhi, 2008.
6. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, 9th Edn., Wiley India, 2009.
7. D. Poole, Linear Algebra: A Modern Introduction, 2nd Edition, Brooks/Cole, 2005.
8. S. L. Ross, Differential Equations, 3rd Ed., Wiley India, 1984.
9. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall India, 1995.
10. E. L. Ince, Ordinary Differential Equations, Dover Publications, 1958.
11. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 7th Ed., Mc-Graw Hill, 2004.
12. N.P. Bali and Manish Goyal, A text book of Engineering Mathematics, Laxmi Publications, Reprint, 2008.
13. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 36th Edition, 2010.


**Note:** The modules have been prepared keeping the following from the Textbooks/References in mind:

(1) Module 1: Sections 7.3-7.5, 7.7, 7.8, 8.1-8.4 of [1].
(2) Module 2: Sections 1.4, 1.5 of [1]; Section 5.1 of [2].
(3) Module 3: Sections 2.5, 2.6, 2.10, 5.1, 5.3, 5.4, 5.5 of [1].
(4) Module 4: Sections 13.3 – 13.7, 17.1 – 17.3 of [1].
(5) Module 5: Sections 14.1 – 14.4, 15.2 – 15.4, 16.1 – 16.4 of [1].

**COURSE OUTCOMES:** The objective of this course is to familiarize the prospective engineers with techniques in matrices, ordinary differential equations and complex variables. It aims to equip the students to deal with advanced level of mathematics and applications that would be essential for their disciplines.

The students will learn:

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

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|---|---|---|
| **Course Code** | **:** | **ES-04** |
| **Course Title** | **:** | **Programming for Problem Solving** |
| **Number of Credits** | **:** | **4 (L: 2, T: 0, P: 4)** |
| **Course Category** | **:** | **Engineering Science Courses** |

**Course Objectives:**

1. To learn the fundamentals of computers.
2. To understand the various steps in program development.
3. To learn the syntax and semantics of C programming language.
4. To learn the usage of structured programming approach in solving problems.
5. To understated and formulate algorithm for programming script
6. To analyze the output based on the given input variables

**Course Contents:**

**Module I:** Introduction to Programming**;** Introduction to components of a computer system (disks, memory, processor, where a program is stored and executed, operating system, compilers etc.)
Idea of Algorithm: steps to solve logical and numerical problems. Representation of Algorithm: Flowchart/Pseudocode with examples.
From algorithms to programs; source code, variables (with data types) variables and memory locations, Syntax and Logical Errors in compilation, object and executable code.
**Module II:** Arithmetic expressions and precedence.

**Module III:** Conditional Branching and Loops. Writing and evaluation of conditionals and consequent branching. Iteration and loops.

**Module IV:** Arrays, Arrays (1-D, 2-D), Character arrays and Strings
**Module V:** Basic Algorithms, Searching, Basic Sorting Algorithms (Bubble, Insertion and Selection), Finding roots of equations, notion of order of complexity through example programs (no formal definition required)

**Module VI:** Function, Functions (including using built in libraries), Parameter passing in functions, call by value, Passing arrays to functions: idea of call by reference

**Module VII:** Recursion, Recursion as a different way of solving problems. Example programs, such as Finding Factorial, Fibonacci series, Ackerman function etc. Quick sort or Merge sort.
**Module VIII:** Structures, Defining structures and Array of Structures

**Module IX:** Pointers, Idea of pointers, Defining pointers, Use of Pointers in self-referential structures, notion of linked list (no implementation)

**Module X:** File handling (only if time is available, otherwise should be done as part of the lab).

**PRACTICALS**:

1. Familiarization with programming environment
2. Simple computational problems using arithmetic expressions
3. Problems involving if-then-else structures

4. Iterative problems e.g., sum of series
5. 1D Array manipulation
6. Matrix problems, String operations
7. Simple functions
8. Programming for solving Numerical methods problems
9. Recursive functions
10. Pointers and structures
11. File operations

**TEXT/REFERENCE BOOKS:**


1. **AICTE's Prescribed Textbook: Programming for Problem Solving, Khanna Book Publishing Co.**
2. Byron Gottfried, Schaum's Outline of Programming with C, McGraw-Hill.
3. E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill.
4. Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice Hall of India.


**Alternative NPTEL/SWAYAM Course:**

| S. No. | NPTEL Course Name | Instructor | Host Institute |
|---|---|---|---|
| 1 | INTRODUCTION TO PROGRAMMING IN C | PROF. SATYADEV NANDAKUMAR | IITK |
| 2 | PROBLEM SOLVING THROUGH PROGRAMMING IN C | PROF. ANUPAM BASU | IIT KGP |

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | Simple computational problems using arithmetic expressions. | http://ps-iiith.vlabs.ac.in/exp7/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab |
| 2 | Iterative problems e.g., sum of series. | http://ps-iiith.vlabs.ac.in/exp4/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab |
| 3 | 1D Array manipulation. | http://cse02-iiith.vlabs.ac.in/exp4/index.html |
| 4 | Matrix problems, String operations. | http://ps-iiith.vlabs.ac.in/exp5/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab |
| 5 | Simple functions. | http://cse02-iiith.vlabs.ac.in/exp2/index.html |

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|---|---|---|
| 6 | Programming for solving Numerical methods problems. | http://ps-iiith.vlabs.ac.in/exp1/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab |
| 7 | Recursive functions. | http://ps-iiith.vlabs.ac.in/exp6/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab |

**COURSE OUTCOMES:** The student will learn following through lectures:

- To formulate simple algorithms for arithmetic and logical problems.
- To translate the algorithms to programs (in C language).
- To test and execute the programs and correct syntax and logical errors.
- To implement conditional branching, iteration and recursion.
- To decompose a problem into functions and synthesize a complete program using divide and conquer approach.
- To use arrays, pointers and structures to formulate algorithms and programs.
- To apply programming to solve matrix addition and multiplication problems and searching and sorting problems.
- To apply programming to solve simple numerical method problems, namely rot finding of function, differentiation of function and simple integration.

The student will learn following through Practicals:

- To formulate the algorithms for simple problems.
- To translate given algorithms to a working and correct program.
- To be able to correct syntax errors as reported by the compilers.
- To be able to identify and correct logical errors encountered at run time.
- To be able to write iterative as well as recursive programs.
- To be able to represent data in arrays, strings and structures and manipulate them through a program.
- To be able to declare pointers of different types and use them in defining self-referential structures.
- To be able to create, read and write to and from simple text files.

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| **SSC-10** | **Linux and Scripting** | **2L:0T:0P** | **2 credits** |

**Prerequisites**

- Basic knowledge of mathematics and physics

**Course Description:**

This course aims to provide students with a comprehensive understanding of Linux operating systems and scripting languages, specifically Python and TCL, in the context of Very Large Scale Integration (VLSI) design. Students will learn how to leverage the power of Linux for VLSI applications, automate design processes using Python and TCL scripts, and gain hands-on experience with the integration of these scripting languages in Electronic Design Automation (EDA) tools.

**Course Outcomes:**

Upon successful completion of this course, students will be able to:

1. Understand the Linux operating system and demonstrate proficiency in command-line usage for VLSI design.
2. Develop Python scripts for automation, data analysis, and interaction with VLSI design tools.
3. Create TCL scripts for automating tasks and extending functionality in VLSI design environments.
4. Integrate Python and TCL scripts to streamline complex VLSI design flows.
5. Apply scripting techniques to optimize productivity, facilitate collaboration, and solve real-world VLSI design challenges.
6. Develop graphical user interfaces (GUIs) using TCL/TK for VLSI applications.

**Teaching Schedule:**

Week 1-2: Introduction to Linux for VLSI Design

- Overview of Linux distributions and their relevance in VLSI design.
- Basic Linux commands and file system navigation.
- Introduction to shell scripting for VLSI applications.

Week 3-4: Advanced Linux Commands for VLSI Design

- Networking and system administration in a VLSI design environment.
- Version control systems (e.g., Git) for collaborative VLSI projects.

Week 5-6: Introduction to Python Programming for VLSI

- Basic Python syntax and data structures.
- Writing and executing Python scripts for VLSI design automation.

Week 7-8: Advanced Python Scripting for VLSI Design

- Interacting with EDA tools using Python.
- Data analysis and visualization in the context of VLSI design.

Week 9-10: Introduction to TCL Scripting for VLSI

- TCL fundamentals and scripting in VLSI applications.
- Integrating TCL with EDA tools for automation.

Week 11-12: Advanced TCL Scripting for VLSI Design

- Developing complex TCL scripts for VLSI design tasks.
- Interfacing TCL with Python for enhanced functionality.

Week 13-14: Group Project - Integrated Scripting for VLSI Design

- Collaborative development of VLSI design projects using integrated Python and TCL scripting.
- Presentation and evaluation of group projects.

Week 15: Final Review and Exam Preparation

- Recapitulation of key concepts.
- Final exam preparation and assessment.

This course provides students with a strong foundation in Linux, Python, and TCL scripting for VLSI design, preparing them to address the challenges of modern VLSI design environments through effective automation and scripting techniques.

**Recommended Books**

- Practical Linux for Systems Administrators (6th Edition) by Mark G. Sobell
- Python for Data Analysis (2nd Edition) by Wes McKinney
- Mastering TCL/TK: A Comprehensive Guide to the Tcl Programming Language (3rd Edition) by Brent B. Welch
- Linux Command Line: A Complete Introduction (2nd Edition) by William Shotts
- Python Crash Course: A Hands-On, Project-Based Introduction to Programming (2nd Edition) by Eric Matthes
- TCL Programming for Beginners: A Hands-On Guide (2nd Edition) by Kevin T. Smith

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| BS-05 | Biology (Biology for Engineers) | 2L:1T:0P | 3 credits |
|---|---|---|---|

**Module 1**. Introduction

**Purpose:** To convey that Biology is as important a scientific discipline as Mathematics, Physics and Chemistry

Bring out the fundamental differences between science and engineering by drawing a comparison between eye and camera, Bird flying and aircraft. Mention the most exciting aspect of biology as an independent scientific discipline. Why we need to study biology? Discuss how biological observations of 18$^{th}$ Century that lead to major discoveries. Examples from Brownian motion and the origin of thermodynamics by referring to the original observation of Robert Brown and Julius Mayor. These examples will highlight the fundamental importance of observations in any scientific inquiry.

**Module 2**. Classification

**Purpose:** To convey that classification per se is not what biology is all about. The underlying criterion, such as morphological, biochemical or ecological be highlighted.

Hierarchy of life forms at phenomenological level. A common thread weaves this hierarchy Classification. Discuss classification based on (a) cellularity- Unicellular or multicellular (b) ultrastructure- prokaryotes or eucaryotes. (c) energy and Carbon utilization -Autotrophs, heterotrophs, lithotropes (d) Ammonia excretion – aminotelic, uricoteliec, ureotelic (e) Habitata- acquatic or terrestrial (e) Molecular taxonomy- three major kingdoms of life. A given organism can come under different category based on classification. Model organisms for the study of biology come from different groups. E.coli, S.cerevisiae, D. Melanogaster, C. elegance, A. Thaliana, M. musculus

**Module 3** -Genetics

**Purpose:** To convey that "Genetics is to biology what Newton's laws are to Physical Sciences"

Mendel's laws, Concept of segregation and independent assortment. Concept of allele. Gene mapping, Gene interaction, Epistasis. Meiosis and Mitosis be taught as a part of genetics. Emphasis to be give not to the mechanics of cell division nor the phases but how genetic material passes from parent to offspring. Concepts of recessiveness and dominance. Concept of mapping of phenotype to genes. Discuss about the single gene disorders in humans. Discuss the concept of complementation using human genetics.

**Module 4**.-Biomolecules

**Purpose**: To convey that all forms of life has the same building blocks and yet the manifestations are as diverse as one can imagine

Molecules of life. In this context discuss monomeric units and polymeric structures. Discuss about sugars, starch and cellulose. Amino acids and proteins. Nucleotides and DNA/RNA. Two carbon units and lipids

**Module 5**. Enzymes

**Purpose**: To convey that without catalysis life would not have existed on earth

Enzymology: How to monitor enzyme catalyzed reactions. How does an enzyme catalyze reactions. Enzyme classification. Mechanism of enzyme action. Discuss at least two examples. Enzyme kinetics and kinetic parameters. Why should we know these parameters to understand biology? RNA catalysis.

**Module 6**. Information Transfer

**Purpose:** The molecular basis of coding and decoding genetic information is universal

Molecular basis of information transfer. DNA as a genetic material. Hierarchy of DNA structure- from single stranded to double helix to nucleosomes. Concept of genetic code. Universality and degeneracy of genetic code. Define gene in terms of complementation and recombination. DICOM Image formats, The DNA Technology (Use and Application) Regulation Bill, 2019

**Module 7**. Macromolecular analysis

**Purpose:** How to analyses biological processes at the reductionistic level

Proteins- structure and function. Hierarch in protein structure. Primary secondary, tertiary and quaternary structure. Proteins as enzymes, transporters, receptors and structural elements.

**Module 8**.- Metabolism

**Purpose**: The fundamental principles of energy transactions are the same in physical and biological world.

Thermodynamics as applied to biological systems. Exothermic and endothermic versus endergonic and exergoinc reactions. Concept of Keq and its relation to standard free energy. Spontaneity. ATP as an energy currency. This should include the breakdown of glucose to CO2 + H2O (Glycolysis and Krebs cycle) and synthesis of glucose from CO2 and H2O (Photosynthesis). Energy yielding and energy consuming reactions. Concept of Energy charge

**Module 9**. Microbiology

Concept of single celled organisms. Concept of species and strains. Identification and classification of microorganisms. Microscopy. Ecological aspects of single celled organisms. Sterilization and media compositions. Growth kinetics.

**References:**


1) General Biology, Uma Devi Koduru, Khanna Book Publishing Company.
2) Biology: A global approach: Campbell, N. A.; Reece, J. B.; Urry, Lisa; Cain, M, L.; Wasserman, S. A.; Minorsky, P. V.; Jackson, R. B. Pearson Education Ltd
3) Outlines of Biochemistry, Conn, E.E; Stumpf, P.K; Bruening, G; Doi, R.H., John Wiley and Sons
4) Principles of Biochemistry (V Edition), By Nelson, D. L.; and Cox, M. M.W.H. Freeman and Company
5) Molecular Genetics (Second edition), Stent, G. S.; and Calender, R.W.H. Freeman and company, Distributed by Satish Kumar Jain for CBS Publisher
6) Microbiology, Prescott, L.M J.P. Harley and C.A. Klein 1995. 2nd edition Wm, C. Brown Publishers


**Course Outcomes**

After studying the course, the student will be able to:

- Describe how biological observations of 18th Century that lead to major discoveries.
- Convey that classification *per se* is not what biology is all about but highlight the underlying criteria, such as morphological, biochemical and ecological
- Highlight the concepts of recessiveness and dominance during the passage of genetic material from parent to offspring
- Convey that all forms of life have the same building blocks and yet the manifestations are as diverse as one can imagine
- Classify enzymes and distinguish between different mechanisms of enzyme action.
- Identify DNA as a genetic material in the molecular basis of information transfer.
- Analyse biological processes at the reductionistic level
- Apply thermodynamic principles to biological systems.
- Identify and classify microorganisms

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|---|---|---|
| **Course Code** | **:** | **ES-05** |
| **Course Title** | **:** | **Digital Fabrication / Workshop/Manufacturing Practices** |
| **Number of Credits** | **:** | **2 (L: 0, T: 0, P: 4)** |
| **Course Category** | **:** | **Engineering Science Courses** |

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|---|---|---|---|
| **ES- 05** | **Digital Fabrication** | **0L:0T:4P** | **2 credits** |

**Course Objective:**

The course is designed to impart knowledge and skills related to 3D printing technologies, selection of material and equipment and develop a product using this technique in Industry 4.0 environment.

**Course Content:**

**1. 3D Printing (Additive Manufacturing)**

Introduction, Process, Classification, Advantages, Additive V/s Conventional Manufacturing processes, Applications.

**2. CAD for Additive Manufacturing**

CAD Data formats, Data translation, Data loss, STL format.

**5. Additive Manufacturing Techniques**

3.1 Stereo- Lithography, LOM, FDM, SLS, SLM, Binder Jet technology.
3.2 Process, Process parameter, Process Selection for various applications.
3.3 Additive Manufacturing Application Domains: Aerospace, Electronics, Health Care, Defence, Automotive, Construction, Food Processing, Machine Tools

4. **Materials**

4.1 Polymers, Metals, Non-Metals, Ceramics
4.2 Various forms of raw material- Liquid, Solid, Wire, Powder; Powder Preparation and their desired properties, Polymers and their properties.
4.3 Support Materials

5. **Additive Manufacturing Equipment**

5.1 Process Equipment- Design and process parameters
5.2 Governing Bonding Mechanism

5.3 Common faults and troubleshooting
5.4 Process Design

6. **Post Processing: Requirement and Techniques**
7. **Product Quality**
   7.1 Inspection and testing
   7.2 Defects and their causes

**LIST OF PRACTICALS**

1. 3D Modelling of a single component.
2. Assembly of CAD modelled Components
3. Exercise on CAD Data Exchange.
6. Generation of .stl files.
7. Identification of a product for Additive Manufacturing and its AM process plan.
8. Printing of identified product on an available AM machine.
9. Post processing of additively manufactured product.
10. Inspection and defect analysis of the additively manufactured product.
11. Comparison of Additively manufactured product with conventional manufactured counterpart.

**Text/Reference Books:**


1. **AICTE's Prescribed Textbook: Workshop / Manufacturing Practices (with Lab Manual), Khanna Book Publishing Co.**
2. Lan Gibson, David W. Rosen and Brent Stucker, "Additive Manufacturing Technologies:
   Rapid Prototyping to Direct Digital Manufacturing", Springer, 2010.
3. Andreas Gebhardt, "Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing", Hanser Publisher, 2011.
4. Sabrie Soloman, "3D Printing and Design", Khanna Publishing House, Delhi.
5. CK Chua, Kah Fai Leong, "3D Printing and Rapid Prototyping- Principles and Applications", World Scientific, 2017.
6. J.D. Majumdar and I. Manna, "Laser-Assisted Fabrication of Materials", Springer Series in
   Material Science, 2013.
7. L. Lu, J. Fuh and Y.S. Wong, "Laser-Induced Materials and Processes for Rapid Prototyping", Kulwer Academic Press, 2001.
8. Zhiqiang Fan And Frank Liou, "Numerical Modelling of the Additive Manufacturing (AM)
   Processes of Titanium Alloy", InTech, 2012.

**Course Outcomes**:

After completion of this course, the students will be able to:

1. Develop CAD models for 3D printing.
2. Import and Export CAD data and generate. stl file.
3. Select a specific material for the given application.
4. Select a 3D printing process for an application.
5. Produce a product using 3D Printing or Additive Manufacturing (AM).

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|---|---|---|---|
| **ES- 05** | **Workshop/Manufacturing Practices** | **0L:0T:4P** | **2 credits** |

**Course Objective:**

1. To provide exposure to the students with hands on experience on various basic engineering practices in Civil, Mechanical, Electrical and Electronics Engineering.
2. To have a study and hands-on-exercise on plumbing and carpentry components.
3. To have a practice on gas welding, foundry operations and fitting
4. To have a study on measurement of electrical quantities, energy and resistance to earth.
5. To have a practice on soldering.

**Course Content:**

**Module I:** Manufacturing Methods- casting, forming, machining, joining, advanced manufacturing methods.
**Module II:** CNC machining, Additive manufacturing.
**Module III:** Fitting operations & power tools.
**Module IV:** Electrical & Electronics.
**Module V:** Carpentry.
**Module VI:** Plastic moulding, glass cutting.
**Module VII:** Metal casting.
**Module VIII:** Welding (arc welding & gas welding), brazing.

**Practicals:**

1. Machine shop
2. Fitting shop
3. Carpentry
4. Electrical & Electronics
5. Welding shop (Arc welding + Gas welding)
6. Casting
7. Smithy
8. Plastic moulding & Glass Cutting

***Examinations could involve the actual fabrication of simple components, utilizing one or more of the techniques covered above.***

**Suggested Text/Reference Books:**

1. Hajra Choudhury S.K., Hajra Choudhury A.K. and Nirjhar Roy S.K., "Elements of Workshop Technology", Vol. I 2008 and Vol. II 2010, Media promoters and publishers private limited, Mumbai**.**
2. Kalpakjian S. And Steven S. Schmid, "Manufacturing Engineering and Technology", 4th edition, Pearson Education India Edition, 2002.
3. Gowri P. Hariharan and A. Suresh Babu," Manufacturing Technology – I" Pearson Education, 2008.
4. Roy A. Lindberg, "Processes and Materials of Manufacture", 4th edition, Prentice Hall India, 1998.
5. Rao P.N., "Manufacturing Technology", Vol. I and Vol. II, Tata McGraw Hill House, 2017.

**EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:**

| S. No. | Experiment Name | Experiment Link(s) |
|---|---|---|
| 1 | Welding shop (Arc welding + Gas welding). | http://mm-coep.vlabs.ac.in/LaserSpotWelding/Theory.html?domain=Mechanical%20Engineering&lab=Welcome%20to%20Micromachining%20laboratory |
| 2 | Casting | http://fab-coep.vlabs.ac.in/exp7/Theory.html?domain=Mechanical%20Engineering&lab=Welcome%20to%20FAB%20laboratory |

**Course Outcomes:** Upon completion of this course, the students will gain knowledge of the different manufacturing processes which are commonly employed in the industry, to fabricate components using different materials.

**Laboratory Outcomes:**

Upon completion of this laboratory course, students will be able:

- To fabricate components with their own hands.
- To relate practical knowledge of the dimensional accuracies and dimensional tolerances possible with different manufacturing processes.
- To design small devices of their interest by assembling different components.

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| HSM (H-102) | Universal Human Values-II: Understanding Harmony And Ethical Human Conduct | 2L:1T:0P | 3 Credits |
|---|---|---|---|

**Pre-requisites:** None. Universal Human Values 1 (Desirable)

**1-COURSES ON HUMAN VALUES**

During the Induction Program, students would get an initial exposure to human values through Universal Human Values-I. This exposure is to be augmented by this compulsory full semester foundation course.

**Objectives of UHV-II Course**

This introductory course input is intended:

1. To help the students appreciate the essential complementarily between 'VALUES' and 'SKILLS' to ensure sustained happiness and prosperity which are the core aspirations of all human beings.
2. To facilitate the development of a Holistic perspective among students towards life and profession as well as towards happiness and prosperity based on a correct understanding of the Human reality and the rest of existence. Such a holistic perspective forms the basis of Universal Human Values and movement towards value-based living in a natural way.
3. To highlight plausible implications of such a Holistic understanding in terms of ethical human conduct, trustful and mutually fulfilling human behavior and mutually enriching interaction with Nature.

Thus, this course is intended to provide a much-needed orientational input in value education to the young enquiring minds.

**Salient Features of the Course**

The salient features of this course are:

1. It presents a universal approach to value education by developing the right understanding of reality (i.e. a worldview of the reality "as it is") through the process of self-exploration.
2. The whole course is presented in the form of a dialogue whereby a set of proposals about various aspects of the reality are presented and the students are encouraged to self-explore the proposals by verifying them on the basis of their natural acceptance within oneself and validate experientially in living.
3. The prime focus throughout the course is toward affecting a qualitative transformation in the life of the student rather than just a transfer of information.
4. While introducing the holistic worldview and its implications, a critical appraisal of the prevailing notions is also made to enable the students discern the difference on their own right.

**Course Methodology**

1. The methodology of this course is explorational and thus universally adaptable. It involves a systematic and rational study of the human being vis-à-vis the rest of existence.
2. The course is in the form of 28 lectures (discussions) and 14 practice sessions.
3. It is free from any dogma or value prescriptions.

4. It is a process of self-investigation and self-exploration, and not of giving sermons. Whatever is found as truth or reality is stated as a proposal and the students are facilitated to verify it in their own right, based on their Natural Acceptance and subsequent Experiential Validation – the whole existence is the lab and every activity is a source of reflection.
5. This process of self-exploration takes the form of a dialogue between the teacher and the students to begin with, and then to continue within the student in every activity, leading to continuous self-evolution.
6. This self-exploration also enables them to critically evaluate their pre-conditionings and present beliefs.

**2-COURSE TOPICS**

The course has 28 lectures and 14 tutorials in 5 modules. The lectures and tutorials are of 01-hour duration. Tutorial sessions are to be used to explore and practice what has been proposed during the lecture sessions.

The Teacher's Manual provides the outline for lectures as well as practice sessions. The teacher is expected to present the issues to be discussed as propositions and encourage the students to have a dialogue.

**The syllabus for the lectures and practice sessions is given below:**

**Module 1 – Introduction to Value Education (6 lectures and 3 tutorials for practice session)**

**Lecture 1:** Right Understanding, Relationship and Physical Facility (Holistic Development and the Role of Education)

**Lecture 2:** Understanding Value Education

**Tutorial 1**: **Practice Session PS1** Sharing about Oneself

**Lecture 3:** Self-exploration as the Process for Value Education

**Lecture 4:** Continuous Happiness and Prosperity – the Basic Human Aspirations

**Tutorial 2: Practice Session PS2** Exploring Human Consciousness

**Lecture 5:** Happiness and Prosperity – Current Scenario

**Lecture 6:** Method to Fulfill the Basic Human Aspirations

**Tutorial 3: Practice Session PS3** Exploring Natural Acceptance

**Expected outcome:**

The students start exploring themselves: get comfortable with each other and with the teacher; they start appreciating the need and relevance for the course.

The students start finding that technical education without study of human values can generate more problems than solutions. They also start feeling that lack of understanding of human values is the root cause of most of the present-day problems; and a sustained solution could emerge only through understanding of value-based living. Any solution brought out through fear, temptation of dogma will not be sustainable.

The students are able to see that verification on the basic of natural acceptance and experiential validation through living is the only way to verify right or wrong, and referring to any external source like text or instrument or any other person cannot enable them to verify with authenticity; it will only develop assumptions.

The students are able to see that their practice in living is not in harmony with their natural acceptance most of the time, and all they need to do is to refer to their natural acceptance to overcome this disharmony.

The students are able to see that lack of right understanding leading to lack of relationship is the major cause of problems in their family and not the lack of physical facility in most of the cases, while they have given higher priority to earning of physical facility in their life giving less value to or even ignoring relationships and not being aware that right understanding is the most important requirement for any human being.

**Module 2 – Harmony in the Human Being (6 lectures and 3 tutorials for practice session)**

**Lecture 7:** Understanding Human being as the Co-existence of the Self and the Body
**Lecture 8:** Distinguishing between the Needs of the Self and the Body
**Tutorial 4: Practice Session PS4** Exploring the difference of Needs of Self and Body
**Lecture 9:** The Body as an Instrument of the Self
**Lecture 10:** Understanding Harmony in the Self
**Tutorial 5: Practice Session PS5** Exploring Sources of Imagination in the Self
**Lecture 11:** Harmony of the Self with the Body
**Lecture 12:** Programme to ensure self-regulation and Health
**Tutorial 6: Practice Session PS6** Exploring Harmony of Self with the Body

**Expected outcome:**

The students are able to see that they can enlist their desires and the desires are not vague. Also they are able to relate their desires to ‘I’ and ‘Body’ distinctly. If any desire appears related to both, they are able to see that the feeling is related to I while the physical facility is related to the body. They are also able to see that ‘I’ and Body are two realities, and most of their desires are related to ‘I’ and not body, while their efforts are mostly centered on the fulfilment of the needs of the body assuming that it will meet the needs of ‘I’ too.

The students are able to see that all physical facility they are required for a limited time in a limited quantity. Also, they are able to see that in case of feelings, they want continuity of the naturally acceptable feelings and they do not want feelings which are not naturally acceptable even for a single moment.

The students are able to see that activities like understanding, desire, though and selection are the activities of ‘I’ only the activities like breathing, palpitation of different parts of the body are fully the activities of the body with the acceptance of ‘I’ while the activities they do with their sense organs like hearing through ears, seeing through eyes, sensing through touch, tasting through tongue and smelling through nose or the activities they do with their work organs like hands, legs etc. are such activities that require the participation of both ‘I’ and body.

The students become aware of their activities of ‘I’ and start finding their focus of attention at different moments. Also they are able to see that most of their desires are coming from outside (through preconditioning or sensation) and are not based on their natural acceptance

The students are able to list down activities related to proper upkeep of the body and practice them in their daily routine. They are also able to appreciate the plants wildly growing in and around the campus which can be beneficial in curing different diseases.

**Module 3 – Harmony in the Family and Society (6 lectures and 3 tutorials for practice session)**

**Lecture 13:** Harmony in the Family – the Basic Unit of Human Interaction
**Lecture 14:** 'Trust' – the Foundational Value in Relationship
**Tutorial 7: Practice Session PS7** Exploring the Feeling of Trust
**Lecture 15:** 'Respect' – as the Right Evaluation
**Tutorial 8: Practice Session PS8** Exploring the Feeling of Respect
**Lecture 16:** Other Feelings, Justice in Human-to-Human Relationship
**Lecture 17:** Understanding Harmony in the Society
**Lecture 18:** Vision for the Universal Human Order
**Tutorial 9: Practice Session PS9** Exploring Systems to fulfil Human Goal

**Expected outcome:**

The students are able to note that the natural acceptance (intention) is always for living in harmony, only competence is lacking! We generally evaluate ourselves on the basis of our intention and others on the basis of their competence! We seldom look at our competence and others’ intention as a result we conclude that I am a good person and other is a bad person.

The students are able to see that respect is right evaluation, and only right evaluation leads to fulfilment in relationship. Many present problems in the society are an outcome of differentiation (lack of understanding of respect), like gender biasness, generation gap, caste conflicts, class struggle, dominations through power play, communal violence, clash of isms and so on so forth. All these problems can be solved by realizing that the other is like me as he has the same natural acceptance, potential and program to ensure a happy and prosperous life for them and for others through he may have different body, physical facility or beliefs.

The students are able to use their creativity for education children. The students are able to see that they can play a role in providing value education for children. They are able to put in simple words the issues that are essential to understand for children and comprehensible to them. The students are able to develop an outline of holistic model for social science and compare it with the existing model.

**Module 4 – Harmony in the Nature/Existence (4 lectures and 2 tutorials for practice session)**

**Lecture 19:** Understanding Harmony in the Nature
**Lecture 20:** Interconnectedness, self-regulation and Mutual Fulfilment among the Four Orders of Nature
**Tutorial 10: Practice Session PS10** Exploring the Four Orders of Nature

**Lecture 21:** Realizing Existence as Co-existence at All Levels
**Lecture 22:** The Holistic Perception of Harmony in Existence
**Tutorial 11: Practice Session PS11** Exploring Co-existence in Existence

**Expected outcome:**
The students are able to differentiate between the characteristics and activities of different orders and study the mutual fulfilment among them. They are also able to see that human being s are not fulfilling to other orders today and need to take appropriate steps to ensure right participation (in terms of nurturing, protection and right utilization) in the nature.
The students feel confident that they can understand the whole existence; nothing is a mystery in this existence. They are also able to see the interconnectedness in the nature, and point out how different courses of study relate to the different units and levels. Also, they are able to make out how these courses can be made appropriate and holistic.

**Module 5 – Implications of the Holistic Understanding – a Look at Professional Ethics (6 lectures and 3 tutorials for practice session)**
**Lecture 23:** Natural Acceptance of Human Values
**Lecture 24:** Definitiveness of (Ethical) Human Conduct
**Tutorial 12: Practice Session PS12** Exploring Ethical Human Conduct
**Lecture 25:** A Basis for Humanistic Education, Humanistic Constitution and Universal Human Order
**Lecture 26**: Competence in Professional Ethics
**Tutorial 13: Practice Session PS13** Exploring Humanistic Models in Education
**Lecture 27:** Holistic Technologies, Production Systems and Management Models-Typical Case Studies
**Lecture 28:** Strategies for Transition towards Value-based Life and Profession
**Tutorial 14: Practice Session PS14** Exploring Steps of Transition towards Universal Human Order

**Expected outcome:**
The students are able to present sustainable solutions to the problems in society and nature. They are also able to see that these solutions are practicable and draw roadmaps to achieve them.
The students are able to grasp the right utilization of their knowledge in their streams of Technology/Engineering/Management/any other area of study to ensure mutual fulfilment. E.g. mutually enriching production system with rest of nature.
The students are able to sincerely evaluate the course and share with their friends. They are also able to suggest measures to make the course more effective and relevant. They are also able to make use of their understanding in the course for the happy and prosperous family and society.

**Guidelines and Content for Practice Sessions (Tutorials)**
In order to connect the content of the proposals with practice (living), 14 practice sessions have been designed. The full set of practice sessions is available in the Teacher's Manual as well as the website.
Practice Sessions for Module 1 – Introduction to Value Education

PS1 Sharing about Oneself
PS2 Exploring Human Consciousness
PS3 Exploring Natural Acceptance

Practice Sessions for Module 2 – Harmony in the Human Being
PS4 Exploring the difference of Needs of Self and Body
PS5 Exploring Sources of Imagination in the Self
PS6 Exploring Harmony of Self with the Body

Practice Sessions for Module 3 – Harmony in the Family and Society
PS7 Exploring the Feeling of Trust
PS8 Exploring the Feeling of Respect
PS9 Exploring Systems to fulfil Human Goal

Practice Sessions for Module 4 – Harmony in the Nature (Existence)
PS10 Exploring the Four Orders of Nature
PS11 Exploring Co-existence in Existence

Practice Sessions for Module 5 – Implications of the Holistic Understanding – a Look at Professional Ethics
PS12 Exploring Ethical Human Conduct
PS13 Exploring Humanistic Models in Education
PS14 Exploring Steps of Transition towards Universal Human Order

As an example, PS 7 is a practice session in module 3 regarding trust. It is explained below:

**PS 7:** Form small groups in the class and in that group initiate dialogue and ask the eight questions related to trust. The eight questions are:

| | |
|---|---|
| 1a. Do I want to make myself happy? | 1b. Am I able to make myself always happy? |
| 2a. Do I want to make the other happy? | 2b. Am I able to make the other always happy? |
| 3a. Does the other want to make him happy? | 3b. Is the other able to make him always happy? |
| 4a. Does the other want to make me happy? | 4b. Is the other able to make me always happy? |
| Intention (Natural Acceptance) | Competence |
| What is the answer? | What is the answer? |

Let each student answer the questions for himself/herself and everyone else. Discuss the difference between intention and competence. Observe whether you evaluate your intention and competence as well as the others' intention and competence.

**Expected outcome of PS 7:** The students are able to see that the first four questions are related to our Natural Acceptance i.e. intention and the next four to our Competence. They are able to note that the intention is always correct, only competence is lacking! We generally evaluate ourselves on the basis of our intention and others on the basis of their competence! We seldom look at our competence and others' intention, as a result we conclude that I am a good person and other is a bad person.

**3-READINGS:**

**3-1-Text Book and Teachers Manual**

a. The Textbook - A Foundation Course in Human Values and Professional Ethics, R R Gaur, R Asthana, G P Bagaria, 2nd Revised Edition, Excel Books, New Delhi, 2019. ISBN 978-93-87034-47-1

b. The Teacher's Manual- Teachers' Manual for A Foundation Course in Human Values and Professional Ethics, RR Gaur, R Asthana, G P Bagaria, 2nd Revised Edition, Excel Books, New Delhi, 2019. ISBN 978-93-87034-53

c. Professional Ethics and Human Values, Premvir Kapoor, ISBN: 978-93-86173-652, Khanna Book Publishing Company, New Delhi, 2022.

**3-2-Reference Books**

1. JeevanVidya: EkParichaya, A Nagaraj, JeevanVidyaPrakashan, Amarkantak, 1999.
2. Human Values, A.N. Tripathi, New Age Intl. Publishers, New Delhi, 2004.
3. The Story of Stuff (Book).
4. The Story of My Experiments with Truth - by Mohandas Karamchand Gandhi
5. Small is Beautiful - E. F Schumacher.
6. Slow is Beautiful - Cecile Andrews
7. Economy of Permanence - J C Kumarappa
8. Bharat Mein Angreji Raj – Pandit Sunderlal
9. Rediscovering India - by Dharampal
10. Hind Swaraj or Indian Home Rule - by Mohandas K. Gandhi
11. India Wins Freedom - Maulana Abdul Kalam Azad
12. Vivekananda - Romain Rolland (English)
13. Gandhi - Romain Rolland (English)

**4-MODE OF CONDUCT (L-T-P-C 2-1-0-3)**

Lecture hours are to be used for interactive discussion, placing the proposals about the topics at hand and motivating students to reflect, explore and verify them.

Tutorial hours are to be used for practice sessions.

While analysing and discussing the topic, the faculty mentor's role is in pointing to essential elements to help in sorting them out from the surface elements. In other words, help the students explore the important or critical elements.

In the discussions, particularly during practice sessions (tutorials), the mentor encourages the student to connect with one's own self and do self-observation, self-reflection and self-exploration.

Scenarios may be used to initiate discussion. The student is encouraged to take up" ordinary" situations rather than" extra-ordinary" situations. Such observations and their analyses are shared and discussed with other students and faculty mentor, in a group sitting.

Tutorials (experiments or practical) are important for the course. The difference is that the laboratory is everyday life, and practical are how you behave and work in real life. Depending on the nature of topics, worksheets, home assignment and/or activity are included. The practice sessions (tutorials) would also provide support to a student in performing actions commensurate to his/her beliefs. It is intended that this would lead to development of commitment, namely behaving and working based on basic human values.

It is recommended that this content be placed before the student as it is, in the form of a basic foundation course, without including anything else or excluding any part of this content. Additional content may be offered in separate, higher courses.

**This course is to be taught by faculty from every teaching department.**

**Teacher preparation with a minimum exposure to at least one 8-day Faculty Development Program on Universal Human Values is deemed essential.**

**5-SUGGESTED ASSESSMENT:**

This is a compulsory credit course. The assessment is to provide a fair state of development of the student, so participation in classroom discussions, self-assessment, peer assessment etc. will be used in evaluation.

**Example:**

Assessment by faculty mentor: 10 marks

Self-assessment: 10 marks

Assessment by peers: 10 marks

Socially relevant project/Group Activities/Assignments: 20 marks

Semester End Examination: 50 marks

The overall pass percentage is 40%. In case the student fails, he/she must repeat the course.

**6-OUTCOME OF THE COURSE:**

By the end of the course, students are expected to become more aware of themselves, and their surroundings (family, society, nature); they would become more responsible in life, and in handling problems with sustainable solutions, while keeping human relationships and human nature in mind.

They would have better critical ability. They would also become sensitive to their commitment towards what they have understood (human values, human relationship and human society). It is hoped that they would be able to apply what they have learnt to their own self in different day-to-day settings in real life, at least a beginning would be made in this direction.

Therefore, the course and further follow up is expected to positively impact common graduate attributes like:

1. Holistic vision of life
2. Socially responsible behaviour
3. Environmentally responsible work
4. Ethical human conduct
5. Having Competence and Capabilities for Maintaining Health and Hygiene

6. Appreciation and aspiration for excellence (merit) and gratitude for all

This is only an introductory foundational input. It would be desirable to follow it up by
a) Faculty-student or mentor-mentee programs throughout their time with the institution
b) Higher level courses on human values in every aspect of living.

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| | | |
|---|---|---|
| **Course Code** | **:** | **AU- 02** |
| **Course Title** | **:** | **Sports and Yoga** |
| **Number of Credits** | **:** | **0 (L: 2^, T: 0, P: 0)** |
| **Course Category** | **:** | **AU** |

**Course Objective(s):**

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

**Course Contents:**

**Module I: Introduction to Physical Education**

- Meaning & definition of Physical Education
- Aims & Objectives of Physical Education
- Changing trends in Physical Education

**Module II: Olympic Movement**

- Ancient & Modern Olympics (Summer & Winter)
- Olympic Symbols, Ideals, Objectives & Values
- Awards and Honours in the field of Sports in India (Dronacharya Award, Arjuna Award, Dhayanchand Award, Rajiv Gandhi Khel Ratna Award etc.)

**Module III: Physical Fitness, Wellness & Lifestyle**

- Meaning & Importance of Physical Fitness & Wellness
- Components of Physical fitness
- Components of Health related fitness
- Components of wellness
- Preventing Health Threats through Lifestyle Change
- Concept of Positive Lifestyle

**Module IV: Fundamentals of Anatomy & Physiology in Physical Education, Sports and Yoga**

- Define Anatomy, Physiology & Its Importance
- Effect of exercise on the functioning of Various Body Systems. (Circulatory System, Respiratory System, Neuro-Muscular System etc.)

**Module V: Kinesiology, Biomechanics & Sports**

- Meaning & Importance of Kinesiology & Biomechanics in Physical Edu. & Sports
- Newton's Law of Motion & its application in sports.
- Friction and its effects in Sports.

**Module VI: Postures**

- Meaning and Concept of Postures.
- Causes of Bad Posture.
- Advantages & disadvantages of weight training.
- Concept & advantages of Correct Posture.
- Common Postural Deformities – Knock Knee; Flat Foot; Round Shoulders; Lordosis, Kyphosis, Bow Legs and Scoliosis.
- Corrective Measures for Postural Deformities

**Module VII: Yoga**

- Meaning & Importance of Yoga
- Elements of Yoga
- Introduction - Asanas, Pranayama, Meditation & Yogic Kriyas
- Yoga for concentration & related Asanas (Sukhasana; Tadasana; Padmasana & Shashankasana)
- Relaxation Techniques for improving concentration - Yog-nidra

**Module VIII: Yoga & Lifestyle**

- Asanas as preventive measures.
- Hypertension: Tadasana, Vajrasana, Pavan Muktasana, Ardha Chakrasana, Bhujangasana, Sharasana.
- Obesity: Procedure, Benefits & contraindications for Vajrasana, Hastasana, Trikonasana, Ardh Matsyendrasana.
- Back Pain: Tadasana, Ardh Matsyendrasana, Vakrasana, Shalabhasana, Bhujangasana.
- Diabetes: Procedure, Benefits & contraindications for Bhujangasana, Paschimottasana, Pavan Muktasana, Ardh Matsyendrasana.
- Asthema: Procedure, Benefits & contraindications for Sukhasana, Chakrasana, Gomukhasana, Parvatasana, Bhujangasana, Paschimottasana, Matsyasana.

**Module IX: Training and Planning in Sports**

- Meaning of Training
- Warming up and limbering down
- Skill, Technique & Style
- Meaning and Objectives of Planning.
- Tournament – Knock-Out, League/Round Robin & Combination.

**Module X: Psychology & Sports**

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

**Module XI: Doping**

- Meaning and Concept of Doping
- Prohibited Substances & Methods
- Side Effects of Prohibited Substances

**Module XII: Sports Medicine**

- First Aid – Definition, Aims & Objectives.
- Sports injuries: Classification, Causes & Prevention.
- Management of Injuries: Soft Tissue Injuries and Bone & Joint Injuries

**Module XIII: Sports / Games**

Following subtopics related to any one Game/Sport of choice of student out of: Athletics, Badminton, Basketball, Chess, Cricket, Kabaddi, Lawn Tennis, Swimming, Table Tennis, Volleyball, Yoga etc.

- History of the Game/Sport.
- Latest General Rules of the Game/Sport.
- Specifications of Play Fields and Related Sports Equipment.
- Important Tournaments and Venues.
- Sports Personalities.
- Proper Sports Gear and its Importance.

**Text Books/References**:

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

**Course Outcomes:** On successful completion of the course the students will be able:

1. To practice Physical activities and Hatha Yoga focusing on yoga for strength, flexibility, and relaxation.
2. To learn techniques for increasing concentration and decreasing anxiety which leads to stronger academic performance.
3. To learn breathing exercises and healthy fitness activities
4. To understand basic skills associated with yoga and physical activities including strength and flexibility, balance and coordination.
5. To perform yoga movements in various combination and forms.
6. To assess current personal fitness levels.
7. To identify opportModuleies for participation in yoga and sports activities.
8. To develop understanding of health-related fitness components: cardiorespiratory endurance, flexibility and body composition etc.
9. To improve personal fitness through participation in sports and yogic activities.
10. To develop understanding of psychological problems associated with the age and lifestyle.
11. To demonstrate an understanding of sound nutritional practices as related to health and physical performance.
12. To assess yoga activities in terms of fitness value.
13. To identify and apply injury prevention principles related to yoga and physical fitness activities.
14. To understand and correctly apply biomechanical and physiological principles elated to exercise and training.

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# SEMESTER – III

| SSC-01 | Control Systems | 2L:0T:0P | 2 credits |
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**Course Description:**

This course serves as an introduction to the fundamental principles of control systems in engineering. Students will delve into key concepts such as feedback, open-loop and closed-loop control, mathematical modeling of dynamic systems, transfer functions, block diagrams, time and frequency domain analysis, stability criteria (Routh-Hurwitz, Nyquist, and Bode plots), system response (transient and steady-state), and PID controller design. The curriculum encompasses various types of control systems, including linear, non-linear, analog, and digital systems, as well as different control strategies and basic control laws. Practical applications, simulations, and exercises are incorporated to provide hands-on experience in understanding and analyzing control systems.

**Course Outcomes:**

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

1. Understand the fundamental principles of control systems engineering.
2. Differentiate between open-loop and closed-loop control systems.
3. Mathematically model dynamic systems and derive transfer functions.
4. Analyze systems using block diagrams in both time and frequency domains.
5. Apply stability criteria, including Routh-Hurwitz, Nyquist, and Bode plots.
6. Analyze system responses in transient and steady-state conditions.
7. Design PID controllers for dynamic systems.
8. Classify and understand various types of control systems, including linear, non-linear, analog, and digital systems.
9. Apply different control strategies to engineering problems.
10. Implement basic control laws in practical applications.

**Teaching Schedule:**

Weeks 1-3: Introduction to Control Systems

- Definition and importance of control systems
- Feedback and its role in engineering
- Open-loop vs. closed-loop control systems

Weeks 4-6: Mathematical Modeling and Transfer Functions

- Mathematical representation of dynamic systems
- Derivation of transfer functions
- Block diagrams for system analysis

Weeks 7-9: Time and Frequency Domain Analysis

- Time domain analysis of control systems

- Frequency domain analysis using Bode plots
- Nyquist stability criteria

Weeks 10-12: System Response and Stability

- Analysis of transient and steady-state system responses
- Stability analysis using Routh-Hurwitz criteria
- PID controller design

Weeks 13-15: Advanced Control Systems and Applications

- Types of control systems: linear, non-linear, analog, digital
- Different control strategies and basic control laws
- Practical applications, simulations, and exercises

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Practical applications and simulations should be integrated throughout the course to provide hands-on experience and enhance understanding.

**Recommended Books:**


- Ozbay H. Introduction to feedback control theory. CrC Press; 2019 Jan 22.
- Houpis CH, Sheldon SN. Linear Control System Analysis and Design with MATLAB®. CRC Press; 2013 Oct 30.
- Callier, Frank. Linear System Theory. Springer Science & Business Media, 2012.
- Bavafa-Toosi, Yazdan. Introduction to Linear Control Systems. Academic Press, 2017.
- Hespanha, João. Linear Systems Theory. Princeton University Press, 2018.


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| SSC-02 | Analog and Digital Signal Processing and Communication | 2L:0T:2P | 3 credits |
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**Course Description:**

This comprehensive course explores the principles and applications of signal processing in both the analog and digital domains, with a specific focus on their role in communication systems. Students will gain insights into the design and analysis of filters, including Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, the Fast Fourier Transform (FFT), and basic communication protocols. The course integrates theoretical concepts with practical applications, enabling students to design, analyze, and optimize analog and digital communication systems.

**Course Outcomes:**
Upon successful completion of this course, students will be able to:

1. Understand the fundamental principles of analog and digital signal processing.
2. Analyze and design analog filters, including both FIR and IIR filters, for signal conditioning in communication systems.
3. Apply the Fast Fourier Transform (FFT) for spectral analysis of signals in both time and frequency domains.
4. Design and implement digital filters, including FIR and IIR filters, for signal processing in communication applications.
5. Evaluate the performance of communication systems, considering noise, distortion, and bandwidth constraints.
6. Develop proficiency in the use of relevant software tools for simulation and analysis of signal processing and communication systems.
7. Understand and apply basic communication protocols in the design of digital communication systems.
8. Explore emerging trends and technologies in the field of communication systems.

**Teaching Schedule:**

Week 1-2: Introduction to Signal Processing and Communication

- Overview of signal processing and communication systems.
- Basics of analog and digital signals.

Week 3-4: Analog Signal Processing: Filters (FIR and IIR)

- Filter fundamentals and types.

- Design and analysis of both FIR and IIR filters.

Week 5-6: Frequency Domain Analysis: FFT

- Introduction to the Fast Fourier Transform (FFT).
- FFT applications in signal processing and communication.

Week 7-8: Analog Communication Systems

- Amplitude Modulation (AM) and Frequency Modulation (FM).
- Analog demodulation techniques.

Week 9-10: Digital Signal Processing: Filters (FIR and IIR)

- Design and analysis of digital FIR and IIR filters.
- Applications in signal processing.

Week 11-12: Digital Modulation and Demodulation Techniques

- Digital modulation schemes: Phase Shift Keying (PSK), Frequency Shift Keying (FSK), and Quadrature Amplitude Modulation (QAM).
- Digital demodulation techniques.

Week 13-14: Communication Protocols and Emerging Technologies

- Overview of communication protocols.
- Exploration of emerging trends in communication technologies.

Week 15: Final Project and Review

- Application of signal processing and communication principles in a design project.
- Comprehensive review of the course content and preparation for the final exam.

**Recommended Books**


1. Tenoudji, Frédéric. Analog and Digital Signal Analysis. Springer, 2016.
2. Tan, Lizhe. Digital Signal Processing. Academic Press, 2013.
3. Kronenburger, John. Analog and Digital Signal Processing (Book Only). Cengage Learning, 2007.
4. Yarlagadda, R. Analog and Digital Signals and Systems. Springer Science & Business Media, 2010.
5. Ambardar, Ashok. Analog and Digital Signal Processing. Brooks/Cole, 1995.
6. Bhooshan, Sunil. *Fundamentals of Analogue and Digital Communication Systems*. Springer Nature, 2021.


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| SSC-09 | Data Structure | 2L:0T:0P | 2 credits |
|---|---|---|---|

**Course Description:**

This course introduces fundamental concepts of data structures and algorithms, essential for effective problem-solving in computer science and programming. Students will learn to design, analyze, and implement various data structures such as arrays, linked lists, stacks, queues, trees, and graphs. The course also covers algorithmic techniques, including sorting, searching, recursion, and dynamic programming. Emphasis is placed on understanding the efficiency and trade-offs associated with different data structures and algorithms. Practical application of these concepts will be reinforced through programming assignments and problem-solving exercises.

**Course Outcomes:**

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

1. Understand the fundamental concepts and importance of data structures.
2. Design and implement arrays, linked lists, stacks, and queues.
3. Analyze and implement various tree structures, including binary trees and balanced trees.
4. Model and work with graph data structures.
5. Apply sorting and searching algorithms efficiently.
6. Demonstrate proficiency in recursive problem-solving.
7. Understand the principles of dynamic programming for algorithmic optimization.
8. Evaluate the efficiency and trade-offs of different data structures and algorithms.
9. Apply data structures and algorithms to solve real-world programming challenges.
10. Write efficient and well-organized code for complex problem-solving.

**Teaching Schedule:**

Weeks 1-2: Introduction to Data Structures and Algorithms

- Overview of data structures and algorithms
- Importance and applications of data structures

Weeks 3-4: Arrays and Linked Lists

- Design and implementation of arrays
- Implementation and manipulation of linked lists

Weeks 5-6: Stacks and Queues

- Applications and implementation of stacks
- Queue operations and circular queues

Weeks 7-8: Trees and Binary Trees

- Introduction to tree structures

- Binary tree operations and traversal

Weeks 9-10: Balanced Trees and Graphs
- AVL trees and other balanced trees
- Basics of graph theory and graph representations

Weeks 11-12: Sorting and Searching Algorithms
- Comparison and analysis of sorting algorithms
- Searching techniques and their applications

Weeks 13-14: Recursion and Dynamic Programming
- Recursive problem-solving strategies
- Principles and applications of dynamic programming

Week 15: Review, Project Work, and Practical Applications
- Recap of key concepts and algorithms
- Application of data structures and algorithms in practical scenarios
- Final project work and assessment

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Programming assignments, problem-solving exercises, and a final project should be integrated throughout the course to provide hands-on experience and reinforce theoretical concepts.

**Recommended Books**


1. G.A Vijayalakshmi Pai. *A textbook of Data Structures and Algorithms 1: Mastering Linear Data Structures.* Wiley Online Library, 2023.
2. Steven S. Skiena. *The Algorithm Design Manual*. Springer, 2020.
3. Narasimha Karumanchi. *Data Structures and Algorithms Made Easy*. CareerMonk Publications, 2016.
4. Sachi Nandan Mohanty, Pabitra Kumar Tripathy. Data Structures and Algorithms Using C++: A Practical Implementation. Scrivener Publishing LLC, 2021.


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| PCC-01 | Electronic Devices 1 | 2L:0T:2P | 3 credits |
|---|---|---|---|

Prerequisites

- Basic knowledge of mathematics and physics

**Course Description**

This course provides a comprehensive introduction to electronic devices, focusing on semiconductor physics and the operation of essential devices such as PN junctions, Junction Field Effect Transistors (JFETs), Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs), and a brief overview of Bipolar Junction Transistors (BJTs). The course emphasizes the principles governing the behavior of these devices, their applications, and the practical considerations involved in their design and implementation.

**Course Outcomes**

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

- Understand the basic principles of semiconductor physics
- Analyze and design PN junctions, JFETs, MOSFETs, and BJTs
- Apply electronic devices to design and implement circuits and systems
- Troubleshoot electronic circuits and systems

**Teaching Schedule:**

Week 1-2: Introduction to Semiconductor Physics and PN Junctions

- Semiconductor fundamentals: intrinsic and extrinsic semiconductors.
- PN junction formation, depletion region, and forward/backward bias.

Week 3-4: PN Junction Diode Applications

- Diode characteristics and ideal diode equation.
- Diode circuits: rectifiers, clippers, and clampers.

Week 5-6: Junction Field Effect Transistors (JFETs)

- JFET fundamentals: construction and operation.
- JFET characteristics and applications.

Week 7-8: Introduction to MOSFETs

- MOSFET fundamentals: n-channel and p-channel MOSFETs.
- MOSFET characteristics and regions of operation.

Week 9-10: MOSFET Amplifiers
- MOSFET small-signal analysis.
- Common source, common gate, and common drain amplifier configurations.

Week 11-12: MOSFET Applications
- MOSFET-based digital circuits.
- MOSFET as a switch and its role in digital systems.

Week 13-14: Overview of Bipolar Junction Transistors (BJTs)
- BJT fundamentals: construction and operation.
- BJT characteristics and comparison with MOSFETs.

Week 15: Advanced MOSFET Concepts and Final Review
- MOSFET scaling and technology trends.
- Final review of course content and preparation for the final exam.

This course equips students with a solid foundation in electronic devices, with a special focus on MOSFETs, enabling them to understand, analyze, and design circuits essential to modern electronics. The emphasis on practical applications and problem-solving will prepare students for further studies in the field of electronic devices and integrated circuit design.

**Recommended Books**


- Gray, P. R., Hurst, P. J., & Lewis, S. H. (2015). Analysis and design of analog integrated circuits (5th ed.). Hoboken, NJ: Wiley.
- Rashid, M. H. (2011). Power electronics: Circuits, devices, and applications (4th ed.). Upper Saddle River, NJ: Prentice Hall.
- Boylestad, R. L., & Nashelsky, L. (2009). Electronic devices and circuit theory (10th ed.). Upper Saddle River, NJ: Prentice Hall.
- Sedra, A. S., & Smith, K. C. (2014). Microelectronic circuits (7th ed.). New York, NY: Oxford University Press.
- Neamen, D. A. (2012). Semiconductor physics and devices: Basic principles (4th ed.). Boston, MA: McGraw-Hill.


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| SSC-06 | Circuit and Network Theory | 3L:0T:0P | 3 credits |
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Prerequisites

- Basic knowledge of mathematics and physics

**Course Description:**

This course covers fundamental topics in electrical engineering, including basic circuit elements (resistors, capacitors, inductors), Ohm's and Kirchhoff's laws, nodal and mesh analysis, circuit theorems (Thevenin's and Norton's theorems), transient and steady-state analysis of circuits under DC and AC conditions, impedance and frequency response, and transfer functions. Students delve into linear circuit modeling, network theorems, operational amplifiers, and various passive and active components used in circuit design. The course emphasizes systematic analysis for solving complex electrical circuits, and understanding the behavior of linear circuits using mathematical methods. Practical applications and laboratory work, using simulation software or physical circuits, complement theoretical concepts to provide hands-on experience in analyzing and designing linear circuits.

**Course Outcomes:**

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

1. Understand the fundamental principles of basic circuit elements (resistors, capacitors, inductors).
2. Apply Ohm's and Kirchhoff's laws for circuit analysis.
3. Conduct nodal and mesh analysis for linear electrical circuits.
4. Apply circuit theorems, including Thevenin's and Norton's theorems, for simplifying complex circuits.
5. Analyze transient and steady-state responses of circuits under DC and AC conditions.
6. Analyze impedance and frequency response in linear circuits.
7. Derive and apply transfer functions for linear circuits.
8. Model linear circuits using mathematical methods for analysis.
9. Analyze and design circuits incorporating various passive and active components.
10. Effectively communicate the results of circuit analysis and design.

**Teaching Schedule:**

Weeks 1-3: Introduction to Basic Circuit Elements

- Overview of resistors, capacitors, and inductors
- Application of Ohm's and Kirchhoff's laws

Weeks 4-6: Nodal and Mesh Analysis

- Techniques for nodal and mesh analysis in linear circuits
- Practical applications and problem-solving exercises

Weeks 7-9: Circuit Theorems and Simplification Techniques

- Thevenin's and Norton's theorems
- Application of circuit theorems to simplify complex circuits

Weeks 10-12: Transient and Steady-State Analysis

- Analysis of circuits under DC and AC conditions
- Impedance and frequency response in linear circuits

Weeks 13-15: Transfer Functions and Advanced Topics

- Derivation and application of transfer functions
- Linear circuit modeling, network theorems, and operational amplifiers
- Laboratory work and simulation exercises

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Practical applications and laboratory work should be integrated throughout the course to provide hands-on experience and enhance understanding.

**Recommended Books**

1. Sundararajan, D. *Introductory Circuit Theory*. Springer Nature, 2019.
2. Rakshit, D. *Fundamentals of Electric Circuit Theory*. S. Chand Publishing, 2000.
3. Bird, John. *Bird's Electrical Circuit Theory and Technology*. Routledge, 2021.
4. Sundararajan, D. *Introductory Circuit Theory*. Springer Nature, 2019.

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| SSC-07 | Digital Electronics | 2L:0T:0P | 2 credits |
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**Course Description:**

Digital Electronics is a foundational course designed to provide students with a comprehensive understanding of digital circuits and systems. The course covers essential topics, including binary number systems, digital logic gates, combinational and sequential circuits, memory devices, microprocessor fundamentals, and state machines. Through theoretical instruction and hands-on experiments, students will develop the skills to design, analyze, and troubleshoot digital circuits, laying the groundwork for advanced studies in digital systems.

**Course Outcomes:**

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

1. Understand the fundamentals of digital electronics and binary number systems.
2. Design and analyze combinational logic circuits.
3. Implement and analyze sequential circuits, including state machines.
4. Describe and analyze memory devices used in digital systems.
5. Comprehend the principles of microprocessor architecture.
6. Analyze and design digital circuits for practical applications.
7. Troubleshoot and debug digital circuits effectively.
8. Apply state machines in digital circuit design.
9. Collaborate and work effectively in a team for project-based learning.

**Teaching Schedule:**

Weeks 1-2: Introduction to Digital Electronics

- Binary number systems and their applications
- Basics of digital logic and gates

Weeks 3-4: Combinational Logic Circuits

- Design and analysis of combinational circuits
- Multiplexers, demultiplexers, and encoders

Weeks 5-6: Sequential Circuits and State Machines

- Introduction to flip-flops and latches
- Analysis and design of sequential circuits, including state machines

Weeks 7-8: Memory Devices

- Types of memory devices and their characteristics
- Read-only memory (ROM) and random-access memory (RAM)

Weeks 9-10: Microprocessor Fundamentals

- Basics of microprocessor architecture

Weeks 11-12: Advanced Digital Circuits

- Shift registers and counters
- Digital comparators and arithmetic circuits

Weeks 13-14: Project Work and Practical Applications

- Hands-on project work applying concepts learned throughout the course
- Troubleshooting exercises and debugging practice

Week 15: Final Presentations and Assessment

- Final project presentations
- Comprehensive assessment and review

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Practical experiments, projects, and collaborative learning should be integrated throughout the course to provide hands-on experience and reinforce theoretical concepts.

**Recommended Books**


- Alexander, Axelevitch. *Digital Electronic Circuits - The Comprehensive View*. World Scientific, 2018.
- Lincoln, Betty. *Introduction to Digital Electronics, 1/E*. Pearson Education India.
- Maini, Anil. *Digital Electronics*. John Wiley & Sons, 2007.


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# SEMESTER – IV

| SSC-04 | Computer and Processor Architecture | 2L:0T:2P | 3 credits |
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**Course Description:**

This course provides an in-depth exploration of computer architecture and design, covering key topics such as instruction set architecture, processor design, memory systems, input/output systems, cache memory, pipelining, parallel processing, and performance evaluation for Arm Cortex A architectures. Students gain insights into the organization and structure of modern computer systems, understanding the interplay between hardware and software, addressing techniques, control unit design, and microarchitecture. The course also delves into advanced topics including computer arithmetic, system-on-chip design, and emerging trends in computer architecture, such as parallel computing, energy-efficient designs, and emerging memory technologies.

**Course Outcomes:**

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

1. Explain key concepts in instruction set architecture, processor design, and memory systems.
2. Analyze the organization and structure of modern computer systems.
3. Evaluate the relationship between hardware and software in computer systems.
4. Demonstrate an understanding of addressing techniques and control unit design.
5. Examine microarchitecture and its role in computer system design.
6. Apply knowledge of cache memory and its impact on system performance.
7. Understand and analyze pipelining and parallel processing in computer architecture.
8. Evaluate performance metrics for Cortex A architectures.
9. Apply principles of computer arithmetic in system design.
10. Explore advanced topics such as system-on-chip design and emerging trends in computer architecture.

**Teaching Schedule:**

Weeks 1-3: Introduction to Computer Architecture

- Overview of computer architecture and design
- Instruction set architecture basics
- Processor design principles

Weeks 4-6: Memory Systems and Input/Output Systems

- Understanding memory hierarchies
- Input/output system organization

Weeks 7-9: Cache Memory and Pipelining

- Principles and types of cache memory
- Overview and analysis of pipelining

Weeks 10-12: Parallel Processing and Performance Evaluation

- Concepts of parallel processing in computer architecture
- Performance evaluation for architectures

Weeks 13-15: Advanced Topics and Emerging Trends

- Computer arithmetic and its role in system design
- System-on-chip design and emerging trends in computer architecture
- Discussion on parallel computing, energy-efficient designs, and emerging memory technologies

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Practical examples and case studies should be integrated throughout the course to provide hands-on experience and enhance understanding.

**Recommended Books**


1. Yiu, Joseph. *System-on-Chip Design with Arm® Cortex®-M Processors*. Arm Education Media, 2019.
2. Furber, Stephen. *ARM System-on-Chip Architecture*. Pearson Education, 2000.
3. Sloss, Andrew. *ARM System Developer's Guide*. Elsevier, 2004.
4. Harris, Sarah. *Digital Design and Computer Architecture, RISC-V Edition*. Morgan Kaufmann, 2021.
5. Ledin, Jim. *Modern Computer Architecture and Organization*. Packt Publishing Ltd, 2022.
6. Dalrymple, Monte. *Inside an Open-Source Processor*. 2021.


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| **SSC-05** | **Operating Systems (Real-time and Embedded)** | **2L:0T:0P** | **2 credits** |

**Course Description:**

This course focuses on the intricacies of real-time and embedded operating systems, covering topics such as process management, CPU scheduling, memory management, file systems, input/output management, and resource allocation. Students explore the design principles, functionalities, and mechanisms of operating systems, including process synchronization, deadlock handling, virtual memory, disk management, and security. Additional areas of study involve different types of operating systems (such as batch processing, time-sharing, distributed systems), threads and concurrency, and the interaction between hardware and software components. The course is designed to equip students with the skills and knowledge necessary for effectively managing real-time and embedded systems.

**Course Outcomes:**

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

1. Demonstrate an understanding of the design principles and functionalities of real-time and embedded operating systems.
2. Analyze and implement process management strategies in real-time and embedded systems.
3. Effectively manage memory resources in real-time and embedded operating systems.
4. Design and implement file systems suitable for embedded applications.
5. Manage input/output operations in real-time and embedded environments.
6. Apply resource allocation principles to meet real-time constraints and optimize system performance.
7. Implement process synchronization mechanisms in real-time systems.
8. Evaluate and implement virtual memory concepts for real-time and embedded applications.
9. Understand and implement security mechanisms tailored for real-time and embedded systems.
10. Explore different types of operating systems suitable for real-time and embedded applications, including batch processing, time-sharing, and distributed systems.

**Teaching Schedule:**

Weeks 1-3: Introduction to Real-Time and Embedded Operating Systems

- Overview of real-time and embedded system design
- Basics of process management and CPU scheduling in embedded systems

Weeks 4-6: Memory Management and File Systems for Embedded Applications

- Principles and techniques of memory management in embedded systems
- Design and management of file systems for embedded applications

Weeks 7-9: Input/Output Management and Resource Allocation in Real-Time Systems

- Effective input/output operations in real-time and embedded systems
- Principles of resource allocation to meet real-time constraints

Weeks 10-12: Process Synchronization and Deadlock Handling in Real-Time Systems

- Mechanisms for process synchronization in real-time systems
- Effective handling of deadlock situations in embedded operating systems

Weeks 13-15: Advanced Topics and Practical Applications

- Virtual memory concepts and implementation in real-time and embedded systems
- Disk management techniques in the context of real-time constraints
- Security mechanisms and policies for real-time and embedded systems

- Different types of operating systems: batch processing, time-sharing, distributed systems
- Threads, concurrency, and the interaction between hardware and software components in real-time systems

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Practical examples, case studies, and projects should be integrated throughout the course to provide hands-on experience and enhance understanding.

**Recommended Books**


1. Li, Qing. *Real-Time Concepts for Embedded Systems*. CRC Press, 2003.
2. Wang, K. C. *Embedded and Real-Time Operating Systems*. Springer, 2017.
3. Lee, Insup. *Handbook of Real-Time and Embedded Systems*. CRC Press, 2007.
4. Fan, Xiaocong. *Real-Time Embedded Systems*. Newnes, 2015.
5. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors, Third Edition by Joseph Yiu
6. White Paper: Cortex-M for Beginners - An overview of the Arm Cortex-M processor family and comparison: https://community.arm.com/developer/ip-products/processors/b/processors-ip-blog/posts/white-paper-cortex-m-for-beginners-an-overview-of-the-arm-cortex-m-processor-family-and-comparison


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| **SSC-03** | **Hardware Systems Engineering** | **2L:0T:0P** | **2 credits** |

Prerequisites

- Basic knowledge of mathematics and physics

**Course Description:**

This course explores the fundamental principles and methodologies in hardware systems engineering for chip design. Students will develop a comprehensive understanding of systems thinking, system lifecycle, requirements analysis, system architecture, system modeling and simulation, risk management, decision analysis, reliability, optimization, trade-off studies, and verification and validation techniques. Emphasis is placed on system integration, system design processes, project management, and teamwork within a multidisciplinary environment. The course incorporates case studies, practical projects, and collaborative work to apply learned principles in real-world scenarios, fostering problem-solving, critical thinking, and communication skills essential for successful system design and implementation.

**Course Outcomes:**

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

1. Apply systems thinking to analyze and solve complex hardware engineering problems.
2. Conduct thorough requirements analysis for hardware system design.
3. Architect and model hardware systems using appropriate methodologies and tools.
4. Evaluate and enhance system reliability through appropriate design and testing methods.
5. Optimize hardware systems through trade-off studies and performance analysis.
6. Apply verification and validation techniques to ensure functionality and correctness of chip designs.
7. Demonstrate an understanding of system integration principles.
8. Implement project management principles for successful hardware system development.
9. Collaborate effectively in a multidisciplinary environment.
10. Communicate effectively, both orally and in writing, about hardware system design concepts and solutions.

**Teaching Schedule:**

Weeks 1-3: Introduction to Hardware Systems Engineering

- Overview of hardware systems engineering
- Systems thinking and its application
- Introduction to the system lifecycle

Weeks 4-6: Requirements Analysis and System Architecture

- Methods for requirements analysis in chip design
- Principles of system architecture
- System modeling and simulation techniques

Weeks 7-9: Risk Management and Decision Analysis

- Identifying and managing risks in hardware system engineering
- Decision analysis techniques for hardware design choices

Weeks 10-12: Reliability, Optimization, and Trade-off Studies

- Enhancing system reliability through design and testing
- Optimization strategies and trade-off studies in chip design

Weeks 13-15: Verification, Validation, and Project Management

- Techniques for verification and validation in chip design
- Project management principles for hardware system development
- Teamwork and collaboration in a multidisciplinary environment

Note: This schedule is indicative and may be adjusted based on the pace of the class and the need for additional reinforcement in specific areas. Practical projects and case studies should be integrated throughout the course to provide hands-on experience and enhance understanding.

**Recommended Books**


1. Kossiakoff, Alexander. *Systems Engineering Principles and Practice*. John Wiley & Sons, 2020.
2. Bonnema, G. *Systems Design and Engineering*. CRC Press, 2016.
3. Badiru, Adedeji. *Systems Engineering Models*. CRC Press, 2019.
4. Liu, Dahai. *Systems Engineering*. CRC Press, 2018.
5. Kung, H. T. *VLSI Systems and Computations*. Springer Science & Business Media, 2012.


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| PCC-02 | Electronic Devices 2 | 2L:0T:2P | 3 credits |
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**Prerequisites**

- Calculus I and II
- Physics I and II
- Basic knowledge of circuit theory

**Course Description:**

This course explores advanced electronic devices with a primary focus on FinFET technology, a cutting-edge development in the field of semiconductor devices. Students will delve into the principles governing traditional electronic devices, including PN junctions, JFETs, and MOSFETs, before immersing themselves in the intricate details of FinFETs. The course aims to provide students with an in-depth understanding of FinFET operation, its advantages, and its applications in contemporary electronic systems.

**Course Outcomes:**

Upon successful completion of this course, students will be able to:

1. Understand the principles of semiconductor physics as they apply to advanced electronic devices.
2. Analyze and describe the operation of traditional electronic devices such as PN junctions, JFETs, and MOSFETs.
3. Demonstrate proficiency in solving problems related to the characteristics and behavior of electronic devices.
4. Explore the principles and advantages of FinFET technology.
5. Design and analyze FinFET-based circuits for specific applications.
6. Evaluate the impact of FinFET technology on the development of advanced semiconductor devices.

**Teaching Schedule:**

Week 1-2: Review of Semiconductor Physics and Traditional Electronic Devices

- Recap of semiconductor fundamentals.
- In-depth review of PN junctions, JFETs, and MOSFETs.

Week 3-4: Introduction to FinFET Technology

- Evolution of MOSFETs to FinFETs.
- Advantages and challenges of FinFET technology.

Week 5-6: FinFET Device Structure and Operation

- FinFET structure and fabrication.
- Operational principles of FinFETs.

Week 7-8: FinFET Characteristics and Modeling

- Analyzing FinFET characteristics.
- Modeling FinFET behavior for circuit simulation.

Week 9-10: FinFET Circuit Design

- Design considerations for FinFET-based circuits.
- Applications of FinFETs in analog and digital circuits.

Week 11-12: FinFET Scaling and Future Trends

- Scaling trends in FinFET technology.
- Exploring the future developments in advanced semiconductor devices.

Week 13-14: FinFET Integration in Modern Electronics

- FinFETs in integrated circuits and system-on-chip (SoC) designs.
- Case studies of FinFET applications in real-world scenarios.

Week 15: Advanced Topics, Review, and Final Exam Preparation

- Advanced concepts in FinFET technology.
- Comprehensive review of the course content and preparation for the final exam.

This course provides students with a unique opportunity to explore the latest advancements in semiconductor technology, focusing on FinFETs. The combination of theoretical concepts, practical applications, and future trends ensures that students are well-prepared to contribute to and thrive in the rapidly evolving field of electronic devices.

**Recommended Books**


1. Corrado Di Natale. *Introduction to Electronic Devices*. Springer, 2023.
2. S. Salivahanan, N. Suresh Kumar.*Electronic Devices and Circuits*.McGrawHill, 2022.
3. Segio M. Rezende. *Introduction to Electronic Materials and Devices*. Springer, 2022.


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| PCC-03 | Microfabrication Semiconductor and Materials | 2L:0T:0P | 2 credits |
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**Prerequisites**

- Basic knowledge of physics and chemistry
- Basic knowledge of circuit theory and electronics

**Course Description**

This course provides an introduction to the principles and processes of microfabrication, with a focus on semiconductor materials and devices. Students will learn about the key steps in microfabrication, such as photolithography, etching, deposition, and diffusion. They will also learn about the properties of semiconductor materials and how they are used to fabricate electronic devices.

**Course Outcomes**

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

- Understand the basic principles of microfabrication
- Design and implement microfabrication processes
- Characterize semiconductor materials and devices
- Apply microfabrication techniques to fabricate electronic devices

**Teaching Schedule**

| 1 | Introduction to microfabrication
| 2 | Semiconductor materials
| 3 | Photolithography
| 4 | Etching
| 5 | Deposition
| 6 | Diffusion
| 7 | Oxidation
| 8 | Ion implantation
| 9 | Metallization

| 10 | Device fabrication
| 11 | Process characterization
| 12 | Device characterization
| 13 | Microfabrication for MEMS and sensors
| 14 | Microfabrication for advanced technologies
| 15 | Final project presentations

**Recommended Books**


- Sze, S. M. (1981). VLSI technology (2nd ed.). New York, NY: McGraw-Hill.
- Madou, M. J. (2002). Fundamentals of microfabrication (2nd ed.). Boca Raton, FL: CRC Press.
- Jaeger, R. C. (2002). Introduction to microelectronic fabrication (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Sze, S. M., & Kwok, K. N. (2006). Physics of semiconductor devices (3rd ed.). Hoboken, NJ: Wiley.


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| **PCC-04** | **Analog Circuits** | **2L:0T:2P** | **3credits** |

**Course Description**

This course introduces the fundamentals of analog circuits and network theory, with a focus on RLC circuits, MOSFETs, and two-port networks. Students will learn the basic principles of circuit operation and analysis, as well as how to design and implement analog circuits for a variety of applications.

**Course Outcomes**

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

- Analyze and design RLC circuits, including series and parallel circuits, resonators, and filters
- Understand the operation of MOSFETs and use them to design amplifier and switching circuits
- Analyze and design two-port networks, including matching networks and filter networks

**Teaching Schedule**

| Week | Topic |
|---|---|
| 1 | Introduction to analog circuits and network theory |
| 2 | RLC circuits: series circuits |
| 3 | RLC circuits: parallel circuits |
| 4 | RLC circuits: resonators and filters |
| 5 | MOSFETs: basic operation and characteristics |
| 6 | MOSFET amplifiers |
| 7 | MOSFET switching circuits |
| 8 | Two-port networks: basic concepts and parameters |
| 9 | Two-port network interconnections |
| 10 | Two-port network functions |
| 11 | Two-port network analysis |
| 12 | Two-port network design: matching networks |
| 13 | Two-port network design: filter networks |
| 14 | Advanced topics in analog circuits and network theory |
| 15 | Final project presentations |

**Recommended Books**


- Kuriakose, C. *CIRCUIT THEORY*. PHI Learning Pvt. Ltd., 2005.
- Rakshit, D. *Fundamentals of Electric Circuit Theory*. S. Chand Publishing, 2000.
- Surajit, Bagchi. *Circuit Theory and Networks*. S. Chand Publishing, 2010.
- Wadhwa, C. *Network Analysis & Synthesis (Including Linear System Analysis)*. New Age International, 2007.


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# SEMESTER – V

| PCC-05 | Linear Integrated Circuits | 2L:0T:2P | 3credits |
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**Course Description:**

This course delves into the principles, design, and applications of linear integrated circuits, with a specific emphasis on operational amplifiers (op-amps). Topics covered include op-amp characteristics, ideal and real op-amp behavior, various feedback configurations (inverting, non-inverting, differential), and op-amp applications in amplifiers, oscillators, filters, comparators, and voltage regulators. Students will explore frequency response, stability, compensation techniques for op-amp circuits, as well as the integration of op-amps in instrumentation and control circuits. The course aims to provide a comprehensive understanding of op-amps, enabling students to design, analyze, and troubleshoot circuits for diverse engineering applications.

**Course Learning Outcomes:**

**Op-Amp Characteristics:**

- Recognize and explain key operational amplifier characteristics.

**Feedback Configurations:**

- Design and analyze inverting, non-inverting, and differential op-amp feedback configurations.

**Op-Amp Applications:**

- Apply operational amplifiers in practical circuits, including amplifiers, oscillators, filters, comparators, and voltage regulators.

**Frequency Response and Stability:**

- Analyze and optimize the frequency response of op-amp circuits.

**Instrumentation and Control Design:**

- Utilize op-amps in instrumentation circuits for measurement and control applications.

**Practical Application:**

- Implement theoretical concepts through hands-on exercises, lab work, and design projects.

**Troubleshooting Skills:**

- Demonstrate the ability to troubleshoot and optimize op-amp circuits in real-world scenarios.

**Real vs. Ideal Op-Amp Behavior:**

- Differentiate between ideal and real op-amp behaviors and understand their implications in circuit design.

**Amplifier Circuit Design:**

- Design and analyze op-amp amplifiers with a focus on practical applications.

**Project Presentation:**

- Deliver a final project presentation demonstrating the application of op-amp concepts in a real-world engineering scenario.

**Teaching Plan:**

*Weeks 1-2: Introduction to Operational Amplifiers*

- Overview of op-amp characteristics and applications.
- Ideal vs. real op-amp behavior.

*Weeks 3-4: Op-Amp Feedback Configurations*

- Inverting, non-inverting, and differential configurations.
- Analysis and design exercises.

*Weeks 5-6: Op-Amp Applications I - Amplifiers*

- In-depth study of op-amp amplifiers.
- Lab work on amplifier circuits.

*Weeks 7-8: Op-Amp Applications II - Oscillators and Filters*

- Oscillator and filter design using op-amps.
- Frequency response analysis.

*Weeks 9-10: Op-Amp Applications III - Comparators and Voltage Regulators*

- Design and analysis of comparators and voltage regulators.
- Stability and compensation techniques.

*Weeks 11-12: Op-Amps in Instrumentation Circuits*

- Application of op-amps in instrumentation circuits.
- Lab work on instrumentation circuits.

*Weeks 13-14: Op-Amps in Control Circuits*

- Design and analysis of op-amp-based control circuits.
- Troubleshooting exercises.

*Week 15: Review and Project Presentation*

- Review of key concepts.
- Final project presentation by students.

**Recommended Books**


- Roy, D. *Linear Integrated Circuits*. New Age International, 2003.
- Stanley, William. *Operational Amplifiers with Linear Integrated Circuits*. Prentice Hall, 1994.
- Shannon, Robin. *Linear Integrated Circuits*. Scientific e-Resources, 2019.
- Huijsing, Johan. *Operational Amplifiers*. Springer, 2016.
- Mancini, Ron. *Op Amps for Everyone*. Newnes, 2003.


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| **PCC-06** | **RF and HF Circuits** | **2L:0T:2P** | **3 credits** |

**Course Description:**

This course explores the principles and techniques of designing RF (Radio Frequency) and HF (High-Frequency) circuits. Topics include passive components used in RF and HF circuits, impedance matching, resonant circuits, filters, and basic RF amplifiers. Students will gain an understanding of the behavior of components at high frequencies, distributed effects, signal propagation, and RF circuit characteristics. The course may cover impedance transformation, matching networks, RF power amplification, mixers, oscillators, and their applications in wireless communication, radio systems, radar, and other high-frequency electronic devices. Practical lab work, simulations, and projects provide hands-on experience in designing and analyzing RF and HF circuits.

**Course Learning Outcomes:**

**Understanding Passive Components in RF/HF Circuits:**

- Explain the behavior of inductors, capacitors, and transmission lines at high frequencies.
- Analyze the impact of distributed effects on passive components in RF and HF circuits.

**Impedance Matching and Resonant Circuits:**

- Design impedance matching networks for efficient power transfer.
- Analyze and design resonant circuits for specific frequency applications.

**RF Amplifiers and Filters:**

- Understand the principles of RF amplifiers and their basic configurations.
- Design and analyze RF filters for signal conditioning in high-frequency circuits.

**RF Power Amplification and Mixing:**

- Analyze and design circuits for RF power amplification.
- Understand the functioning of mixers and their applications in RF systems.

**Oscillators and Practical Applications:**

- Design and analyze RF oscillators for frequency generation.
- Apply RF and HF circuit concepts in practical applications such as wireless communication and radar systems.

**Teaching Plan:**

*Weeks 1-2: Introduction to RF and HF Circuits*

- Overview of RF and HF circuit applications.
- Introduction to passive components in high-frequency environments.

*Weeks 3-4: Impedance Matching and Resonant Circuits*

- Principles of impedance matching.
- Design and analysis of resonant circuits.

*Weeks 5-6: RF Amplifiers and Filters*

- Basic configurations of RF amplifiers.
- Design and analysis of RF filters.

*Weeks 7-8: Distributed Effects and Signal Propagation**

- Understanding distributed effects in high-frequency circuits.
- Analysis of signal propagation in RF circuits.

*Weeks 9-10: RF Power Amplification and Mixing**

- Principles and design of RF power amplifiers.
- Functioning of mixers in RF systems.

*Weeks 11-12: Oscillators in RF Systems**

- Design and analysis of RF oscillators.
- Practical applications of RF and HF circuits in wireless communication.

*Weeks 13-14: Simulations and Lab Work**

- Hands-on simulations of RF and HF circuits.
- Laboratory work on practical applications.

*Week 15: Project and Review**

- Final project presentations by students.
- Review of key concepts and applications in RF and HF circuit design.

**Recommended Books**

1. Hans L. Hartnagel, Rudiger Quay, Ulrich L.Rohde, Matthias Rudolph. *Fundamentals of RF and Microwave Techniques and Technologies*.Springer, 2023.
2. Robert Sobot. *Wireless Communication Electronics Introduction to RF Circuits and Design Techniques*. Springer, 2021.
3. Duran Leblebici, Yusuf Leblebici. *Fundamentals of High Frequency CMOS Analog Integrated Circuits.* Springer, 2021.

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| **PCC-07** | **CMOS Integrated Circuits** | **2L:0T:2P** | **3credits** |

**Course Description:**
This course explores the principles and techniques of designing CMOS (Complementary Metal-Oxide-Semiconductor) integrated circuits with a dual focus on both analog and digital circuits. Topics include CMOS device characteristics, analog circuit design principles, digital CMOS logic, and their integration. Students will learn about the design of operational amplifiers, voltage references, analog-to-digital converters, digital CMOS gates, and sequential logic circuits. Practical applications in both analog and digital domains will be emphasized. The course includes hands-on lab work, simulations, and projects to provide students with practical experience in CMOS integrated circuit design.

**Course Learning Outcomes:**

**Understanding CMOS Device Characteristics:**

- Explain the fundamental characteristics of CMOS devices.
- Analyze the behavior of MOS transistors in CMOS technology.

**Analog CMOS Circuit Design:**

- Design and analyze analog circuits using CMOS technology, including operational amplifiers and voltage references.
- Understand the impact of process variations on analog circuit performance.

**Digital CMOS Logic Design:**

- Design and analyze digital CMOS logic gates and circuits.
- Understand the principles of CMOS digital logic families.

**Integration of Analog and Digital Circuits:**

- Explore the integration of analog and digital components in CMOS circuits.
- Design and analyze mixed-signal CMOS circuits.

**Practical Applications and Project Work:**

- Apply CMOS design principles to real-world applications.
- Demonstrate proficiency in designing and simulating CMOS circuits through individual or group projects.

**Teaching Plan:**

*Weeks 1-2: Introduction to CMOS Technology and Devices*

- Overview of CMOS technology.
- Characteristics and behavior of CMOS devices.

*Weeks 3-4: Analog CMOS Circuit Design - Part 1*

- Design principles of operational amplifiers in CMOS.
- Lab work on analog CMOS circuit simulations.

*Weeks 5-6: Analog CMOS Circuit Design - Part 2*

- Design principles of voltage references in CMOS.
- Impact of process variations on analog circuit performance.

*Weeks 7-8: Digital CMOS Logic Design - Part 1*

- Principles of digital CMOS logic gates.
- Design and analysis of basic CMOS digital circuits.

*Weeks 9-10: Digital CMOS Logic Design - Part 2*

- Introduction to CMOS digital logic families.
- Lab work on digital CMOS logic simulations.

*Weeks 11-12: Integration of Analog and Digital Circuits*

- Mixed-signal CMOS circuit design.
- Case studies on integrated analog and digital systems.

*Weeks 13-14: Practical Applications and Project Work*

- Application of CMOS design principles in real-world scenarios.
- Progress presentations on individual or group projects.

*Week 15: Project Completion and Review*

- Final project presentations.
- Review of key concepts in CMOS integrated circuit design.

**Recommended Books**


1. Behzad Razavi. *Design of Analog CMOS Integrated Circuits*. McGrawHill, Second edition.
2. Karim Abbas. *Handbook of Digital CMOS technology, Circuits and Systems*.Springer, 2020.
3. Yuan Taur. *Fundamentals of Modern VLSI Devices.* Cambridge, Second Edition.


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| PCC-08 | Electronics System Design | 1L:0T:4P | 3 credits |
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**Course Description:**

This course is centered on Electronics System Design with a specific focus on VHDL (VHSIC Hardware Description Language), Verilog, and FPGA (Field-Programmable Gate Array) technologies. Students will gain a comprehensive understanding of hardware description languages, digital system design principles, and the implementation of electronic systems on FPGAs. The course includes hands-on lab work, simulations, and projects to reinforce theoretical concepts and provide practical experience in designing complex electronic systems.

**Course Learning Outcomes:**

**Proficiency in VHDL/Verilog:**

- Demonstrate proficiency in writing and understanding VHDL and Verilog code.
- Apply VHDL/Verilog for the description of digital systems and components.

**Digital System Design Principles:**

- Understand the fundamental principles of digital system design.
- Analyze and design combinational and sequential circuits using VHDL/Verilog.

**FPGA Implementation:**

- Learn the architecture and capabilities of FPGAs.
- Implement digital systems on FPGAs using VHDL/Verilog.

**Advanced FPGA Features:**

- Explore advanced features of FPGAs, such as embedded processors and memory.
- Design and implement complex systems utilizing these advanced FPGA features.

**System-Level Design and Integration:**

- Integrate digital components into larger electronic systems.
- Develop skills in system-level design using VHDL/Verilog and FPGA technologies.

**Detailed Syllabus**

**Module 1: Proficiency in VHDL/Verilog**

- Overview of VHDL and Verilog languages.
- Writing and understanding VHDL and Verilog code.
- Practical Exercises: Implementing basic digital components.

**Module 2: Digital System Design Principles**

- Fundamental Principles of Digital System Design.
- Combinational Circuit Design using VHDL/Verilog.
- Sequential Circuit Design using VHDL/Verilog.
- Hands-On Projects: Analyzing and Designing Digital Systems.

**Module 3: FPGA Implementation**

- Introduction to Field-Programmable Gate Arrays (FPGAs).
- FPGA Architecture and Capabilities.

- Implementing Digital Systems on FPGAs using VHDL/Verilog.
- Lab Sessions: Programming FPGAs with VHDL/Verilog.

**Module 4: Advanced FPGA Features**

- Exploration of Advanced FPGA Features.
- Embedded Processors in FPGAs.
- FPGA Memory Architecture and Utilization.
- Designing Complex Systems with Advanced FPGA Features.

**Module 5: System-Level Design and Integration**

- Principles of System-Level Design.
- Integrating Digital Components into Larger Systems.
- Project-Based Learning: Developing Complete Systems using VHDL/Verilog and FPGAs.
- Final Project: System-Level Design and Integration Showcase.

**Teaching Plan:**

*Weeks 1-2: Introduction to VHDL and Verilog*

- Overview of VHDL and Verilog.
- Basic syntax, data types, and constructs.

*Weeks 3-4: Digital System Design Principles*

- Combinational and sequential circuit design.
- Behavioral and structural modeling with VHDL/Verilog.

*Weeks 5-6: FPGA Architecture and Basics*

- Introduction to FPGA architecture.
- Basics of FPGA programming and configuration.

*Weeks 7-8: FPGA Implementation with VHDL/Verilog - Part 1*

- Implementing basic digital systems on FPGAs.

- Lab work on VHDL/Verilog simulation and FPGA programming.

*Weeks 9-10: FPGA Implementation with VHDL/Verilog - Part 2*

- Advanced features of FPGAs (embedded processors, memory).
- Design and implementation of more complex systems.

*Weeks 11-12: System-Level Design with VHDL/Verilog and FPGA*

- Integration of digital components into larger systems.
- Case studies on system-level design.

*Weeks 13-14: Project Work and Advanced Topics*

- Individual or group projects using VHDL/Verilog and FPGAs.
- Exploration of advanced topics based on student interest.

*Week 15: Project Presentations and Review*

- Final project presentations.
- Review of key concepts in Electronics System Design with VHDL/Verilog and FPGA.

**Recommended Books**


1. Cem Unsalan, Bora Tar. *Digital System Design with FPGA: Implementation using Verilog and VHDL.* McGrawHill, First Edition.
2. Simon Monk. *Programming FPGAs Getting Started with Verilog*. McGrawHill, First Edition.


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| **PCC-09** | **Embedded Systems** | **2L:0T:2P** | **3credits** |

**Course Description:**

This course provides a comprehensive exploration of embedded systems, focusing on microcontroller programming. Students will delve into the principles and practices of designing and programming embedded systems, gaining hands-on experience with microcontrollers. The curriculum covers fundamental concepts of embedded systems, microcontroller architectures, and real-time programming. Practical applications include interfacing with sensors and actuators, as well as designing embedded systems for various applications. The course emphasizes programming in C/C++ for microcontrollers, providing a solid foundation for students pursuing careers in embedded systems development.

**Course Learning Outcomes:**

**Understanding Embedded Systems Fundamentals:**

- Grasp the fundamental principles and characteristics of embedded systems.
- Understand the role and significance of embedded systems in various applications.

**Microcontroller Architecture and Programming:**

- Gain proficiency in microcontroller architectures.
- Develop skills in programming microcontrollers using C/C++.

**Real-Time Programming for Embedded Systems:**

- Understand the concepts of real-time programming in the context of embedded systems.
- Apply real-time programming techniques to ensure timely responses in embedded applications.

**Interfacing with Sensors and Actuators:**

- Learn techniques for interfacing microcontrollers with sensors.
- Implement actuator control in embedded systems.

**Embedded System Design for Various Applications:**

- Apply embedded system design principles to different application domains.
- Develop and implement embedded systems tailored for specific tasks and functionalities.

**Detailed Syllabus**

**Module 1: Introduction to Embedded Systems**

- Definition and Characteristics of Embedded Systems.
- Historical Evolution and Key Milestones.
- Importance and Significance of Embedded Systems in Various Applications.

**Module 2: Microcontroller Architecture and Programming**

- Overview of Microcontroller Architectures (e.g., Arm, AVR, PIC).
- Internal Structure and Components of a Microcontroller.
- Introduction to C/C++ Programming for Microcontrollers.
- Hands-On Exercises: Writing Basic Programs for Microcontrollers.

**Module 3: Real-Time Programming for Embedded Systems**

- Understanding Real-Time Constraints in Embedded Systems.
- Real-Time Operating Systems (RTOS) Overview.
- Techniques for Achieving Timely Responses in Embedded Applications.
- Practical Applications: Developing Real-Time Programs for Embedded Systems.

**Module 4: Interfacing with Sensors and Actuators**

- Principles of Sensor Interfacing with Microcontrollers.
- Actuator Control and Implementation.
- Communication Protocols (e.g., I2C, SPI) for Sensor Integration.
- Hands-On Lab: Interfacing Sensors and Implementing Actuator Control.

**Module 5: Embedded System Design for Various Applications**

- Fundamental Principles of Embedded System Design.
- Application-Specific Considerations and Requirements.
- Case Studies: Designing Embedded Systems for Different Domains (e.g., Automotive, IoT, Robotics).
- Final Project: Applying Design Principles to Develop and Implement Embedded Systems.

**Teaching Plan:**

*Weeks 1-2: Introduction to Embedded Systems**

- Overview of embedded systems and their applications.
- Introduction to microcontroller architectures.

*Weeks 3-4: Microcontroller Programming in C/C++**

- Basic programming concepts for microcontrollers.
- Hands-on exercises in C/C++ programming for microcontrollers.

*Weeks 5-6: Real-Time Programming for Embedded Systems**

- Understanding real-time constraints in embedded systems.
- Practical applications of real-time programming in microcontroller projects.

*Weeks 7-8: Microcontroller Interfacing with Sensors and Actuators**

- Techniques for interfacing microcontrollers with sensors.
- Implementing actuator control in embedded systems.

*Weeks 9-10: Embedded System Design Principles**

- Principles of embedded system design.
- Applying design principles to specific application scenarios.

*Weeks 11-12: Practical Projects and Case Studies**

- Hands-on projects involving microcontroller programming.
- Case studies of real-world embedded system implementations.

*Weeks 13-14: Advanced Topics in Embedded Systems**

- Exploration of advanced topics in embedded systems.
- Integration of advanced concepts into practical applications.

*Week 15: Project Work and Final Presentations**

- Practical exercises and projects on microcontroller programming.
- Final project presentations showcasing embedded system design and programming skills.

**Recommended Textbooks**

1. KCS Murti. *Design Principles for Embedded Systems*.Springer, 2022.
2. Pete Warden, Daniel Situnayake. *Tiny ML: Machine Learning with TensorFlow Lite on Arduino and Ultra Low Power Microcontrollers.* O Reilly Media, Inc, 2019.
3. Brian Amos. *Hands On RTOS with Microcontrollers.*Packt.
4. The Definitive Guide to the ARM Cortex-M0 by Joseph Yiu
5. Embedded Systems Fundamentals on Arm Cortex-M based Microcontrollers: A Practical Approach by Alexander G. Dean https://www.arm.com/resources/education/textbooks/efficient-embedded-systems
6. White Paper: Cortex-M for Beginners - An overview of the Arm Cortex-M processor family and comparison:
7. https://community.arm.com/developer/ip-products/processors/b/processors-ip-blog/posts/white-paper-cortex-m-for-beginners-an-overview-of-the-arm-cortex-m-processor-family-and-comparison

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| **PCC-11** | **SOC Design 1: Design & Verification** | **2L:0T:2P** | **3credits** |
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**Course Description:**

This comprehensive course covers the complete System-on-Chip (SoC) chip design flow, focusing on practical exposure to the front-end of the chip design cycle. The curriculum encompasses Verilog-based RTL (Register-Transfer Level) design, integration of digital and analog IPs (Intellectual Properties) in SoC design, RTL verification using simulation and formal methods, and scripting languages such as TCL and Perl. The primary languages for RTL design are Verilog and SystemVerilog, aligning with industry standards. The course introduces rapid prototyping using FPGAs and validation using emulation hardware. EDA tools from Synopsys, Cadence, and Siemens are recommended, but open-source tools like Open-Road and Open-Lane can be used in their absence.

**Course Learning Outcomes:**

**Complete SoC Chip Design Flow:**

- Understand and apply the complete SoC chip design flow, from conception to implementation.
- Demonstrate proficiency in using EDA tools for chip design tasks.

**Verilog-Based RTL Design:**

- Master Verilog as a language for RTL design.
- Design and implement complex digital systems using Verilog.

**Integration of Digital and Analog IPs in SoC Design:**

- Integrate digital and analog IPs into a cohesive SoC design.
- Understand the challenges and considerations in combining different IP blocks.

**RTL Verification with Simulation and Formal Methods:**

- Use simulation techniques for thorough RTL verification.
- Apply formal methods for rigorous verification of RTL designs.

**Scripting Languages (TCL and Perl) for Chip Design Automation:**

- Utilize scripting languages such as TCL and Perl for chip design automation.
- Develop automation scripts to enhance design productivity.

**Teaching Plan:**

*Weeks 1-2: Introduction to SoC Chip Design Flow*

- Overview of the complete SoC chip design flow.
- Introduction to EDA tools: Synopsys, Cadence, Siemens, and open-source alternatives.

*Weeks 3-4: Verilog-Based RTL Design*

- In-depth study of Verilog syntax and constructs.
- Hands-on lab work on Verilog-based digital system design.

*Weeks 5-6: Integration of Digital and Analog IPs in SoC Design*

- Understanding digital and analog IPs.
- Techniques for integrating diverse IPs into a single SoC.

*Weeks 7-8: RTL Verification using Simulation Methods*

- Simulation-based verification techniques.
- Practical exercises using EDA tools.

*Weeks 9-10: RTL Verification using Formal Methods*

- Introduction to formal verification.

- Application of formal methods in RTL verification.

*Weeks 11-12: Scripting Languages for Chip Design Automation**

- Introduction to scripting languages (TCL and Perl).
- Development of automation scripts for design tasks.

*Weeks 13-14: Rapid Prototyping with FPGAs and Emulation Hardware Validation**

- Rapid prototyping using FPGAs.
- Validation of designs using emulation hardware.

*Week 15: Project Work and Final Presentations**

- Individual or group projects demonstrating SoC design and verification skills.
- Final project presentations and review of key concepts.

**Recommended Books**


1. Cem Unsalan, Bora Tar. *Digital System Design with FPGA: Implementation using Verilog and VHDL.* McGrawHill, First Edition.
2. Nekoogar, Farzad. *From ASICs to SOCs*. Prentice Hall Professional, 2003.
3. Wolf, Wayne. *Modern VLSI Design*. Pearson Education, 2002.
4. Chakravarthi, Veena. *A Practical Approach to VLSI System on Chip (SoC) Design*. Springer Nature, 2019.


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# SEMESTER – VI

| PCC-10 | CAD for VLSI | 3L:0T:0P | 3 credits |
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**Course Description:**

This course delves into the algorithms and tools utilized in Computer-Aided Design (CAD) for Very Large Scale Integration (VLSI) circuits. Students will gain a deep understanding of the algorithms underpinning VLSI CAD tools, focusing on design automation, optimization, and verification. The curriculum covers key aspects such as logic synthesis, physical design, and verification algorithms, providing hands-on experience with industry-standard tools. Emphasis is placed on algorithmic efficiency, design exploration, and the application of cutting-edge tools to solve complex VLSI design challenges.

**Course Learning Outcomes:**

**Algorithmic Proficiency:**

- Demonstrate proficiency in understanding and implementing algorithms used in VLSI CAD tools.
- Apply algorithmic concepts to solve design challenges in VLSI circuits.

**Optimization Techniques in CAD:**

- Understand optimization techniques applied in the design and synthesis of VLSI circuits.
- Apply optimization strategies to enhance circuit performance and power efficiency.

**Hands-On Experience with CAD Tools:**

- Gain practical experience with industry-standard VLSI CAD tools.
- Navigate through the design flow, utilizing tools for logic synthesis, physical design, and verification.

**Design Exploration and Automation:**

- Explore design space and automate aspects of the VLSI design process.
- Implement automated algorithms for design exploration and optimization.

**Application of Cutting-Edge Tools:**

- Understand and apply cutting-edge CAD tools for advanced VLSI design.
- Develop skills in integrating and utilizing emerging tools in the field.

**Teaching Plan:**

*Weeks 1-2: Introduction to VLSI CAD Algorithms and Tools**

- Overview of CAD algorithms and tools in VLSI design.

- Introduction to key optimization and automation concepts.
- Familiarization with industry-standard tools.

*Weeks 3-4: Logic Synthesis Algorithms**

- In-depth study of logic synthesis algorithms.
- Optimization techniques in logic synthesis.
- Lab sessions: Hands-on exercises with logic synthesis tools.

*Weeks 5-6: Physical Design and Optimization**

- Algorithms for floorplanning, placement, and routing.
- Optimization strategies in physical design.
- Lab sessions: Applying physical design algorithms to real-world layouts.

*Weeks 7-8: Verification Algorithms in VLSI**

- Functional and timing verification algorithms.
- Model checking and formal verification techniques.
- Lab sessions: Verification exercises using industry-standard tools.

*Weeks 9-10: Design Exploration and Automation**

- Exploration algorithms for design space.
- Automation techniques in VLSI design.
- Lab sessions: Implementing automated design exploration.

*Weeks 11-12: Advanced Tools in VLSI CAD**

- Introduction to cutting-edge CAD tools.
- Integration and application of emerging tools.
- Lab sessions: Exploring advanced features in CAD tools.

*Weeks 13-14: Project Work and Algorithm Implementation**

- Individual or group projects implementing VLSI CAD algorithms.
- Final project presentations showcasing algorithmic solutions.
- Review and discussion of project outcomes.

*Week 15: Future Trends and Industry Applications**

- Exploration of emerging trends in VLSI CAD.
- Discussion of industry applications and real-world challenges.
- Course review and wrap-up.

**Recommended Books**


1. Trimberger, Stephen. *An Introduction to CAD for VLSI*. Springer, 1987.
2. Hill, D. D. *Multi-Level Simulation for VLSI Design*. Springer Science & Business Media, 2012.
3. Brunvand, Erik. *Digital VLSI Chip Design with Cadence and Synopsys CAD Tools*. Pearson, 2010.
4. Hill, D. D. *Multi-Level Simulation for VLSI Design*. Springer Science & Business Media, 2012.
5. N., Chiplunkar. *Vlsi Cad*. PHI Learning Pvt. Ltd.
6. Setliff, Dorothy. *Automatic Programming Applied to VLSI CAD Software: A Case Study*. Springer Science & Business Media, 2012.


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| **PCC-12** | **SOC Design 2: Chip Implementation with Physical Design leading to Tape-Out** | **2L:0T:2P** | **3credits** |

**Course Description:**

This course focuses on the Physical Design SoC Flow, covering the entire process from synthesis to tape-out. Participants will gain practical experience in the back end of the SoC design, using EDA tools to implement the latest technologies and techniques. The curriculum includes key topics such as standard cell and design elements, logic and physical synthesis, timing constraints, floor planning, placement, clock tree synthesis, routing, timing closure, physical design verification, tape-out, and an introduction to DFT (Design for Testability) and DFM (Design for Manufacturability). Recommended EDA tools include Synopsys, Cadence, Siemens, and open-source alternatives like Open-Road and Open-Lane.

**Course Learning Outcomes:**

**Understanding of Standard Cell and Key Design Elements:**

- Identify and analyze standard cells and other key design elements.
- Understand their role in the overall SoC design process.

**Logic & Physical Synthesis:**

- Apply logic synthesis techniques to optimize digital circuits.

- Perform physical synthesis for efficient placement and routing.

**Timing Constraints and Analysis:**

- Define and implement timing constraints for the design.
- Analyze timing characteristics and address potential issues.

**Floor Planning and Placement:**

- Develop floor plans for efficient chip layout.
- Optimize chip placement for performance and area.

**Clock Tree Synthesis and Routing:**

- Implement clock tree synthesis for stable clock distribution.
- Perform routing to establish interconnections within the design.

**Timing Closure Techniques:**

- Apply techniques to achieve timing closure in the design.
- Understand the challenges and solutions in meeting timing requirements.

**Physical Design Verification and Tape-Out:**

- Employ physical design verification methods to ensure correctness.
- Understand the tape-out process and requirements.

**Introduction to DFT & DFM:**

- Gain an overview of Design for Testability (DFT) and Design for Manufacturability (DFM) principles.
- Understand their significance in the overall chip implementation process.

**Teaching Plan:**

***Weeks 1-2: Introduction to Physical Design SoC Flow***

- Overview of the complete Physical Design SoC flow.
- Introduction to EDA tools: Synopsys, Cadence, Siemens, and open-source alternatives.

***Weeks 3-4: Standard Cell and Key Design Elements***

- Analysis of standard cells and essential design elements.
- Hands-on exercises using EDA tools.

***Weeks 5-6: Logic & Physical Synthesis***

- Application of logic synthesis techniques.
- Physical synthesis for placement and routing optimization.

***Weeks 7-8: Timing Constraints and Analysis***

- Definition and implementation of timing constraints.
- Analysis of timing characteristics and mitigation strategies.

***Weeks 9-10: Floor Planning and Placement***

- Development of floor plans for efficient chip layout.
- Optimization of chip placement for performance and area.

***Weeks 11-12: Clock Tree Synthesis and Routing***

- Implementation of clock tree synthesis.
- Routing techniques for interconnections within the design.

***Weeks 13-14: Timing Closure Techniques***

- Application of techniques to achieve timing closure.
- Addressing challenges in meeting timing requirements.

***Week 15: Physical Design Verification, Tape-Out, and DFT/DFM Introduction****

- Methods for physical design verification.
- Overview of the tape-out process.
- Introduction to Design for Testability (DFT) and Design for Manufacturability (DFM) principles.

**IP access**

https://www.arm.com/resources/research/enablement/academic-access

**Recommended Books**


1. Cem Unsalan, Bora Tar. *Digital System Design with FPGA: Implementation using Verilog and VHDL.* McGrawHill, First Edition.
2. Nekoogar, Farzad. *From ASICs to SOCs*. Prentice Hall Professional, 2003.
3. Chakravarthi, Veena. *SoC Physical Design*. Springer Nature, 2022.
4. Kahng, Andrew. *VLSI Physical Design: From Graph Partitioning to Timing Closure*. Springer Science & Business Media, 2011.
5. Michael Keating, Synopsys. *The Simple Art of SoC Design*. Springer Science & Business Media, 2011.
6. Sait, Sadiq. *VLSI Physical Design Automation*. World Scientific, 1999.

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| **PCC-13** | **Optoelectronics** | **3L:0T:0P** | **3 credits** |

**Course Description:**

This course provides a comprehensive exploration of optoelectronics, with a specific focus on lasers, Light Emitting Diodes (LEDs), Organic Light Emitting Diodes (OLEDs), and Liquid Crystal Displays (LCDs). Students will delve into the principles, design, and applications of optoelectronic devices, gaining an understanding of their underlying physics and engineering applications. The curriculum covers the fundamental concepts of light generation, modulation, and detection, as well as the technology behind lasers and display technologies. Practical applications and hands-on projects reinforce theoretical concepts and provide insight into real-world optoelectronic systems.

**Course Learning Outcomes:**

**Understanding Optoelectronic Principles:**

- Grasp the fundamental principles of optoelectronics.
- Understand the interaction of light with semiconductor materials.

**In-depth Knowledge of Lasers and LED Technologies:**

- Gain a deep understanding of the principles behind lasers and LED technologies.
- Analyze and design optoelectronic systems based on lasers and LEDs.

**Applications and Design of OLEDs:**

- Explore the principles and applications of Organic Light Emitting Diodes (OLEDs).
- Design and implement systems utilizing OLED technology.

**LCD Technology and Display Systems:**

- Understand the fundamentals of Liquid Crystal Displays (LCDs).
- Analyze and design LCD-based display systems.

**Integration of Optoelectronic Technologies:**

- Develop skills in integrating various optoelectronic technologies for specific applications.
- Design and implement projects that combine lasers, LEDs, OLEDs, and LCDs.

**Teaching Plan:**

*Weeks 1-2: Introduction to Optoelectronics**

- Overview of optoelectronic devices and their applications.
- Introduction to the physics of light and its interaction with materials.
- Historical context and milestones in optoelectronics.

*Weeks 3-4: Principles of Lasers**

- Principles of laser operation.
- Types of lasers and their applications.
- Lab sessions: Hands-on experiments with lasers.

*Weeks 5-6: Light Emitting Diodes (LEDs)**

- LED technology and operation.
- Different types of LEDs and their applications.
- Lab sessions: Design and testing of LED circuits.

*Weeks 7-8: Organic Light Emitting Diodes (OLEDs)**

- Introduction to OLED technology.
- Applications of OLEDs in displays and lighting.
- Lab sessions: Design and fabrication of OLED devices.

*Weeks 9-10: Liquid Crystal Displays (LCDs)**

- Principles of Liquid Crystal Displays.
- Types of LCDs and their applications.
- Lab sessions: Hands-on projects with LCD technology.

*Weeks 11-12: Integration of Optoelectronic Technologies**

- Design principles for integrating lasers, LEDs, OLEDs, and LCDs.
- Case studies: Real-world applications of integrated optoelectronic systems.
- Group projects: Integrating multiple optoelectronic devices into a system.

*Weeks 13-14: Advanced Topics and Emerging Technologies**

- Emerging trends in optoelectronics.
- Advanced applications and technologies in the field.

- Lab sessions: Exploration of cutting-edge optoelectronic devices.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing integrated optoelectronic systems.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future trends in optoelectronics.

**Recommended Books**

1. Naci Balkan, Ayse Erol.*Semiconductors for Optoelectronics*. Springer, 2021.
2. Mitsuhiro Koden. *Flexible OLEDs Fundamental and Novel Practical Technologies*. Springer, 2022.
3. Dhruba J. Biswas. *A Beginner's Guide to Lasers and Their Applications, Part 1*. Springer, 2023.

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|---|---|---|---|
| **PCC-14** | **IC Packaging** | **3L:0T:0P** | **3 credits** |

**Course Description:**

This course provides a comprehensive exploration of Integrated Circuit (IC) packaging, covering various packaging technologies, materials, and techniques used in semiconductor packaging. Students will delve into the complexities of packaging design, considering factors such as thermal management, interconnection technologies, and the impact on electrical, mechanical, and thermal performance. The curriculum includes an in-depth study of different packaging types, materials, and the trade-offs involved in the design process. Practical projects, case studies, and hands-on experiences will be integral components, preparing students for roles in the semiconductor industry, manufacturing, and product development.

**Course Learning Outcomes:**

**Understanding Packaging Technologies:**

- Grasp the fundamentals of various IC packaging technologies.
- Differentiate between through-hole, surface-mount, and ball grid array packaging types.

**Materials and Interconnection Techniques:**

- Acquire knowledge of packaging materials used in semiconductor packaging.

- Understand interconnection technologies and their impact on electrical performance.

**Thermal Management in IC Packaging:**

- Analyze and implement thermal management strategies in IC packaging.
- Evaluate the impact of packaging on the thermal performance of integrated circuits.

**Considerations for Signal and Power Integrity:**

- Gain insights into the complexities of signal integrity in packaging design.
- Understand power integrity considerations and their implications in IC packaging.

**Reliability and Trade-offs in Packaging Design:**

- Evaluate reliability factors in IC packaging.
- Learn to make informed trade-offs considering various aspects of packaging design.

**Teaching Plan:**

*Weeks 1-2: Introduction to IC Packaging Technologies**

- Overview of IC packaging and its significance.
- Historical context and evolution of packaging technologies.
- Introduction to packaging types: through-hole, surface-mount, ball grid array.

*Weeks 3-4: Packaging Materials and Interconnection Techniques**

- Study of materials used in semiconductor packaging.
- Interconnection techniques: wire bonding, flip-chip, and solder bump technologies.
- Lab sessions: Hands-on experience with interconnection techniques.

*Weeks 5-6: Thermal Management in IC Packaging**

- Principles of thermal management in IC packaging.
- Techniques for heat dissipation and cooling.
- Case studies: Analyzing thermal management strategies.

*Weeks 7-8: Signal and Power Integrity Considerations**

- Signal integrity challenges in IC packaging.
- Power integrity considerations and solutions.

- Lab sessions: Simulation exercises for signal and power integrity.

*Weeks 9-10: Packaging Types and Trade-offs**

- In-depth study of through-hole, surface-mount, and ball grid array packaging.
- Trade-offs involved in selecting packaging types.
- Project: Designing a packaging solution considering trade-offs.

*Weeks 11-12: Reliability in IC Packaging**

- Factors affecting reliability in IC packaging.
- Testing and validation techniques for packaged ICs.
- Lab sessions: Reliability testing exercises.

*Weeks 13-14: Advanced Topics in IC Packaging**

- Emerging trends in IC packaging technologies.
- Advanced materials and techniques.
- Group projects: Exploring advanced IC packaging concepts.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing IC packaging designs.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in IC packaging.

**Recommended Books**

1. John H. Lau. *Semiconductor Advanced Packaging*. Springer, 2021.
2. King-Ning Tu, Chih Chen, Hung-Ming Chen. *Electronic Packaging Science and Technology*. John Wiley and Sons Inc., 2022.

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## Appendix-1

# Specialization:

1. Semiconductor Devices /Manufacturing
2. Analog Mixed Signal and RF Circuits
3. Digital Design and Systems
4. Electronic Design Automation
5. Display Technologies
6. Semiconductor Packaging

# Specialization: Semiconductor Devices /Manufacturing

| Advanced Semiconductor Manufacturing | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This advanced course in semiconductor manufacturing provides an in-depth exploration of cutting-edge technologies and methodologies used in the fabrication of semiconductor devices. Students will gain insights into advanced manufacturing processes, equipment, and materials critical to the production of integrated circuits (ICs). The curriculum covers topics such as lithography, etching, deposition, metrology, and process integration. Emphasis is placed on the challenges and innovations in scaling down semiconductor devices, enhancing performance, and addressing reliability concerns. Practical applications, case studies, and exposure to state-of-the-art manufacturing tools will prepare students for careers in semiconductor manufacturing and research.

**Course Learning Outcomes:**

**Comprehensive Knowledge of Advanced Manufacturing Processes:**

- Acquire a thorough understanding of advanced semiconductor manufacturing processes.
- Explore the principles of lithography, etching, deposition, and other critical processes.

**In-Depth Understanding of Semiconductor Materials and Equipment:**

- Gain insight into advanced materials used in semiconductor manufacturing.
- Understand the operation and optimization of state-of-the-art manufacturing equipment.

**Process Integration Strategies:**

- Learn strategies for integrating complex manufacturing processes.
- Explore process integration challenges and solutions.

**Performance Enhancement and Scaling Down Technologies:**

- Understand techniques for enhancing the performance of semiconductor devices.
- Explore innovations in scaling down semiconductor technologies.

**Reliability Considerations in Semiconductor Manufacturing:**

- Analyze and address reliability concerns in semiconductor manufacturing.
- Develop skills in implementing quality control and reliability testing procedures.

**Teaching Plan:**

*Weeks 1-2: Introduction to Advanced Semiconductor Manufacturing**

- Overview of semiconductor manufacturing and its significance.
- Historical context and evolution of semiconductor manufacturing technologies.
- Introduction to advanced processes and equipment.

*Weeks 3-4: Lithography Techniques and Innovations**

- Principles of photolithography in semiconductor manufacturing.
- Advanced lithography techniques and innovations.
- Lab sessions: Hands-on experience with lithography tools.

*Weeks 5-6: Etching and Deposition Processes**

- In-depth study of etching processes and equipment.
- Techniques for thin film deposition in semiconductor manufacturing.
- Lab sessions: Hands-on exercises with etching and deposition tools.

*Weeks 7-8: Semiconductor Materials and Equipment**

- Overview of advanced materials used in semiconductor manufacturing.
- Operation and optimization of state-of-the-art manufacturing equipment.
- Project: Analyzing material and equipment interactions.

*Weeks 9-10: Process Integration Strategies**

- Strategies for integrating complex manufacturing processes.
- Case studies: Examining challenges and solutions in process integration.
- Lab sessions: Simulation exercises for process integration.

*Weeks 11-12: Performance Enhancement and Scaling Down Technologies**

- Techniques for enhancing semiconductor device performance.
- Innovations in scaling down semiconductor technologies.
- Project: Designing a process for scaling down semiconductor devices.

*Weeks 13-14: Reliability Considerations in Semiconductor Manufacturing**

- Factors affecting reliability in semiconductor manufacturing.
- Quality control and reliability testing procedures.
- Lab sessions: Reliability testing exercises.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing advanced semiconductor manufacturing designs.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in semiconductor manufacturing.

**Recommended Books**


1. Yaguang Lian. *Semiconductor Microchips and Fabrication: A Practical Guide to Theory and Manufacturing*. John Wiley and Sons Inc., 2023.
2. Glendinning, William. *Handbook of VLSI Microlithography*. William Andrew, 2012.
3. Moyne, James. *Run-to-Run Control in Semiconductor Manufacturing*. CRC Press, 2018.
4. Wittmann, Juergen. *Introduction to Quality Management in the Semiconductor Industry*. Createspace Independent Publishing Platform, 2018.
5. Zhang, Jie. *Wafer Fabrication*. Walter de Gruyter GmbH & Co KG, 2018.
6. Pecht, Michael. *Guidebook for Managing Silicon Chip Reliability*. CRC Press, 2017.
7. Gan, Zhenghao. *Semiconductor Process Reliability in Practice*. McGraw Hill Professional, 2012.


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| **Compound Semiconductors** | **2L:0T:0P** | **2 credits** |
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**Course Description:**

This course offers an in-depth exploration of compound semiconductors, focusing on the unique properties, materials, and applications that distinguish them from traditional elemental semiconductors. Students will delve into the fabrication processes, device physics, and emerging technologies associated with compound semiconductors. The curriculum covers key compound semiconductor materials, such as gallium arsenide (GaAs) and indium phosphide (InP), and explores their applications in electronic, optoelectronic, and high-frequency devices. Practical demonstrations, case studies, and exposure to state-of-the-art fabrication techniques will provide students with a comprehensive understanding of compound semiconductor technology.

**Course Learning Outcomes:**

**Comprehensive Understanding of Compound Semiconductor Materials:**

- Acquire a detailed knowledge of compound semiconductor materials, including their structures and properties.
- Differentiate between various compound semiconductors such as GaAs, InP, and others.

**Device Physics of Compound Semiconductors:**

- Understand the device physics specific to compound semiconductors.
- Explore the principles governing electronic, optoelectronic, and high-frequency devices.

**Fabrication Techniques and Processes:**

- Gain practical insights into the fabrication processes for compound semiconductor devices.
- Learn about epitaxial growth, lithography, and etching techniques specific to compound semiconductors.

**Applications in Electronic and Optoelectronic Devices:**

- Explore applications of compound semiconductors in electronic devices (e.g., high-speed transistors) and optoelectronic devices (e.g., lasers, photodetectors).
- Analyze the advantages and limitations of using compound semiconductors in different applications.

**Emerging Technologies and Trends in Compound Semiconductors:**

- Stay updated on the latest developments and emerging technologies in the field of compound semiconductors.
- Evaluate the potential impact of compound semiconductors in future electronic and optoelectronic systems.

**Teaching Plan:**

*Weeks 1-2: Introduction to Compound Semiconductors**

- Overview of compound semiconductors and their significance.
- Historical context and evolution of compound semiconductor technologies.
- Introduction to key compound semiconductor materials.

*Weeks 3-4: Crystal Structures and Properties of Compound Semiconductors**

- Crystal structures and properties of compound semiconductors.
- Comparison with elemental semiconductors.
- Lab sessions: Crystallography and material characterization.

*Weeks 5-6: Device Physics of Compound Semiconductors**

- Device physics principles specific to compound semiconductors.
- Electronic devices: High-speed transistors and integrated circuits.
- Lab sessions: Simulation exercises for electronic device behavior.

*Weeks 7-8: Optoelectronic Devices and Applications**

- Principles and applications of optoelectronic devices using compound semiconductors.

- Lasers, photodetectors, and light-emitting diodes (LEDs).
- Lab sessions: Hands-on experiments with optoelectronic devices.

*Weeks 9-10: Fabrication Techniques for Compound Semiconductors**

- Epitaxial growth techniques for compound semiconductors.
- Lithography and etching processes specific to compound semiconductors.
- Project: Designing a fabrication process for a compound semiconductor device.

*Weeks 11-12: Applications in High-Frequency Devices**

- Applications of compound semiconductors in high-frequency devices.
- Microwave transistors and communication devices.
- Lab sessions: Testing and characterization of high-frequency devices.

*Weeks 13-14: Emerging Technologies in Compound Semiconductors**

- Latest developments and trends in compound semiconductor technology.
- Advanced applications and emerging technologies.
- Group projects: Exploring and presenting emerging technologies.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing compound semiconductor applications.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in compound semiconductor technology.

**Recommended Books**


1. Keh Yung Cheng. *III-V Compound Semiconductors and Devices*. Springer,2020.
2. Udo W. Pohl. *Epitaxy of Semiconductors Physics and Fabrication of Heterostructures.* Springer, 2020.
3. Gupta, S. *OPTOELECTRONIC DEVICES AND SYSTEMS*. PHI Learning Pvt. Ltd., 2014.
4. Birtalan, Dave. *Optoelectronics*. CRC Press, 2018.


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| Semiconductor Manufacturing Instruments | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This advanced course focuses on the design principles, characterization methods, and challenges associated with semiconductor instruments used in the manufacturing environment. Students will explore the instruments critical to the production of semiconductor devices, such as metrology tools, inspection systems, and wafer testing equipment. The curriculum will cover the principles governing the design of these instruments, methods for characterizing semiconductor materials and devices, and the challenges in ensuring precision and reliability in a manufacturing setting. Practical exercises, case studies, and exposure to state-of-the-art manufacturing tools will prepare students for roles in semiconductor manufacturing, quality control, and process development.

**Course Learning Outcomes:**

**Comprehensive Understanding of Semiconductor Manufacturing Instruments:**

- Develop a comprehensive understanding of instruments used in semiconductor manufacturing.
- Differentiate between metrology tools, inspection systems, and testing equipment.

**Design Principles of Semiconductor Instruments:**

- Gain insight into the design principles governing semiconductor manufacturing instruments.
- Understand how design choices impact the precision and efficiency of manufacturing tools.

**Characterization Methods for Semiconductor Materials and Devices:**

- Explore methods for characterizing semiconductor materials and devices.
- Analyze the role of metrology in ensuring quality and reliability in semiconductor manufacturing.

**Challenges in Semiconductor Manufacturing Instrumentation:**

- Identify and analyze challenges in implementing and maintaining precision in semiconductor manufacturing instruments.
- Develop strategies for overcoming common manufacturing instrumentation challenges.

**Application of Instruments in Quality Control and Process Development:**

- Apply semiconductor manufacturing instruments in quality control processes.
- Understand the role of instrumentation in process development and optimization.

**Teaching Plan:**

*Weeks 1-2: Introduction to Semiconductor Manufacturing Instruments**

- Overview of semiconductor manufacturing instruments and their significance.
- Historical context and evolution of instruments in semiconductor manufacturing.

- Introduction to metrology tools, inspection systems, and testing equipment.

*Weeks 3-4: Design Principles of Semiconductor Instruments**

- Principles governing the design of semiconductor manufacturing instruments.
- Case studies: Examining design choices and their impact on instrument performance.
- Lab sessions: Hands-on experience with design considerations.

*Weeks 5-6: Characterization Methods for Semiconductor Materials**

- Methods for characterizing semiconductor materials in the manufacturing process.
- Analyzing the impact of material properties on device performance.
- Lab sessions: Material characterization techniques.

*Weeks 7-8: Metrology Tools in Semiconductor Manufacturing**

- In-depth study of metrology tools and their applications.
- Hands-on exercises with tools such as ellipsometers and profilometers.
- Lab sessions: Metrology techniques and data interpretation.

*Weeks 9-10: Inspection Systems for Quality Control**

- Principles of inspection systems in semiconductor manufacturing.
- Application of inspection tools in quality control processes.
- Project: Designing an inspection system for a specific manufacturing application.

*Weeks 11-12: Wafer Testing Equipment and Process Development**

- Overview of wafer testing equipment and its role in process development.
- Hands-on exercises with wafer testing tools.
- Lab sessions: Wafer testing and data analysis.

*Weeks 13-14: Challenges in Semiconductor Manufacturing Instrumentation**

- Identification and analysis of challenges in semiconductor manufacturing instrumentation.
- Strategies for overcoming common challenges.
- Group projects: Addressing a specific instrumentation challenge in manufacturing.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing the application of semiconductor manufacturing instruments.

- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in semiconductor manufacturing instrumentation.

**Recommended Books**


1. Dieter K Schroder. *Semiconductor Material and Device Characterization*. John Wiley and Sons Inc., third edition.
2. Su, Bo. *Introduction to Metrology Applications in IC Manufacturing*. 2015.
3. Bowen, D. *X-Ray Metrology in Semiconductor Manufacturing*. CRC Press, 2018.
4. Diebold, Alain. *Handbook of Silicon Semiconductor Metrology*. CRC Press, 2001.
5. Nehme, Charles. *From Sand to Silicon: An Insider's Guide to Semiconductor Manufacturing*. Charles Nehme.


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| **Emerging Memory Devices** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of emerging memory devices, focusing on novel technologies that have the potential to revolutionize the landscape of data storage and retrieval. Students will delve into the principles, design, and applications of non-volatile memory technologies beyond traditional options such as NAND and NOR flash. The curriculum covers emerging memory devices like Resistive Random-Access Memory (RRAM), Phase Change Memory (PCM), Magnetic RAM (MRAM), and more. Through theoretical study, hands-on experiments, and exposure to cutting-edge research, students will gain a comprehensive understanding of the capabilities and challenges associated with these next-generation memory technologies.

**Course Learning Outcomes:**

**Comprehensive Understanding of Emerging Memory Technologies:**

- Develop a thorough understanding of various emerging memory devices.
- Differentiate between Resistive RAM, Phase Change Memory, Magnetic RAM, and other novel technologies.

**Principles and Mechanisms of Operation:**

- Understand the principles and mechanisms of operation behind emerging memory devices.
- Explore the physical processes that enable data storage and retrieval in these devices.

**Applications and Use Cases:**

- Analyze the applications and use cases for emerging memory technologies.
- Explore how these devices can enhance performance and efficiency in various computing and storage systems.

**Integration Challenges and Solutions:**

- Identify challenges in integrating emerging memory devices into existing architectures.
- Explore solutions and strategies for seamless integration and compatibility.

**Hands-On Experience and Experimental Analysis:**

- Gain hands-on experience with emerging memory devices through laboratory exercises.
- Conduct experimental analysis to understand the behavior, performance, and reliability of these devices.

**Teaching Plan:**

*Weeks 1-2: Introduction to Emerging Memory Technologies**

- Overview of traditional and emerging memory devices.
- Historical context and evolution of memory technologies.
- Introduction to Resistive RAM, Phase Change Memory, and Magnetic RAM.

*Weeks 3-4: Resistive Random-Access Memory (RRAM)**

- Principles and mechanisms of operation in RRAM.
- Applications and advantages of RRAM in data storage.
- Lab sessions: Hands-on experiments with RRAM devices.

*Weeks 5-6: Phase Change Memory (PCM)**

- Detailed study of the principles behind PCM.
- Use cases and integration challenges of PCM in computing systems.
- Lab sessions: Experimental analysis of PCM behavior.

*Weeks 7-8: Magnetic RAM (MRAM)**

- Mechanisms and characteristics of MRAM.
- Applications in non-volatile memory and real-time systems.

- Lab sessions: Hands-on experience with MRAM devices.

*Weeks 9-10: Other Emerging Memory Technologies**

- Overview of additional emerging memory devices (e.g., Ferroelectric RAM, Memristors).
- Comparative analysis of various emerging memory technologies.
- Project: Evaluating the suitability of different emerging memories for specific applications.

*Weeks 11-12: Integration Challenges and Compatibility**

- Challenges in integrating emerging memory devices into existing systems.
- Compatibility issues and strategies for addressing them.
- Group projects: Designing solutions for seamless integration.

*Weeks 13-14: Experimental Analysis and Performance Evaluation**

- Advanced lab sessions: Experimental analysis of emerging memory devices.
- Performance evaluation and reliability testing.
- Group projects: Analyzing experimental data and drawing conclusions.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing applications or improvements with emerging memory devices.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in emerging memory technologies.

**Recommended Textbooks**

1. Ielmini, Daniele. *Resistive Switching*. 2016.
2. Ye Zhou. *Advanced Memory Technologies Functional Materials and Devices*. Royal Society of Chemistry, 2023.
3. Redaelli, Andrea. *Phase Change Memory*. Springer, 2018.
4. Yu, Shimeng. *Resistive Random Access Memory (RRAM)*. Springer Nature, 2022.
5. Tang, Denny. *Magnetic Memory Technology*. John Wiley & Sons, 2021.

# Specialization - Analog Mixed Signal and RF Circuits

| Mixed Signal Circuits | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides a comprehensive exploration of mixed signal circuits, focusing on the integration of both analog and digital components within a single system. Students will delve into the design principles, analysis techniques, and practical considerations involved in mixed signal circuitry. The curriculum covers topics such as analog-to-digital conversion (ADC), digital-to-analog conversion (DAC), signal processing, noise analysis, and the coexistence of analog and digital elements. Through theoretical study, practical simulations, and hands-on projects, students will gain the skills needed to design and analyze mixed signal circuits for a variety of applications.

**Course Learning Outcomes:**

**Comprehensive Understanding of Mixed Signal Circuits:**

- Develop a thorough understanding of mixed signal circuits and their applications.
- Differentiate between analog and digital components within a mixed signal system.

**Design Principles for Analog and Digital Integration:**

- Understand the design principles involved in integrating analog and digital components.
- Explore techniques for achieving seamless interaction between analog and digital domains.

**Analog-to-Digital and Digital-to-Analog Conversion:**

- Grasp the principles of analog-to-digital conversion (ADC) and digital-to-analog conversion (DAC).
- Analyze the performance and limitations of ADC and DAC circuits.

**Signal Processing in Mixed Signal Systems:**

- Explore signal processing techniques within mixed signal systems.
- Understand the impact of signal processing on overall system performance.

**Noise Analysis and Noise Mitigation Strategies:**

- Analyze noise sources in mixed signal circuits.
- Develop strategies for mitigating noise and ensuring signal integrity.

**Teaching Plan:**

*Weeks 1-2: Introduction to Mixed Signal Circuits**

- Overview of mixed signal circuits and their importance.

- Historical context and evolution of mixed signal design.
- Introduction to key components: ADC, DAC, and mixed signal systems.

*Weeks 3-4: Design Principles for Analog and Digital Integration**

- Principles governing the integration of analog and digital components.
- Case studies: Analyzing successful mixed signal designs.
- Lab sessions: Introduction to design tools for mixed signal circuits.

*Weeks 5-6: Analog-to-Digital Conversion (ADC)**

- Principles of ADC circuits and architectures.
- Performance metrics and specifications for ADC.
- Lab sessions: Simulations and hands-on exercises with ADC.

*Weeks 7-8: Digital-to-Analog Conversion (DAC)**

- Principles of DAC circuits and architectures.
- Performance metrics and specifications for DAC.
- Lab sessions: Simulations and hands-on exercises with DAC.

*Weeks 9-10: Signal Processing in Mixed Signal Systems**

- Overview of signal processing techniques in mixed signal systems.
- Case studies: Application of signal processing in real-world scenarios.
- Project: Designing a mixed signal system with signal processing elements.

*Weeks 11-12: Noise Analysis and Mitigation Strategies**

- Analysis of noise sources in mixed signal circuits.
- Strategies for mitigating noise and preserving signal integrity.
- Lab sessions: Noise analysis and simulations.

*Weeks 13-14: Advanced Topics and Emerging Trends**

- Emerging trends in mixed signal circuit design.
- Advanced components and techniques.
- Group projects: Exploring and presenting emerging trends.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing mixed signal circuit designs.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in mixed signal circuitry.

**Recommended Books**

1. Marcel Pelgrom. *Analog to Digital Conversion*. Springer, 2017.
2. Mourad Fakhfakh, Esteban Tlelo Cuautle, Rafael Castro Lopez. *Analog/RF and Mixed Signal Circuit Systematic Design*. Springer, 2013.

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| Low Power Circuit Designs | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of low-power circuit design, specifically focusing on the integration of CMOS and FinFET technologies. Students will delve into the principles, techniques, and challenges associated with designing energy-efficient circuits using these advanced semiconductor technologies. The curriculum covers low-power design strategies, optimization techniques, and practical considerations for achieving minimal power consumption. Through theoretical study, simulations, and hands-on projects, students will develop the skills necessary to design circuits with reduced power consumption while leveraging the benefits of CMOS and FinFET technologies.

**Course Learning Outcomes:**

**Advanced Understanding of Low Power Circuit Design with CMOS and FinFETs:**

- Develop an advanced understanding of low-power circuit design principles in the context of CMOS and FinFET technologies.
- Differentiate between traditional CMOS and FinFET design considerations for low-power applications.

**Low Power Design Strategies and Techniques with Advanced Technologies:**

- Understand advanced low-power design strategies and techniques applicable to CMOS and FinFET technologies.
- Explore the trade-offs involved in optimizing power consumption while

leveraging the benefits of advanced semiconductor technologies.

**Energy-Efficient Components and Architectures in CMOS and FinFETs:**

- Identify energy-efficient components and circuit architectures specific to CMOS and FinFET technologies.
- Analyze the impact of component selection on overall power efficiency in advanced semiconductor designs.

**Power Management and Optimization with CMOS and FinFETs:**

- Grasp the principles of power management specific to CMOS and FinFET technologies.
- Develop optimization techniques tailored to these advanced semiconductor technologies for achieving minimal power consumption.

**Practical Implementation and Simulation with CMOS and FinFETs:**

- Apply low-power design principles in practical circuit implementations using CMOS and FinFET technologies.
- Utilize simulation tools specific to advanced semiconductor technologies for analyzing and validating power performance.

**Teaching Plan:**

*Weeks 1-2: Introduction to Low Power Circuit Design with CMOS and FinFETs**

- Overview of the importance of low-power circuit design in CMOS and FinFET technologies.
- Historical context and evolution of low-power design in advanced semiconductor devices.
- Introduction to key concepts: power consumption, efficiency, and trade-offs specific to CMOS and FinFET technologies.

*Weeks 3-4: Low Power Design Strategies and Techniques in Advanced Technologies**

- Principles of advanced low-power design strategies in CMOS and FinFET technologies.
- Techniques for minimizing power consumption in digital and analog circuits with advanced semiconductor technologies.
- Lab sessions: Simulation exercises focusing on low-power techniques with CMOS and FinFETs.

*Weeks 5-6: Energy-Efficient Components and Architectures in CMOS and FinFETs**

- Identification of energy-efficient components and circuit architectures specific to CMOS and FinFET technologies.

- Case studies: Analyzing the impact of component selection on power efficiency in advanced semiconductor designs.
- Lab sessions: Hands-on exercises with energy-efficient components in CMOS and FinFETs.

*Weeks 7-8: Power Management and Optimization in CMOS and FinFETs**

- Principles of power management specific to CMOS and FinFET technologies.
- Optimization techniques for minimizing power consumption in advanced semiconductor designs.
- Lab sessions: Power management simulations and exercises with CMOS and FinFETs.

*Weeks 9-10: Practical Implementation of Low Power Designs with Advanced Technologies**

- Application of low-power design principles in practical circuit implementations using CMOS and FinFET technologies.
- Group projects: Designing low-power circuits for specific applications with advanced semiconductor technologies.
- Lab sessions: Hands-on projects and troubleshooting exercises with CMOS and FinFETs.

*Weeks 11-12: Simulation Tools for Low Power Design with CMOS and FinFETs**

- Overview of simulation tools specific to advanced semiconductor technologies for analyzing and validating power performance.
- Hands-on training with simulation software tailored to CMOS and FinFET designs.
- Project: Simulating and optimizing the power performance of a complex circuit with CMOS and FinFETs.

*Weeks 13-14: Advanced Topics and Emerging Trends in Low Power Design**

- Emerging trends in low-power circuit design with CMOS and FinFET technologies.
- Advanced components and techniques for ultra-low power applications in advanced semiconductor devices.
- Group projects: Exploring and presenting emerging trends specific to CMOS and FinFET technologies.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing low-power circuit designs with CMOS and FinFET technologies.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in low-power circuitry with advanced semiconductor technologies.

**Recommended Books**


1. Samar K. Saha. *FinFET Devices for VLSI Circuits and Systems*. Taylor and Francis Group, 2020.
2. Shilpi Birla, Shashi Kant Dargar, Neha Singh, P. Sivakumar. *Low Power Designs in Nanodevices and Circuits for Emerging Applications*. Taylor and Francis Group, 2023.


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| MEMS | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides a comprehensive exploration of Microelectromechanical Systems (MEMS), a multidisciplinary field at the intersection of electrical engineering, mechanical engineering, and material science. Students will delve into the principles, design methodologies, and applications of MEMS devices. The curriculum covers topics such as fabrication techniques, sensing and actuation mechanisms, modeling and simulation, and practical considerations in MEMS design. Through theoretical study, hands-on projects, and exposure to real-world applications, students will gain the skills necessary to contribute to the development of MEMS devices.

**Course Learning Outcomes:**

**Comprehensive Understanding of MEMS Principles:**

- Develop a comprehensive understanding of the fundamental principles underlying MEMS devices.
- Differentiate between various MEMS technologies and their applications.

**Design and Fabrication Techniques:**

- Understand the design methodologies and fabrication techniques used in MEMS devices.
- Explore materials, processes, and tools employed in MEMS fabrication.

**Sensing and Actuation Mechanisms in MEMS:**

- Grasp the principles of sensing and actuation mechanisms in MEMS.
- Analyze the integration of sensors and actuators in MEMS devices.

**Modeling and Simulation of MEMS Devices:**

- Develop skills in modeling and simulating MEMS devices.
- Utilize software tools for MEMS design, analysis, and optimization.

**Practical Application of MEMS Technology:**

- Apply MEMS principles in practical applications and real-world scenarios.
- Explore current trends and emerging applications in the field of MEMS.

Teaching Plan:

*Weeks 1-2: Introduction to MEMS and Its Applications**

- Overview of MEMS and its significance in various industries.
- Historical context and evolution of MEMS technology.
- Introduction to key concepts: sensing, actuation, and microfabrication.

*Weeks 3-4: MEMS Design and Fabrication Techniques**

- Principles of MEMS design and design considerations.
- Fabrication techniques: bulk micromachining, surface micromachining, and more.
- Lab sessions: Hands-on experience with MEMS design software and basic fabrication processes.

*Weeks 5-6: Sensing and Actuation Mechanisms in MEMS**

- Principles of sensing mechanisms in MEMS devices.
- Actuation mechanisms and their integration into MEMS.
- Lab sessions: Designing simple MEMS sensors and actuators.

*Weeks 7-8: Modeling and Simulation of MEMS Devices**

- Introduction to MEMS modeling and simulation tools.
- Hands-on exercises with software for MEMS design, analysis, and optimization.
- Project: Simulating the behavior of a MEMS device.

*Weeks 9-10: Materials and Processes in MEMS Fabrication**

- Materials used in MEMS fabrication and their properties.
- Processes such as lithography, deposition, and etching in MEMS fabrication.
- Lab sessions: Advanced fabrication exercises.

*Weeks 11-12: MEMS Integration and System Design**

- Integration of MEMS devices into larger systems.

- System-level considerations and challenges in MEMS applications.
- Project: Designing a complete MEMS-based system.

*Weeks 13-14: Advanced Topics and Emerging Trends in MEMS**

- Emerging trends in MEMS technology.
- Advanced applications and interdisciplinary research in MEMS.
- Group projects: Exploring and presenting emerging trends in MEMS.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing MEMS designs and applications.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in MEMS technology.

Recommended Books

1. Tai-Ran Hsu. *MEMS and Microsystems: Design, Manufacture and Nanoscale Engineering*. John Wiley and Sons Inc., 2020.
2. Zhuoqing Yang. *Advanced MEMS/NEMS Fabrication and Sensors*. Springer, 2022.

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| **High Power Circuit Designs** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of the principles, methodologies, and challenges associated with designing high-power circuits. Students will delve into the complexities of circuits handling significant power levels, emphasizing applications in power electronics, energy systems, and high-performance devices. The curriculum covers topics such as power semiconductor devices, power amplifiers, high-frequency converters, thermal management, and practical considerations in high-power design. Through theoretical study, simulations, and hands-on projects, students will gain the skills necessary to design robust, efficient, and reliable high-power circuits.

Course Learning Outcomes:

**Comprehensive Understanding of High Power Circuit Design Principles:**

- Develop a comprehensive understanding of the fundamental principles governing high-power circuit designs.

- Differentiate between various high-power circuit architectures and their applications.

**Design Methodologies for High Power Applications:**

- Understand the design methodologies specific to high-power applications.
- Explore techniques for optimizing efficiency and reliability in high-power circuits.

**Power Semiconductor Devices and their Applications:**

- Grasp the principles of power semiconductor devices and their applications in high-power circuits.
- Analyze the performance characteristics and limitations of different power devices.

**High-Frequency Converters and Power Amplifiers:**

- Explore the design of high-frequency converters and power amplifiers.
- Understand the challenges and considerations in achieving high efficiency in power conversion.

**Thermal Management in High Power Systems:**

- Develop skills in thermal management for high-power circuits.
- Analyze strategies for dissipating heat and ensuring the reliability of high-power systems.

**Teaching Plan:**

*Weeks 1-2: Introduction to High Power Circuit Design**

- Overview of the importance of high-power circuit design in various industries.
- Historical context and evolution of high-power technologies.
- Introduction to key concepts: power levels, efficiency, and thermal considerations.

*Weeks 3-4: Design Methodologies for High Power Applications**

- Principles of high-power design methodologies.
- Techniques for optimizing efficiency and reliability in high-power circuits.
- Lab sessions: Simulation exercises focusing on high-power design.

*Weeks 5-6: Power Semiconductor Devices and Applications**

- In-depth study of power semiconductor devices (MOSFETs, IGBTs, etc.).
- Applications of power devices in high-power circuits.
- Lab sessions: Hands-on exercises with power devices.

*Weeks 7-8: High-Frequency Converters and Power Amplifiers**

- Principles of high-frequency converters and power amplifiers.
- Design considerations and challenges in high-frequency power conversion.
- Lab sessions: Simulations and hands-on exercises with high-frequency converters.

*Weeks 9-10: Thermal Management in High Power Systems**

- Principles of thermal management for high-power circuits.
- Heat dissipation strategies and thermal modeling.
- Lab sessions: Thermal analysis and simulations.

*Weeks 11-12: Applications of High Power Circuit Design**

- Real-world applications of high-power circuit designs.
- Case studies: Analyzing successful high-power system implementations.
- Project: Designing a high-power circuit for a specific application.

*Weeks 13-14: Advanced Topics and Emerging Trends in High Power Design**

- Emerging trends in high-power circuit design.
- Advanced components and techniques for achieving higher efficiency and reliability.
- Group projects: Exploring and presenting emerging trends in high-power design.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing high-power circuit designs.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in high-power circuitry.

**Recommended Books**

1. Duran Leblebici, Yusuf Leblebici.*Fundamentals of High Frequency CMOS Analog Integrated Circuits*. Springer, 2021.
2. Sorin Voinigescu. *High Frequency Integrated Circuits.* Cambridge University Press.

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| AI Circuits | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course explores the intersection of artificial intelligence (AI) and integrated circuit design, delving into the principles, techniques, and challenges associated with creating circuits tailored for AI applications. Students will gain insights into the design considerations, hardware architectures, and optimization strategies that enable efficient and high-performance AI circuitry. The curriculum covers topics such as neuromorphic computing, hardware accelerators for machine learning, parallel processing architectures, and practical aspects of implementing AI circuits. Through theoretical study, hands-on projects, and exposure to cutting-edge developments, students will acquire the skills necessary to contribute to the rapidly evolving field of AI circuit design.

**Course Learning Outcomes:**

**Comprehensive Understanding of AI Circuit Design Principles:**

- Develop a comprehensive understanding of the fundamental principles governing the design of circuits for artificial intelligence applications.
- Differentiate between various AI circuit architectures and their applications.

**Design Methodologies for AI Applications:**

- Understand the design methodologies specific to AI applications in integrated circuits.
- Explore techniques for optimizing efficiency and performance in AI circuits.

**Neuromorphic Computing and AI Hardware Accelerators:**

- Grasp the principles of neuromorphic computing and its relevance in AI circuit design.
- Study hardware accelerators tailored for machine learning and AI tasks.

**Parallel Processing Architectures for AI:**

- Explore parallel processing architectures and their applications in AI circuits.
- Understand the challenges and considerations in achieving parallelism for AI applications.

**Practical Implementation and Optimization of AI Circuits:**

- Apply AI circuit design principles in practical applications and real-world scenarios.
- Optimize AI circuits for efficiency, speed, and power consumption.

**Teaching Plan:**

*Weeks 1-2: Introduction to AI Circuit Design**

- Overview of the significance of AI circuit design in modern technology.
- Historical context and evolution of AI hardware.
- Introduction to key concepts: AI algorithms, hardware acceleration, and neural network architectures.

*Weeks 3-4: Design Methodologies for AI Applications**

- Principles of design methodologies for AI applications.
- Techniques for optimizing efficiency and performance in AI circuits.
- Lab sessions: Simulation exercises focusing on AI circuit design.

*Weeks 5-6: Neuromorphic Computing and Hardware Accelerators**

- In-depth study of neuromorphic computing principles.
- Exploration of hardware accelerators designed for machine learning and AI tasks.
- Lab sessions: Hands-on exercises with neuromorphic computing models and hardware accelerators.

*Weeks 7-8: Parallel Processing Architectures for AI**

- Principles of parallel processing architectures and their applications in AI circuits.
- Design considerations and challenges in achieving parallelism for AI applications.
- Lab sessions: Simulations and hands-on exercises with parallel processing for AI.

*Weeks 9-10: Optimization of AI Circuits**

- Techniques for optimizing AI circuits for efficiency, speed, and power consumption.
- Case studies: Analyzing successful implementations of optimized AI circuits.
- Lab sessions: Optimization exercises and simulations.

*Weeks 11-12: Practical Implementation of AI Circuits**

- Application of AI circuit design principles in practical circuits.
- Group projects: Designing AI circuits for specific applications.
- Lab sessions: Hands-on projects and troubleshooting exercises.

*Weeks 13-14: Advanced Topics and Emerging Trends in AI Circuit Design**

- Emerging trends in AI circuit design.
- Advanced components and techniques for enhancing AI circuit performance.
- Group projects: Exploring and presenting emerging trends in AI circuit design.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing AI circuit designs.
- Final project presentations and demonstrations.

- Course review, feedback, and discussion of future developments in AI circuitry.

**Recommended Books**


1. Sze, Vivienne. *Efficient Processing of Deep Neural Networks*. Morgan & Claypool Publishers, 2020.
2. Mohammad, Baker. *In-Memory Computing Hardware Accelerators for Data-Intensive Applications*. Springer Nature, 2023.
3. Takano, Shigeyuki. *Thinking Machines*. Academic Press, 2021.
4. Mishra, Ashutosh. *Artificial Intelligence and Hardware Accelerators*. Springer Nature, 2023.
5. Munir, Arslan. *Accelerators for Convolutional Neural Networks*. John Wiley & Sons, 2023.
6. Zheng, Nan. *Learning in Energy-Efficient Neuromorphic Computing: Algorithm and Architecture Co-Design*. John Wiley & Sons, 2019.


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# Specialization - Digital Design and Systems

| Design for Testability | 2L:0T:0P | 2 credits |
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**Course Description:**

This course focuses on the principles, methodologies, and techniques of designing electronic circuits with testability in mind. Students will explore strategies to enhance the ease and effectiveness of testing integrated circuits during manufacturing and throughout their operational life. The curriculum covers topics such as built-in self-test (BIST), scan chains, fault modeling, and practical considerations in designing for testability. Through theoretical study, hands-on projects, and exposure to industry-standard tools, students will acquire the skills necessary to contribute to the development of robust and easily testable electronic systems.

**Course Learning Outcomes:**

**Comprehensive Understanding of Design for Testability Principles:**

- Develop a comprehensive understanding of the fundamental principles governing the design of electronic circuits for enhanced testability.
- Differentiate between various design strategies and their impact on testability.

**Built-in Self-Test (BIST) Techniques:**

- Understand the principles and implementation of built-in self-test techniques.
- Explore the advantages and limitations of BIST in electronic circuit testing.

**Scan Chains and Serial Testing:**

- Grasp the concept of scan chains and their role in serial testing.
- Learn how to implement and optimize scan chains for improved testability.

**Fault Modeling and Simulation:**

- Develop skills in fault modeling for electronic circuits.
- Utilize simulation tools to predict and analyze potential faults in a design.

**Practical Implementation of Design for Testability:**

- Apply design for testability principles in practical circuit implementations.
- Analyze the trade-offs between design complexity and testability.

**Teaching Plan:**

*Weeks 1-2: Introduction to Design for Testability**

- Overview of the importance of design for testability in modern electronic systems.
- Historical context and evolution of testability strategies.
- Introduction to key concepts: fault models, testing methodologies, and industry standards.

*Weeks 3-4: Built-in Self-Test (BIST) Techniques**

- Principles and implementation of built-in self-test techniques.
- Advantages and limitations of BIST in electronic circuit testing.
- Lab sessions: Simulations and exercises focusing on BIST.

*Weeks 5-6: Scan Chains and Serial Testing**

- Concept of scan chains and their role in serial testing.
- Implementation and optimization of scan chains for improved testability.
- Lab sessions: Hands-on exercises with scan chain design and testing.

*Weeks 7-8: Fault Modeling and Simulation**

- Development of fault models for electronic circuits.
- Utilization of simulation tools to predict and analyze potential faults in a design.
- Lab sessions: Fault simulation exercises.

*Weeks 9-10: Design for Testability Strategies**

- Exploration of various design for testability strategies.
- Case studies: Analyzing successful implementations of design for testability.
- Lab sessions: Designing circuits with testability considerations.

*Weeks 11-12: Industry Standards in Testability**

- Overview of industry standards related to testability.
- Compliance and certification requirements for testable designs.
- Lab sessions: Assessing designs against industry standards.

*Weeks 13-14: Advanced Topics and Emerging Trends in Design for Testability**

- Emerging trends in design for testability.
- Advanced components and techniques for enhancing testability.
- Group projects: Exploring and presenting emerging trends in design for testability.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing designs with enhanced testability.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future developments in design for testability.

**Recommended Books**


1. Tripathi, Suman. *Advanced VLSI Design and Testability Issues*. CRC Press, 2020.
2. Wang, Laung-Terng. *VLSI Test Principles and Architectures*. Morgan Kaufmann, 2006.
3. Huhn, Sebastian. Design for Testability, Debug and Reliability. Springer Nature, 2021.


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| FPGA Programming | 2L:0T:0P | 2 credits |
|---|---|---|

Course Description:

This course is designed to provide students with a comprehensive understanding of Field-Programmable Gate Arrays (FPGAs) and hands-on experience in programming and designing digital circuits using FPGA technology. Students will explore FPGA architecture, programming languages (VHDL and Verilog), and practical applications of FPGAs in various electronic systems. The curriculum emphasizes theoretical foundations, practical implementation, and real-world projects to equip students with the skills needed to effectively utilize FPGAs in digital design and prototyping.

**Course Learning Outcomes:**

**Understanding FPGA Architecture and Functionality:**

- Gain a comprehensive understanding of FPGA architecture, including logic elements, routing, and configuration.
- Explore the functionality and capabilities of FPGAs in digital circuit design.

**Proficiency in VHDL and Verilog Programming:**

- Develop proficiency in both VHDL and Verilog programming languages for FPGA design.
- Apply VHDL and Verilog to describe and implement digital circuits on FPGA platforms.

**Digital Circuit Design and Implementation on FPGAs:**

- Learn to design and implement digital circuits on FPGAs using VHDL and Verilog.
- Gain hands-on experience in translating design specifications into functional FPGA-based systems.

**Integration of IP Cores and System-Level Design:**

- Understand the integration of Intellectual Property (IP) cores into FPGA designs.
- Explore system-level design concepts and practices for developing complex

FPGA-based systems.

**Real-World Applications and Project Development:**

- Apply FPGA programming skills to real-world applications in digital signal processing, communication, and control systems.
- Develop and complete a project that demonstrates mastery of FPGA programming concepts.

**Teaching Plan:**

*Weeks 1-2: Introduction to FPGAs and Digital Design**

- Overview of FPGA technology and its applications.
- Basic concepts in digital design and logic circuits.
- Introduction to FPGA programming languages (VHDL and Verilog).

*Weeks 3-4: FPGA Architecture and Configuration**

- In-depth study of FPGA architecture and internal components.
- Configuration processes and the role of bitstream files.
- Lab sessions: Basic FPGA programming exercises.

*Weeks 5-6: VHDL and Verilog Programming for FPGAs**

- Comprehensive introduction to VHDL and Verilog programming.
- Hands-on exercises translating simple digital designs into VHDL/Verilog.
- Lab sessions: Basic programming tasks and simulations.

*Weeks 7-8: Digital Circuit Design on FPGAs**

- Techniques for designing digital circuits on FPGAs.
- Implementation of combinational and sequential logic circuits.
- Lab sessions: Design and implementation exercises.

*Weeks 9-10: IP Cores and System-Level Design**

- Integration of IP cores into FPGA designs.
- System-level design practices for developing complex systems.
- Lab sessions: Incorporating IP cores into FPGA projects.

*Weeks 11-12: Real-World Applications of FPGAs**

- Case studies of FPGAs in real-world applications (e.g., signal processing, communication).
- Exploration of industry trends and emerging applications.
- Lab sessions: Hands-on projects simulating real-world applications.

*Weeks 13-14: Project Development**

- Initiation and planning of individual or group projects.
- Implementation and troubleshooting of FPGA-based projects.
- Lab sessions: Project work and consultations.

*Week 15: Project Presentations and Course Review**

- Final presentations of individual or group projects.
- Course review, feedback, and discussion of advanced topics.
- Future trends in FPGA technology and applications.

**Recommended Books**

1. Rajewski, Justin. *Learning FPGAs*. "O'Reilly Media, Inc.," 2017.
2. Monk, Simon. *Programming FPGAs: Getting Started with Verilog*. McGraw Hill Professional, 2016.
3. Pellerin, David. *Practical FPGA Programming in C*. Prentice Hall, 2005.
4. Bruno, Frank. *FPGA Programming for Beginners*. Packt Publishing Ltd, 2021.

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| **Verification Tools and Techniques** | **2L:0T:0P** | **2 credits** |
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**Course Description:**

This course provides a comprehensive exploration of verification tools and techniques employed in the design and validation of digital systems. Students will gain insights into various verification methodologies, simulation tools, and formal verification techniques used to ensure the correctness and reliability of digital designs. The curriculum emphasizes both theoretical understanding and hands-on experience with industry-standard tools, preparing students for effective verification practices in the field of digital system design.

**Course Learning Outcomes:**

**Comprehensive Understanding of Verification Methodologies:**

- Develop a comprehensive understanding of verification methodologies used in digital system design.
- Differentiate between simulation-based and formal verification approaches.

**Proficiency in Simulation Tools:**

- Gain proficiency in using simulation tools for functional verification of digital designs.
- Apply simulation techniques to identify and rectify design issues.

**Formal Verification Techniques:**

- Understand the principles and applications of formal verification techniques.
- Learn to use formal verification tools to ensure design correctness.

**Advanced Verification Strategies:**

- Explore advanced verification strategies such as constrained-random testing and assertion-based verification.
- Apply these strategies to enhance the verification process and identify corner cases.

**Hands-on Experience with Industry-Standard Tools:**

- Gain hands-on experience with industry-standard verification tools.
- Apply tools and techniques learned in class to real-world digital design scenarios.

**Teaching Plan:**

*Weeks 1-2: Introduction to Verification in Digital Design**

- Overview of the importance of verification in digital system design.
- Basic concepts in functional verification.
- Introduction to simulation-based verification.

*Weeks 3-4: Simulation Tools and Basic Verification Techniques**

- Proficiency in using simulation tools (e.g., ModelSim, VCS).
- Basic verification techniques: testbenches, stimulus generation, and result analysis.
- Lab sessions: Simple simulation exercises.

*Weeks 5-6: Formal Verification Principles**

- Introduction to formal verification principles and methods.
- Model checking and theorem proving techniques.
- Lab sessions: Formal verification exercises.

*Weeks 7-8: Constrained-Random Testing and Advanced Verification Strategies**

- Principles of constrained-random testing.
- Assertion-based verification and coverage-driven verification.
- Lab sessions: Applying advanced verification strategies.

*Weeks 9-10: Industry-Standard Verification Tools**

- Overview of industry-standard verification tools (e.g., Questa, VCS).
- Hands-on experience with tool functionalities and features.
- Lab sessions: Using industry-standard tools for verification.

*Weeks 11-12: SystemVerilog for Verification**

- Introduction to SystemVerilog for verification.
- Using SystemVerilog constructs for effective verification.
- Lab sessions: SystemVerilog-based verification exercises.

*Weeks 13-14: Case Studies and Real-World Applications**

- Case studies of verification challenges in real-world digital designs.
- Analyzing and solving complex verification issues.
- Group projects: Applying verification tools and techniques to real-world scenarios.

*Week 15: Project Work and Final Presentations**

- Individual or group projects showcasing verification practices.
- Final project presentations and demonstrations.
- Course review, feedback, and discussion of future trends in verification tools and techniques.

**Recommended Books**

1. Perry, Douglas. *Applied Formal Verification*. McGraw Hill Professional, 2005.

2. Birtwistle, Graham. *VLSI Specification, Verification and Synthesis*. Springer Science & Business Media, 2012.
3. Kropf, Thomas. *Introduction to Formal Hardware Verification*. Springer Science & Business Media, 2013.
4. Seligman, Erik. *Formal Verification*. Elsevier, 2023.

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| On-Chip Interfaces | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course explores the fundamental principles and advanced techniques associated with on-chip interfaces in the context of integrated circuit design. Students will delve into the intricacies of communication between different components within a chip, emphasizing data transfer, synchronization, and control. The course covers a wide range of on-chip interface protocols, including serial and parallel interfaces, addressing both digital and mixed-signal aspects. Practical implementation challenges and strategies for optimizing on-chip communication performance will be addressed, providing students with a comprehensive understanding of the critical role that interfaces play in modern semiconductor devices.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand On-Chip Interface Basics:**

- Explain the fundamental concepts of on-chip interfaces, including data transfer protocols, clock synchronization, and control mechanisms.

**Design and Implement Serial and Parallel Interfaces:**

- Design and implement both serial and parallel on-chip interfaces, considering factors such as data rate, power consumption, and signal integrity.

**Analyze Mixed-Signal Interfaces:**

- Evaluate the challenges and solutions associated with mixed-signal on-chip interfaces, considering the integration of digital and analog components.

**Optimize On-Chip Communication Performance:**

- Apply optimization techniques to enhance on-chip communication performance, considering factors such as latency, throughput, and power efficiency.

**Troubleshoot and Debug On-Chip Interfaces:**

- Develop skills to identify and troubleshoot common issues in on-chip interfaces, using simulation tools and practical debugging techniques.

**Teaching Plan:**

**Weeks 1-2: Introduction to On-Chip Interfaces**
- Overview of on-chip communication
- Importance of interfaces in integrated circuit design
- Basic principles of data transfer and synchronization

**Weeks 3-5: Serial Interfaces**
- Introduction to serial communication
- UART, SPI, and I2C protocols
- Design considerations and trade-offs in serial interfaces

**Weeks 6-8: Parallel Interfaces**
- Basics of parallel communication
- Address and data buses
- Parallel interface standards (e.g., PCI Express)

**Weeks 9-10: Mixed-Signal Interfaces**
- Integration of digital and analog components
- Challenges in mixed-signal communication
- Case studies on mixed-signal interface design

**Weeks 11-12: Optimization Techniques**
- Techniques for improving data transfer rates
- Power optimization strategies
- Trade-offs between performance and power

**Weeks 13-14: Troubleshooting and Debugging**
- Common issues in on-chip interfaces
- Simulation tools for interface analysis
- Hands-on debugging exercises

**Week 15: Project and Review**
- Final project: Design and optimize an on-chip interface
- Review of key concepts and applications

**Recommended Books**

1. Mishra, Sanjeeb. *System on Chip Interfaces for Low Power Design*. Morgan Kaufmann, 2015.

2. Veendrick, Harry. *Bits on Chips*. Springer, 2018.
3. Doboli, Alex. *Introduction to Mixed-Signal, Embedded Design*. Springer Science & Business Media, 2010.
4. Pasricha, Sudeep. *On-Chip Communication Architectures*. Morgan Kaufmann, 2010.
5. Solari, Edward. *The Complete PCI Express Reference*. 2003.

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| **Memory Design** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course delves into the principles and practices of memory design for integrated circuits. Students will explore the various types of memories, including SRAM, DRAM, and Flash, and understand the trade-offs involved in designing efficient and reliable memory systems. The course covers topics such as memory architectures, timing considerations, power optimization, and emerging memory technologies. Practical aspects of memory design, including layout techniques and simulation tools, will be emphasized to provide students with a solid foundation in the field of memory design.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Memory Fundamentals:**

- Explain the fundamental principles of different types of memories, including SRAM, DRAM, and Flash.

**Design Efficient Memory Architectures:**

- Design and optimize memory architectures considering factors such as access time, storage capacity, and power consumption.

**Analyze Timing and Signal Integrity in Memory Design:**

- Evaluate and analyze timing constraints, addressing issues related to setup and hold times, clock-to-q delays, and signal integrity in memory circuits.

**Optimize Power Consumption in Memory Systems:**

- Apply power optimization techniques to reduce energy consumption in memory systems, considering both active and standby power.

**Explore Emerging Memory Technologies:**

- Investigate and assess emerging memory technologies, such as resistive RAM (RRAM) and phase-change memory (PCM), and understand their advantages and challenges.

**Teaching Plan:**

**Weeks 1-2: Introduction to Memory Design**

- Overview of memory types and their applications
- Importance of memory design in integrated circuits
- Basic principles of memory operation

**Weeks 3-5: Static Random-Access Memory (SRAM)**

- SRAM cell design and optimization
- Memory bit-cell stability and read/write operations
- SRAM array architecture and peripheral circuitry

**Weeks 6-8: Dynamic Random-Access Memory (DRAM)**

- DRAM cell design and refresh mechanisms
- Memory array organization and addressing
- Timing considerations in DRAM design

**Weeks 9-10: Flash Memory**

- NAND and NOR Flash architectures
- Programming and erasing mechanisms
- Wear leveling and error correction in Flash memory

**Weeks 11-12: Timing and Signal Integrity**

- Setup and hold time analysis
- Clock-to-q delay considerations
- Signal integrity challenges in memory circuits

**Weeks 13-14: Power Optimization in Memory Systems**

- Active and standby power consumption in memory
- Power-gating and clock gating techniques
- Low-power design strategies for memory circuits

**Week 15: Emerging Memory Technologies and Project**

- Overview of emerging memory technologies
- Final project: Design and analyze a memory system
- Review of key concepts and applications

**Recommended Books**

1. Itoh, Kiyoo. *VLSI Memory Chip Design*. Springer Science & Business Media, 2013.
2. Tanović, Sabina. *Designing Memory*. Cambridge University Press, 2019.
3. Campardo, Giovanni. *VLSI-Design of Non-Volatile Memories*. Springer Science & Business Media, 2005.

4. Singhee, Amith. *Extreme Statistics in Nanoscale Memory Design*. Springer Science & Business Media, 2010.
5. Yu, Shimeng. *Resistive Random Access Memory (RRAM)*. Springer Nature, 2022.
6. Kim, Chulwoo. *High-Bandwidth Memory Interface*. Springer Science & Business Media, 2013.

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# Specialization - Electronic Design Automation

| Logic Synthesis | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course explores the principles and techniques of logic synthesis in the context of digital circuit design. Students will delve into the process of transforming high-level descriptions of digital circuits into optimized gate-level representations. Topics include Boolean algebra, combinational and sequential logic synthesis, optimization algorithms, and the use of hardware description languages (HDLs). Practical aspects such as timing considerations, area optimization, and power consumption will be covered to equip students with the skills needed to design efficient and high-performance digital circuits.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Principles of Logic Synthesis:**

- Explain the fundamental principles of logic synthesis, including Boolean algebra, two-level and multi-level logic optimization, and technology mapping.

**Design and Optimize Combinational Logic Circuits:**

- Design combinational logic circuits using hardware description languages (HDLs) and optimize them for performance, area, and power.

**Develop Sequential Logic Circuits:**

- Design and synthesize sequential logic circuits, including finite state machines (FSMs), and optimize them for speed and resource utilization.

**Apply Timing Constraints and Optimization:**

- Apply timing constraints to ensure proper operation of digital circuits, and use optimization techniques to meet timing requirements while minimizing area and power consumption.

**Utilize Advanced Synthesis Techniques:**

- Explore advanced synthesis techniques, such as technology mapping, retiming, and logic restructuring, to enhance the performance and efficiency of digital circuits.

**Teaching Plan:**

**Weeks 1-2: Introduction to Logic Synthesis**

- Overview of logic synthesis in digital circuit design

- Basic concepts of Boolean algebra
- Introduction to hardware description languages (HDLs)

**Weeks 3-4: Combinational Logic Synthesis**

- Combinational logic design using HDLs
- Two-level and multi-level logic optimization techniques
- Introduction to logic synthesis tools

**Weeks 5-7: Sequential Logic Synthesis**

- Design and synthesis of sequential logic circuits
- Finite state machine (FSM) design and optimization
- Timing analysis for sequential circuits

**Weeks 8-9: Timing Constraints and Optimization**

- Introduction to timing constraints in digital circuits
- Timing analysis and optimization techniques
- Area and power optimization strategies

**Weeks 10-11: Technology Mapping and Retiming**

- Advanced synthesis techniques: technology mapping
- Retiming to optimize sequential circuits
- Case studies and practical applications

**Weeks 12-13: Logic Restructuring and Advanced Optimization**

- Logic restructuring techniques for performance improvement
- Advanced optimization algorithms in logic synthesis
- Practical implementation and case studies

**Weeks 14-15: Project and Review**

- Final project: Design and optimize a digital circuit
- Review of key concepts and applications
- Q&A and discussion of emerging trends in logic synthesis

**Recommended Books**

1. Hachtel, Gary. *Logic Synthesis and Verification Algorithms*. Springer Science & Business Media, 2007.
2. Barkalov, Alexander. *Logic Synthesis for FSM-Based Control Units*. Springer Science & Business Media, 2009.
3. Kurup, Pran. *Logic Synthesis Using Synopsys®*. Springer Science & Business Media, 2013.
4. Hassoun, Soha. *Logic Synthesis and Verification*. Springer Science & Business Media, 2012.
5. Reis, André. *Advanced Logic Synthesis*. Springer, 2017.

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| Semiconductor Device Modeling | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This advanced course explores the intricacies of semiconductor device modeling for electronic design. Students will delve into the mathematical formulations, physical principles, and simulation techniques that underlie the accurate representation of semiconductor devices. The course covers a range of devices, including diodes, transistors, and advanced semiconductor structures. Emphasis is placed on developing in-depth knowledge of the underlying physics and applying that knowledge to construct models suitable for electronic circuit simulation and analysis.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Comprehend Semiconductor Physics for Modeling:**

- Understand advanced semiconductor physics concepts, including carrier statistics, band-to-band tunneling, and quantum effects, essential for accurate device modeling.

**Construct Comprehensive Device Models:**

- Develop detailed and accurate mathematical models for a variety of semiconductor devices, considering both DC and AC characteristics.

**Simulate and Analyze Device Behavior:**

- Utilize simulation tools to analyze the behavior of semiconductor devices under different operating conditions, considering transient and frequency-domain responses.

**Explore Advanced Device Structures:**

- Study and model advanced semiconductor device structures, such as FinFETs, nanowire transistors, and emerging technologies, understanding their unique characteristics.

**Optimize Models for Performance and Variability:**

- Optimize device models to balance accuracy and computational efficiency, taking into account variability and parameter extraction challenges.

**Teaching Plan:**

**Weeks 1-2: Advanced Semiconductor Physics**

- Carrier statistics in semiconductors
- Quantum effects and their impact on device behavior

- Advanced topics in semiconductor physics

**Weeks 3-4: Diode Modeling Beyond Ideal Behavior**

- Reverse-bias breakdown and avalanche effects
- High-frequency diode behavior
- Modeling temperature-dependent characteristics

**Weeks 5-7: Bipolar Junction Transistor (BJT) Modeling**

- Non-ideal effects in BJT operation
- High-frequency and low-frequency BJT models
- Impact of temperature and process variations on BJT characteristics

**Weeks 8-9: Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) Modeling**

- Advanced MOSFET models for nanoscale technologies
- Quantum effects in MOSFETs
- Compact modeling for variability analysis

**Weeks 10-11: Advanced Transistor Structures**

- FinFET and nanowire transistor modeling
- Tunnel FETs and other emerging transistor technologies
- Trade-offs and advantages of advanced transistor structures

**Weeks 12-13: Simulation Challenges and Solutions**

- Simulation challenges in advanced semiconductor devices
- Monte Carlo simulations for statistical variability
- Case studies and practical solutions

**Weeks 14-15: Project and Review**

- Final project: Model and simulate an advanced semiconductor device
- Review of key concepts and applications
- Discussion of current trends in semiconductor device modeling

**Recommended Books**

1. Wu, Yung-Chun. *3D TCAD Simulation for CMOS Nanoeletronic Devices*. Springer, 2017.
2. Chauhan, Yogesh. *FinFET Modeling for IC Simulation and Design*. Academic Press, 2015.
3. Snowden, Christopher. *Semiconductor Device Modelling*. Springer Science & Business Media, 2012.
4. Massabrio, Giuseppe. *Semiconductor Device Modeling with Spice*. McGraw Hill Professional, 1998.

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| AI and ML for VLSI CAD | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course explores the integration of Artificial Intelligence (AI) and Machine Learning (ML) techniques in the field of VLSI CAD. Students will learn how AI and ML methodologies can be applied to automate and enhance various stages of the VLSI design process. Topics include pattern recognition, optimization, design rule checking, layout generation, and performance prediction. Practical applications and case studies will illustrate the use of AI and ML in addressing challenges and improving the efficiency of VLSI CAD tools.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand AI and ML Fundamentals:**

- Explain the fundamental principles of Artificial Intelligence and Machine Learning, including supervised and unsupervised learning, neural networks, and decision trees.

**Apply AI/ML Techniques to VLSI CAD:**

- Apply AI and ML algorithms to automate and optimize various aspects of the VLSI CAD process, such as layout design, routing, and timing analysis.

**Optimize Design Rule Checking with ML:**

- Utilize Machine Learning to enhance design rule checking processes, identifying violations and suggesting design fixes.

**Automate Layout Generation:**

- Implement AI/ML techniques for automated layout generation, considering factors such as area, power, and signal integrity.

**Predict Performance with ML Models:**

- Develop Machine Learning models to predict the performance of VLSI circuits, considering parameters like power consumption, speed, and reliability.

15-Week Teaching Plan:

**Weeks 1-2: Introduction to AI and ML in VLSI CAD**

- Overview of AI and ML applications in VLSI CAD
- Basics of supervised and unsupervised learning
- Introduction to neural networks and decision trees

**Weeks 3-4: Pattern Recognition in VLSI CAD**

- Application of AI for pattern recognition in IC design
- Feature extraction and classification techniques
- Case studies on pattern recognition in layout design

**Weeks 5-7: Optimization Techniques with ML**

- Optimization algorithms in VLSI design
- Genetic algorithms, simulated annealing, and particle swarm optimization
- Application of ML for automatic optimization in CAD tools

**Weeks 8-9: Design Rule Checking with ML**

- Enhancing design rule checking using Machine Learning
- Classification and regression models for DRC
- Case studies on DRC optimization with ML

**Weeks 10-11: Automated Layout Generation**

- AI/ML techniques for automated layout generation
- Considerations for area, power, and signal integrity in layout design
- Case studies on automated layout generation

**Weeks 12-13: Performance Prediction with ML Models**

- Developing ML models for performance prediction
- Power, speed, and reliability prediction using Machine Learning
- Validation and accuracy assessment of ML models

**Weeks 14-15: Project and Review**

- Final project: Implement AI/ML techniques in a VLSI CAD tool
- Review of key concepts and applications
- Discussion of current trends in AI and ML for VLSI CAD

**Recommended books**

1. Joobbani, R. *An Artificial Intelligence Approach to VLSI Routing*. Springer Science & Business Media, 2012.
2. Sait, Sadiq. *VLSI Physical Design Automation*. World Scientific, 1999.
3. Kumar, Abhishek. *Machine Learning Techniques for VLSI Chip Design*. John Wiley & Sons, 2023.
4. Elfadel, Ibrahim. *Machine Learning in VLSI Computer-Aided Design*. Springer, 2019.
5. Lu, Bing. *Layout Optimization in VLSI Design*. Springer Science & Business Media, 2001.
6. Kahng, Andrew. *VLSI Physical Design: From Graph Partitioning to Timing Closure*. Springer Nature, 2022.
7. Ren, Haoxing. *Machine Learning Applications in Electronic Design Automation*. Springer Nature, 2023.

| Formal Methods | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course introduces students to formal methods, a set of mathematically based techniques for the specification, design, verification, and analysis of software and hardware systems. Students will explore formal languages, logic, and tools used in modeling and reasoning about complex systems. The course covers various formal methods, including model checking, theorem proving, and abstract interpretation, with a focus on their application in ensuring the correctness and reliability of software and hardware systems.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Formal Languages and Logics:**

- Grasp the principles of formal languages and logics used in computer science, including propositional and first-order logic, temporal logic, and formal specification languages.

**Apply Model Checking Techniques:**

- Apply model checking techniques to verify and validate finite-state systems, analyzing system properties and identifying potential errors.

**Utilize Theorem Proving for Verification:**

- Use theorem proving methods to formally verify the correctness of software and hardware systems, including the development and analysis of formal proofs.

**Apply Abstract Interpretation for Analysis:**

- Utilize abstract interpretation to analyze and approximate program behaviors, identifying potential issues such as bugs, security vulnerabilities, or performance bottlenecks.

**Develop Formal Specifications:**

- Develop formal specifications for software and hardware systems, translating high-level requirements into precise mathematical models that facilitate rigorous analysis and verification.

**Teaching Plan:**

**Weeks 1-2: Introduction to Formal Methods**

- Overview of formal methods in computer science
- Importance of formal verification in system design

- Basic concepts of formal languages and logics

**Weeks 3-4: Propositional and First-Order Logic**

- In-depth study of propositional logic
- Introduction to first-order logic and its applications in formal methods
- Practical exercises on logical reasoning

**Weeks 5-7: Model Checking Techniques**

- Principles of model checking
- Temporal logics (e.g., CTL and LTL)
- Case studies and hands-on experience with model checking tools

**Weeks 8-9: Theorem Proving for Verification**

- Introduction to automated and interactive theorem proving
- Use of theorem provers for program verification
- Practical exercises on formal proofs

**Weeks 10-11: Abstract Interpretation**

- Principles of abstract interpretation for program analysis
- Developing abstract domains and transfer functions
- Case studies on applying abstract interpretation to real-world programs

**Weeks 12-13: Formal Specification Languages**

- Overview of formal specification languages
- Writing and analyzing formal specifications
- Integration of formal specifications in the software development process

**Weeks 14-15: Project and Review**

- Final project: Apply formal methods to verify a given system
- Review of key concepts and applications
- Discussion of current trends and challenges in formal methods

**Recommended Books**

1. Aziz, Adnan. *Formal Methods in VLSI System Design*. 1996.
2. Seligman, Erik. *Formal Verification*. Elsevier, 2023.
3. Grimm, Christoph. *Languages for System Specification*. Springer Science & Business Media, 2007.
4. Clarke, Edmund. *Model Checking, Second Edition*. MIT Press, 2018.

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# Specialization - Display Technologies

| Thin Film Transistors (TFTs) | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of Thin Film Transistors (TFTs), a crucial technology in modern electronics. Students will delve into the principles, fabrication methods, and applications of TFTs. The course covers thin film deposition techniques, TFT fabrication processes, and their integration into various electronic devices such as flat-panel displays, sensors, and flexible electronics. Emphasis is placed on understanding the electrical and optical characteristics of TFTs and their role in advancing electronic technologies.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand the Principles of Thin Film Transistors:**

- Comprehend the fundamental principles of operation of Thin Film Transistors, including the role of thin films in electronic devices.

**Analyze Thin Film Deposition Techniques:**

- Analyze various thin film deposition techniques, including physical vapor deposition (PVD) and chemical vapor deposition (CVD), and understand their applications in TFT fabrication.

**Design and Fabricate Thin Film Transistors:**

- Design and understand the fabrication processes of Thin Film Transistors, including semiconductor layer deposition, patterning, and post-processing steps.

**Characterize Electrical and Optical Properties:**

- Characterize the electrical and optical properties of Thin Film Transistors, including charge carrier mobility, threshold voltage, and optical transparency.

**Explore Applications of Thin Film Transistors:**

- Explore and evaluate the diverse applications of Thin Film Transistors in electronic devices, such as active-matrix displays, sensors, and flexible electronics.

**Teaching Plan:**

**Weeks 1-2: Introduction to Thin Film Transistors**

- Overview of Thin Film Transistors and their significance in electronics
- Historical perspective and evolution of TFT technology

**Weeks 3-4: Principles of Operation**

- Understanding the working principles of Thin Film Transistors
- Types of TFTs: amorphous, polysilicon, and organic TFTs

**Weeks 5-7: Thin Film Deposition Techniques**

- Overview of thin film deposition methods: PVD, CVD, and atomic layer deposition (ALD)
- Material selection and considerations in thin film deposition for TFTs

**Weeks 8-9: TFT Fabrication Processes**

- Semiconductor layer deposition and patterning
- Gate dielectric and electrode fabrication
- Source and drain electrode deposition and contact formation

**Weeks 10-11: Electrical Characterization of TFTs**

- Measurement techniques for electrical parameters: mobility, threshold voltage, and on/off ratio
- Role of thin film properties in electrical performance

**Weeks 12-13: Optical Properties and Applications**

- Optical transparency and its significance in TFT applications
- Applications of TFTs in flat-panel displays and sensors
- Emerging trends in flexible electronics using TFT technology

**Weeks 14-15: Project and Review**

- Final project: Design and simulate a Thin Film Transistor-based electronic device
- Review of key concepts and applications
- Discussion of current challenges and advancements in Thin Film Transistor technology

**Recommended Books**


1. Kagan, Cherie. *Thin-Film Transistors*. CRC Press, 2003.
2. Brotherton, S. D. *Introduction to Thin Film Transistors*. Springer Science & Business Media, 2013.
3. Zhou, Ye. *Semiconducting Metal Oxide Thin-Film Transistors*. IOP Publishing Limited, 2020.
4. Facchetti, Antonio. *Transparent Electronics*. John Wiley & Sons, 2010.


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| OLEDs and LCDs: Display Technologies | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of two prominent display technologies: Organic Light-Emitting Diodes (OLEDs) and Liquid Crystal Displays (LCDs). Students will gain a comprehensive understanding of the working principles, fabrication processes, and applications of OLEDs and LCDs in various electronic devices. The course covers the underlying physics, design considerations, and emerging trends in these display technologies, preparing students to engage with the rapidly evolving field of display technology.

**Course Learning Outcomes:**
Upon successful completion of the course, students will be able to:

**Understand the Principles of OLEDs and LCDs:**

- Comprehend the fundamental principles of operation for both Organic Light-Emitting Diodes and Liquid Crystal Displays, including the roles of organic materials, emissive layers, liquid crystals, and backlighting.

**Analyze Fabrication Processes:**

- Analyze the fabrication processes for OLEDs and LCDs, including thin film deposition techniques, patterning methods, and post-processing steps.

**Characterize Electrical and Optical Properties:**

- Characterize the electrical and optical properties of OLEDs and LCDs, including luminance, color reproduction, contrast ratio, and response times.

**Design Display Systems:**

- Design display systems incorporating OLEDs and LCDs, considering factors such as pixel arrangement, backlighting, and image processing to achieve optimal visual quality and user experience.

**Explore Applications and Emerging Trends:**

- Explore the diverse applications of OLEDs and LCDs in electronic devices, such as smartphones, TVs, and wearables, and stay abreast of emerging trends in display technologies.

**Teaching Plan:**

**Weeks 1-2: Introduction to Display Technologies**

- Overview of display technologies, with a focus on OLEDs and LCDs
- Historical development and evolution of OLED and LCD technologies

**Weeks 3-4: Principles of OLEDs**

- Working principles of OLEDs
- Types of OLEDs: small molecule vs. polymer-based
- Emissive layer materials and device structure

**Weeks 5-7: OLED Fabrication and Design**

- Thin film deposition techniques for OLEDs
- Patterning methods and post-processing steps
- Design considerations for OLED-based display systems

**Weeks 8-9: Principles of LCDs**

- Working principles of Liquid Crystal Displays
- Types of LCDs: Twisted Nematic (TN), In-Plane Switching (IPS), and Vertical Alignment (VA)
- Liquid crystal alignment and color filters

**Weeks 10-11: LCD Fabrication and Design**

- Fabrication processes for LCDs
- Backlighting techniques and advancements
- Design considerations for LCD-based display systems

**Weeks 12-13: Electrical and Optical Characterization**

- Measurement techniques for OLED and LCD parameters
- Evaluating luminance, color accuracy, contrast ratio, and response times
- Comparative analysis of OLED and LCD performance

**Weeks 14-15: Applications and Emerging Trends**

- Diverse applications of OLEDs and LCDs in electronic devices
- Exploration of emerging trends in display technologies
- Final project: Comparative analysis and design considerations for an OLED and LCD-based display system

**Reference Books**


1. Lee, Jiun-Haw. *Introduction to Flat Panel Displays*. John Wiley & Sons, 2020.
2. Linliu, Kung. *Micro-Led Display*. 2018.
3. Tsujimura, Takatoshi. *OLED Display Fundamentals and Applications*. John Wiley & Sons, 2017.
4. Linliu, Kung. *A Perfect Display! Micro-LED, OLED, LCD and CRT*. 2018.


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| Principles of Nanomaterials and Quantum Dots | 2L:0T:0P | 2 credits |
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**Course Description:**

This course provides a comprehensive exploration of the principles underlying nanomaterials, with a specific focus on quantum dots. Students will delve into the unique properties and behaviors exhibited by materials at the nanoscale. The course covers the synthesis methods, characterization techniques, and applications of nanomaterials, with an emphasis on the principles governing quantum dots. Topics include quantum mechanics at the nanoscale, electronic and optical properties, and the integration of nanomaterials into various technological applications.

**Course Learning Outcomes:**
Upon successful completion of the course, students will be able to:

**Understand Nanomaterials and Quantum Dots:**

- Grasp the fundamental principles of nanomaterials, including quantum dots, and the distinct characteristics that arise at the nanoscale.

**Analyze Synthesis Methods and Characterization Techniques:**

- Analyze various synthesis methods employed in creating nanomaterials, with a focus on quantum dots, and understand the characterization techniques used to assess their properties.

**Evaluate Electronic and Optical Properties:**

- Evaluate the electronic and optical properties of nanomaterials, particularly quantum dots, and how these properties differ from those observed in bulk materials.

**Explore Applications of Nanomaterials:**

- Explore and assess the diverse applications of nanomaterials, including quantum dots, in fields such as electronics, medicine, and energy.

**Synthesize and Design Nanomaterials:**

- Develop the skills to synthesize and design nanomaterials, with a specific focus on quantum dots, for specific applications, considering factors such as size, shape, and surface properties.

**Teaching Plan:**

**Weeks 1-2: Introduction to Nanomaterials and Quantum Dots**

- Overview of nanomaterials and their significance
- Introduction to quantum dots and their unique properties
- Historical development and key discoveries in the field

**Weeks 3-4: Quantum Mechanics at the Nanoscale**

- Principles of quantum mechanics applied to nanoscale materials
- Quantum confinement and its effects on electronic structure
- Size-dependent behaviors and phenomena

**Weeks 5-7: Synthesis Methods for Nanomaterials**

- Bottom-up and top-down synthesis approaches
- Chemical vapor deposition, sol-gel, and other techniques
- Case studies on the synthesis of quantum dots

**Weeks 8-9: Characterization Techniques**

- Microscopy techniques: TEM, SEM, and AFM
- Spectroscopic techniques: UV-Vis, XPS, and Raman
- Assessing size distribution and surface properties

**Weeks 10-11: Electronic and Optical Properties of Nanomaterials**

- Bandgap engineering in nanomaterials
- Quantum dots as emitters and absorbers
- Optical properties: fluorescence, phosphorescence, and quantum yield

**Weeks 12-13: Applications of Nanomaterials**

- Nanomaterials in electronics: transistors, sensors, and memory devices
- Medical applications: drug delivery, imaging, and diagnostics
- Energy-related applications: solar cells and batteries

**Weeks 14-15: Synthesis Project and Future Trends**

- Final synthesis project: Design and synthesize nanomaterials for a specific application
- Discussion of current trends and future directions in nanomaterials and quantum dots
- Review of key concepts and applications

**Reference Books**

1. Inamuddin. *Quantum Dots*. Materials Research Forum LLC, 2021.
2. Kumar, Challa. *Semiconductor Nanomaterials*. John Wiley & Sons, 2010.
3. Peskin, Uri. *Quantum Mechanics in Nanoscience and Engineering*. Cambridge University Press, 2023.

4. Weiner, John. *Light-Matter Interaction*. Oxford University Press, 2017.
5. Abdullaeva, Zhypargul. *Synthesis of Nanoparticles and Nanomaterials*. Springer, 2017.
6. Mansfield, Elisabeth. *Metrology and Standardization for Nanotechnology*. John Wiley & Sons, 2017.
7. de Oliveira, Osvaldo. *Nanocharacterization Techniques*. William Andrew, 2017.

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| **Display Systems Design** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of the design principles, technologies, and considerations involved in creating advanced display systems. Students will gain a comprehensive understanding of various display technologies, including LCDs, OLEDs, and emerging technologies. The course covers the entire design process, from conceptualization and specification to prototyping and evaluation. Emphasis is placed on achieving optimal visual quality, usability, and efficiency in display systems across diverse applications such as consumer electronics, automotive displays, and augmented reality.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Display Technologies:**

- Grasp the fundamental principles and characteristics of various display technologies, including LCDs, OLEDs, and emerging technologies, to inform design decisions.

**Analyze User Requirements and System Specifications:**

- Analyze user requirements and translate them into detailed system specifications, considering factors such as resolution, color accuracy, and viewing conditions.

**Design Display Systems for Optimal Visual Quality:**

- Design display systems with a focus on achieving optimal visual quality, considering aspects such as contrast ratio, color reproduction, and response time.

**Integrate Emerging Technologies in Design:**

- Integrate emerging display technologies, such as AR/VR and holographic displays, into the design process, understanding their unique capabilities and challenges.

**Prototype and Evaluate Display Systems:**

- Develop prototypes of display systems and implement evaluation methodologies to assess factors like usability, readability, and overall user experience.

**Teaching Plan:**

**Weeks 1-2: Introduction to Display Systems Design**

- Overview of display technologies and their applications
- Importance of user-centric design in display systems

**Weeks 3-4: Display Technologies Deep Dive**

- In-depth study of LCDs, OLEDs, and emerging display technologies
- Comparative analysis of characteristics and applications

**Weeks 5-7: User Requirements and System Specifications**

- User-centered design principles
- Translating user requirements into detailed specifications
- Case studies on effective specification design

**Weeks 8-9: Designing for Visual Quality**

- Principles of visual quality in display systems
- Design considerations for contrast ratio, color accuracy, and viewing angles
- Application of design principles in practical scenarios

**Weeks 10-11: Emerging Technologies Integration**

- Overview of augmented reality (AR) and virtual reality (VR) technologies
- Integrating AR/VR into display system design
- Challenges and opportunities in adopting emerging technologies

**Weeks 12-13: Prototyping Display Systems**

- Prototyping methods for display systems
- Hands-on exercises in building display prototypes
- Evaluation criteria for prototype assessment

**Weeks 14-15: Project and Review**

- Final project: Design and prototype an innovative display system
- User testing and evaluation of the designed system

- Review of key concepts, project outcomes, and discussion of current trends in display systems design

**Reference Books**


1. Miller, Michael. *Color in Electronic Display Systems*. Springer, 2018.
2. Bennett, Kevin. *Display and Interface Design*. CRC Press, 2011.
3. Committee, G. 10TDS. *Touch Interactive Display Systems: Human Factors Considerations, System Design and Performance Guidelines*. 2019.
4. MacDonald, Lindsay. *Display Systems*. John Wiley & Sons, 1997.


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| **Light Management Films** | **2L:0T:0P** | **2 credits** |
|---|---|---|

Course Description:

This course provides an in-depth exploration of light management films, a crucial aspect of optoelectronics for controlling the propagation, absorption, and reflection of light in various devices. Students will gain a comprehensive understanding of the principles, fabrication methods, and applications of light management films in diverse fields such as solar cells, displays, and optical sensors. The course covers film materials, optical design principles, and the integration of light management strategies into optoelectronic devices.

Course Learning Outcomes:

Upon successful completion of the course, students will be able to:

Understand the Principles of Light Management:

- Comprehend the fundamental principles of light management, including the interaction of light with different materials and the role of films in controlling light propagation.

Analyze Light Management Materials:

- Analyze various materials used in light management films, including polymers, nanostructures, and coatings, and understand their optical properties and fabrication methods.

Design and Optimize Light Management Strategies:

- Design and optimize light management strategies for specific applications, considering factors such as light absorption, reflection, and scattering to enhance device performance.

Apply Light Management in Solar Cells and Displays:

- Apply light management concepts in the design and optimization of solar cells and displays, considering efficiency, color accuracy, and visibility under various lighting conditions.

Evaluate Light Management Performance:

- Develop skills to evaluate the performance of light management films, utilizing measurement techniques, simulations, and analysis to assess their impact on device efficiency and optical characteristics.

Teaching Plan:

Weeks 1-2: Introduction to Light Management

- Overview of light management principles in optoelectronics
- Historical development and key concepts in light management films

Weeks 3-4: Optical Properties of Materials

- Study of optical properties of materials relevant to light management
- Introduction to transparent conductive films and anti-reflective coatings

Weeks 5-7: Light Management Films in Solar Cells

- Principles of light trapping and absorption in solar cells
- Design and optimization of light management films for solar energy conversion
- Case studies on successful applications in solar cell technologies

Weeks 8-9: Light Management in Displays and Lighting

- Light management strategies for enhancing display performance
- Optical films in display technologies, including polarizers and brightness enhancement films
- Applications in lighting systems for efficiency and color control

Weeks 10-11: Nanostructures and Metamaterials

- Introduction to nanostructures and metamaterials in light management
- Optical design principles utilizing nanostructures for advanced light control
- Case studies on the application of nanostructures in optoelectronic devices

Weeks 12-13: Fabrication Techniques for Light Management Films

- Thin film deposition methods, including physical and chemical vapor deposition
- Roll-to-roll processing and printing techniques for scalable production
- Practical exercises on film fabrication and optimization

Weeks 14-15: Project and Review

- Final project: Design and analyze a light management film for a specific optoelectronic application

- Review of key concepts and applications
- Discussion of current trends and future directions in light management films and optoelectronics

Reference Books


1. Mayer, Jan. *Light Management Films for Enhanced Harvesting in Printable Photovoltaics*. 2017.
2. Subramanyam, Guru. *Thin Film Nanophotonics*. Elsevier, 2021.
3. Enrichi, Francesco. *Solar Cells and Light Management*. Elsevier, 2019.
4. Papp, Jeffrey. *Quality Management in the Imaging Sciences - E-Book*. Elsevier Health Sciences, 2014.


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| **Color Science** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course delves into the interdisciplinary field of color science, exploring the principles of color perception, color reproduction, and color technologies. Students will gain a comprehensive understanding of the physics, psychology, and technology behind color. The course covers topics such as color models, color spaces, color measurement, and the application of color science in various industries, including imaging, design, and display technologies.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand the Fundamentals of Color Perception:**

- Comprehend the physiological and psychological aspects of color perception, including the mechanisms of human vision and the factors influencing color sensation.

**Analyze Color Models and Spaces:**

- Analyze different color models and color spaces, including RGB, CMYK, CIE XYZ, and LAB, understanding their characteristics, advantages, and applications.

**Apply Color Measurement Techniques:**

- Apply color measurement techniques and instruments to quantify and describe color properties, including colorimeters and spectrophotometers.

**Explore Color Reproduction Technologies:**

- Explore various color reproduction technologies, including displays, printers, and cameras, and understand the challenges and techniques involved in accurate color reproduction.

**Integrate Color Science in Design and Imaging:**

- Integrate color science principles into design processes, imaging technologies, and other applications, ensuring effective and meaningful use of color in various contexts.

**Teaching Plan:**

**Weeks 1-2: Introduction to Color Science**

- Overview of color science and its interdisciplinary nature
- Historical development and key concepts in color perception

**Weeks 3-4: Physiology and Psychology of Color Perception**

- Study of the human visual system and the physiology of color vision
- Psychological aspects of color perception, including color constancy and color harmony

**Weeks 5-7: Color Models and Spaces**

- Introduction to color models: RGB, CMYK, HSV, and others
- Understanding color spaces, including CIE XYZ and LAB
- Comparative analysis of different color models and spaces

**Weeks 8-9: Color Measurement Techniques**

- Principles of color measurement using colorimeters and spectrophotometers
- Practical exercises on color measurement and calibration
- Case studies on color quality control in industries

**Weeks 10-11: Color Reproduction Technologies**

- Principles of color reproduction in displays, printers, and cameras
- Challenges and techniques for achieving accurate color reproduction
- Hands-on activities on color calibration and profiling

**Weeks 12-13: Applications of Color Science**

- Integrating color science in design processes
- Color management in imaging technologies
- Industry-specific applications in fields such as printing, fashion, and digital media

**Weeks 14-15: Project and Review**

- Final project: Apply color science principles to solve a real-world problem
- Review of key concepts and applications
- Discussion of current trends and emerging technologies in color science

**Reference Books**


1. Shevell, Steven. *The Science of Color*. Elsevier Science Limited, 2003.
2. Shamey, Renzo. *Encyclopedia of Color Science and Technology*. Springer, 2023.
3. Colorimetry, Optical. *The Science of Color*. 1963.
4. Lee, Hsien-Che. *Introduction to Color Imaging Science*. Cambridge University Press, 2005.


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| **Touch Panel Technology** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of touch panel technology, a critical component in modern interactive devices. Students will gain comprehensive knowledge of the principles, design considerations, and applications of touch panels. The course covers various touch technologies, including capacitive, resistive, infrared, and surface acoustic wave, and explores the integration of touch panels into devices such as smartphones, tablets, interactive displays, and kiosks. Emphasis is placed on understanding the underlying technologies, touch sensing mechanisms, and the challenges and innovations in the field.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand the Principles of Touch Panel Technology:**

- Comprehend the fundamental principles and technologies underlying touch panels, including different touch sensing methods and their applications.

**Analyze Various Touch Panel Technologies:**

- Analyze and compare various touch panel technologies, such as capacitive, resistive, infrared, and surface acoustic wave, understanding their strengths, limitations, and suitable applications.

**Design Touch Panel Systems:**

- Design touch panel systems by considering factors such as touch accuracy, responsiveness, and multitouch capabilities, tailoring designs to specific applications and user interactions.

**Integrate Touch Panels into Devices:**

- Understand the integration of touch panels into various devices, including smartphones, tablets, interactive displays, and kiosks, considering form factors, power consumption, and user experience.

**Troubleshoot and Optimize Touch Panel Performance:**

- Develop skills in troubleshooting common issues in touch panel systems and optimizing their performance, including addressing calibration errors, interference, and environmental factors.

**Teaching Plan:**

**Weeks 1-2: Introduction to Touch Panel Technology**

- Overview of touch panel technology and its evolution
- Historical development and key milestones in touch panel technology

**Weeks 3-4: Principles of Touch Sensing**

- Basic principles of touch sensing mechanisms
- Capacitive, resistive, infrared, and surface acoustic wave technologies
- Comparative analysis of touch sensing methods

**Weeks 5-7: Capacitive Touch Technology**

- In-depth study of capacitive touch panels
- Projected capacitive vs. surface capacitive technology
- Design considerations and challenges in capacitive touch systems

**Weeks 8-9: Resistive and Infrared Touch Technologies**

- Principles and applications of resistive touch panels
- Infrared touch technology: reflective and projective approaches
- Comparative analysis and design considerations

**Weeks 10-11: Surface Acoustic Wave (SAW) Technology**

- Working principles of surface acoustic wave touch panels
- Applications and limitations of SAW technology
- Hands-on exercises on designing with SAW touch panels

**Weeks 12-13: Integration and Design Considerations**

- Integration of touch panels into devices: smartphones, tablets, and interactive displays
- Design considerations for optimizing touch panel performance
- Case studies on successful touch panel implementations

**Weeks 14-15: Project and Review**

- Final project: Design and prototype an interactive device with a touch panel interface
- Review of key concepts and applications
- Discussion of current trends and future directions in touch panel technology

**Reference Books**


1. Lee, Jiun-Haw. *Introduction to Flat Panel Displays*. John Wiley & Sons, 2020.
2. Gray, Tony. *Projected Capacitive Touch*. Springer, 2018.
3. Gray, Leon. *How Does a Touch Screen Work?* The Rosen Publishing Group, 2013.
4. Ruppel, Clemens. *Advances in Surface Acoustic Wave Technology, Systems and Applications*. World Scientific, 2001.


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| Display Testing & Characterization | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course offers an in-depth exploration of the methodologies, tools, and techniques involved in the testing and characterization of display technologies. Students will gain comprehensive knowledge of the evaluation process for displays, covering aspects such as color accuracy, brightness, contrast, response time, and overall performance. The course emphasizes hands-on experience with testing equipment and software tools commonly used in the industry for display quality assessment. Practical applications include display calibration, quality control, and troubleshooting.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Display Testing Fundamentals:**

- Grasp the fundamental principles of display testing, including key parameters such as color accuracy, brightness, contrast, and response time.

**Utilize Testing Equipment and Software:**
- Utilize testing equipment and software tools commonly used in the industry for display characterization and quality assessment.

**Conduct Comprehensive Display Evaluations:**
- Conduct comprehensive evaluations of displays, considering various factors such as uniformity, viewing angles, and energy efficiency.

**Troubleshoot Display Issues:**
- Develop skills in troubleshooting common display issues through systematic testing and analysis, identifying the root causes of problems and proposing solutions.

**Interpret and Communicate Test Results:**
- Interpret display test results accurately and communicate findings effectively, both in written reports and oral presentations.

**Teaching Plan:**

**Weeks 1-2: Introduction to Display Testing**
- Overview of display testing and its significance
- Historical development and key milestones in display testing methodologies

**Weeks 3-4: Fundamentals of Display Parameters**
- Color accuracy and calibration methods
- Brightness, contrast, and dynamic range in displays
- Response time and input lag considerations

**Weeks 5-7: Testing Equipment and Tools**
- Overview of testing equipment: colorimeters, spectrophotometers, and luminance meters
- Introduction to display testing software
- Hands-on exercises on using testing equipment

**Weeks 8-9: Display Uniformity and Viewing Angles**
- Evaluation of display uniformity
- Understanding the impact of viewing angles on display performance
- Practical exercises on assessing uniformity and viewing angles

**Weeks 10-11: Energy Efficiency and Environmental Considerations**
- Measurement of power consumption and energy efficiency in displays
- Considerations for environmental impact and sustainability in display technologies
- Case studies on eco-friendly display solutions

**Weeks 12-13: Troubleshooting Display Issues**
- Common display issues and their root causes
- Diagnostic techniques for identifying and resolving display problems
- Practical exercises on troubleshooting and problem-solving

**Weeks 14-15: Project and Review**

- Final project: Comprehensive display evaluation and troubleshooting report
- Review of key concepts and applications
- Discussion of current trends and emerging technologies in display testing and characterization

**Reference Books**


1. Lee, Jun. *Liquid Crystal Display Device and Method for Testing Pixels of the Same*. 2020.
2. Balasubramanian R. Device characterization. In Digital color imaging handbook 2017 Dec 19 (pp. 269-384). CRC Press.
3. Lasance CJ, Poppe A, editors. Thermal management for LED applications. New York: Springer; 2014.


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# Specialization - Semiconductor Packaging

| Materials for Semiconductor Packaging | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides a comprehensive exploration of materials used in semiconductor packaging, a critical aspect of the electronics industry. Students will gain in-depth knowledge of the materials' properties, selection criteria, fabrication processes, and their impact on the reliability and performance of packaged semiconductor devices. The course covers a range of packaging materials, including substrates, encapsulants, die attach materials, and interconnects. Emphasis is placed on understanding the role of materials in enhancing thermal management, electrical performance, and overall reliability in semiconductor packages.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Semiconductor Packaging Materials:**

- Comprehend the properties and characteristics of materials commonly used in semiconductor packaging, including substrates, encapsulants, and interconnects.

**Evaluate Material Selection Criteria:**

- Evaluate the criteria for selecting packaging materials based on the specific requirements of semiconductor devices, considering factors such as thermal conductivity, electrical conductivity, and reliability.

**Analyze Fabrication Processes:**

- Analyze the fabrication processes for semiconductor packaging materials, including die attach methods, molding processes, and interconnect technologies.

**Optimize Thermal Management in Semiconductor Packages:**

- Optimize the thermal management of semiconductor packages through the selection and design of materials with high thermal conductivity and effective heat dissipation properties.

**Enhance Reliability and Performance:**

- Enhance the reliability and performance of semiconductor devices by understanding the role of packaging materials in preventing issues such as moisture ingress, thermal stress, and mechanical failure.

**Teaching Plan:**

**Weeks 1-2: Introduction to Semiconductor Packaging Materials**

- Overview of semiconductor packaging and the role of materials
- Historical development and key advancements in packaging materials

**Weeks 3-4: Substrate Materials**

- Properties and selection criteria for substrate materials (e.g., FR-4, ceramics)
- Fabrication processes for substrates, including PCB technologies

**Weeks 5-7: Die Attach Materials**

- Characteristics of die attach materials (e.g., adhesives, solders)
- Die attach fabrication processes and considerations for different device types

**Weeks 8-9: Encapsulant Materials**

- Properties and selection criteria for encapsulant materials (e.g., epoxy, molding compounds)
- Molding and encapsulation processes in semiconductor packaging

**Weeks 10-11: Interconnect Technologies**

- Overview of wire bonding and flip-chip interconnects
- Material considerations for bonding wires and solder bumps
- Advanced interconnect technologies, including copper pillars and TSVs

**Weeks 12-13: Thermal Management in Semiconductor Packaging**

- Importance of thermal management in semiconductor packages
- Thermal interface materials (TIMs) and heat spreaders
- Design considerations for effective heat dissipation

**Weeks 14-15: Project and Review**

- Final project: Design a semiconductor package considering material selection and fabrication processes
- Review of key concepts and applications
- Discussion of current trends and emerging materials in semiconductor packaging

**Reference Books**

1. Chen, Andrea. *Semiconductor Packaging*. CRC Press, 2016.
2. Chung, Deborah. *Materials for Electronic Packaging*. Elsevier, 1995.
3. Lau, John. *Semiconductor Advanced Packaging*. Springer Nature, 2021.
4. Lu, Daniel. *Materials for Advanced Packaging*. Springer, 2016.

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| Advanced Packaging Technologies | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course delves into the intricate world of advanced packaging technologies for semiconductor devices, exploring cutting-edge methods that go beyond traditional packaging approaches. Students will gain a profound understanding of the latest innovations, including 3D packaging, system-in-package (SiP), fan-out wafer-level packaging (FOWLP), and heterogeneous integration. The course covers design considerations, fabrication processes, and applications of advanced packaging technologies, addressing the challenges and opportunities they present in the evolving semiconductor industry.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand Advanced Packaging Technologies:**

- Comprehend the principles and methodologies of advanced packaging technologies, including 3D packaging, SiP, FOWLP, and heterogeneous integration.

**Evaluate Design Considerations:**

- Evaluate design considerations specific to advanced packaging technologies, such as interconnect density, thermal management, and electrical performance.

**Analyze Fabrication Processes:**

- Analyze the fabrication processes involved in advanced packaging, including 3D stacking, wafer-level processes, and integration techniques for heterogeneous devices.

**Apply System-in-Package (SiP) Concepts:**

- Apply the concepts of System-in-Package (SiP) to integrate multiple functions and technologies into a single package, addressing challenges related to connectivity and co-design.

**Explore Emerging Trends and Future Directions:**

- Explore emerging trends in advanced packaging, such as chiplet integration, flexible electronics, and bio-integrated devices, and analyze their potential impact on the semiconductor industry.

**Teaching Plan:**

**Weeks 1-2: Introduction to Advanced Packaging Technologies**

- Overview of advanced packaging and its significance in the semiconductor industry
- Historical development and key advancements in advanced packaging

**Weeks 3-4: 3D Packaging**

- Principles of 3D packaging and stacking technologies
- Design considerations for vertical integration and through-silicon vias (TSVs)
- Case studies on successful implementations of 3D packaging

**Weeks 5-7: System-in-Package (SiP)**

- Concepts and advantages of System-in-Package (SiP)
- Design considerations for integrating diverse functionalities in a single package
- Hands-on exercises on SiP design

**Weeks 8-9: Fan-Out Wafer-Level Packaging (FOWLP)**

- Introduction to Fan-Out Wafer-Level Packaging
- Wafer-level processes for FOWLP and advantages over traditional packaging
- Case studies on FOWLP applications in industry

**Weeks 10-11: Heterogeneous Integration**

- Principles of heterogeneous integration
- Integration of diverse devices and materials in semiconductor packages
- Challenges and opportunities in heterogeneous integration

**Weeks 12-13: Emerging Trends and Innovations**

- Exploration of emerging trends in advanced packaging
- Chiplet integration, flexible electronics, and bio-integrated devices
- Guest lectures from industry experts on the latest innovations

**Weeks 14-15: Project and Review**

- Final project: Design an advanced semiconductor package considering 3D stacking, SiP, or FOWLP
- Review of key concepts and applications
- Discussion of current trends and future directions in advanced packaging technologies

**Reference Books**


1. Lau, John. *Chiplet Design and Heterogeneous Integration Packaging*. Springer Nature, 2023.
2. He, Lei. *System-in-Package*. Now Publishers Inc, 2011.
3. Chen, Andrea. *Semiconductor Packaging*. CRC Press, 2016.
4. Qu, Shichun. *Wafer-Level Chip-Scale Packaging*. Springer, 2014.
5. Pecht, Michael. *Handbook of Electronic Package Design*. CRC Press, 2018.
6. Lau, John. *Semiconductor Advanced Packaging*. Springer Nature, 2021.


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| **Package Design and Simulation Tools** | **2L:0T:0P** | **2 credits** |
|---|---|---|

**Course Description:**

This course provides an in-depth exploration of the design and simulation tools essential for semiconductor package development. Students will gain hands-on experience with industry-standard software tools used in package design, simulation, and analysis. The course covers various aspects, including thermal analysis, signal integrity, power integrity, and 3D modeling. Emphasis is placed on practical application, enabling students to design and simulate semiconductor packages for optimal performance and reliability.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Navigate Package Design and Simulation Tools:**

- Navigate and proficiently use industry-standard package design and simulation tools, gaining practical skills in software interfaces and workflows.

**Conduct Thermal Analysis:**

- Conduct thermal simulations and analyses using specialized tools to optimize heat dissipation and manage thermal issues in semiconductor packages.

**Analyze Signal Integrity:**

- Analyze signal integrity in semiconductor packages, considering factors such as impedance matching, signal attenuation, and crosstalk to ensure reliable data transmission.

**Optimize Power Integrity:**

- Optimize power distribution networks within packages, considering power integrity aspects such as voltage drop, power delivery, and minimizing noise.

**Utilize 3D Modeling for Package Design:**

- Utilize 3D modeling tools to create and analyze realistic representations of semiconductor packages, considering the spatial arrangement of components and their impact on performance.

## Teaching Plan:

**Weeks 1-2: Introduction to Package Design and Simulation Tools**

- Overview of semiconductor package design and the role of simulation tools
- Introduction to industry-standard software tools and their applications

**Weeks 3-4: Thermal Analysis Tools**

- Introduction to thermal analysis in semiconductor packages
- Hands-on exercises using thermal simulation tools for heat dissipation optimization

**Weeks 5-7: Signal Integrity Analysis**

- Fundamentals of signal integrity in semiconductor packages
- Practical application of signal integrity analysis tools for optimal data transmission

**Weeks 8-9: Power Integrity Simulation**

- Principles of power integrity and its significance in package design
- Simulation exercises for power distribution network optimization

**Weeks 10-11: 3D Modeling for Package Design**

- Introduction to 3D modeling tools and techniques
- Creating realistic 3D models of semiconductor packages for spatial analysis

**Weeks 12-13: Multi-Physics Simulations**

- Integration of thermal, signal integrity, and power integrity simulations
- Hands-on exercises in multi-physics simulations for comprehensive package analysis

**Weeks 14-15: Project and Review**

- Final project: Design and simulate a semiconductor package using integrated tools
- Review of key concepts and applications
- Discussion of current trends and emerging technologies in package design and simulation

## Reference Books

1. Greig, William. *Integrated Circuit Packaging, Assembly and Interconnections*. Springer Science & Business Media, 2007.

2. Li, Suny. *SiP System-in-Package Design and Simulation*. John Wiley & Sons, 2017.
3. Zhang, Hengyun. *Modeling, Analysis, Design, and Tests for Electronics Packaging beyond Moore*. Woodhead Publishing, 2019.
4. Liu, Sheng. *Modeling and Simulation for Microelectronic Packaging Assembly*. John Wiley & Sons, 2011.

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| EMC and Signal Integrity | 2L:0T:0P | 2 credits |
|---|---|---|

**Course Description:**

This course provides a comprehensive exploration of Electromagnetic Compatibility (EMC) and Signal Integrity in electronic systems. Students will gain an understanding of the principles, methodologies, and tools used to manage electromagnetic interference (EMI) and ensure signal integrity in high-speed digital and mixed-signal designs. The course covers topics such as PCB layout considerations, EMI mitigation techniques, and simulation tools for signal integrity analysis. Emphasis is placed on practical applications, enabling students to design electronic systems that meet EMC standards and maintain robust signal integrity.

**Course Learning Outcomes:**

Upon successful completion of the course, students will be able to:

**Understand EMC Principles:**

- Comprehend the fundamental principles of Electromagnetic Compatibility (EMC), including the sources of electromagnetic interference and the mechanisms of EMC compliance.

**Conduct Signal Integrity Analysis:**

- Conduct signal integrity analysis for high-speed digital and mixed-signal designs, considering factors such as impedance matching, reflections, and transmission line effects.

**Implement PCB Layout Techniques:**

- Implement PCB layout techniques to minimize electromagnetic interference and maintain signal integrity, considering guidelines for high-speed routing, power distribution, and grounding.

**Apply EMI Mitigation Strategies:**

- Apply effective EMI mitigation strategies, including filtering, shielding, and grounding techniques, to ensure compliance with EMC standards and regulations.

**Utilize Simulation Tools:**

- Utilize simulation tools for EMC and signal integrity analysis, gaining practical experience in predicting and mitigating potential issues in electronic designs.

**Teaching Plan:**

**Weeks 1-2: Introduction to EMC and Signal Integrity**

- Overview of Electromagnetic Compatibility (EMC) and Signal Integrity
- Importance of EMC in electronic systems and its impact on signal integrity

**Weeks 3-4: EMC Standards and Regulations**

- Study of international EMC standards and regulatory requirements
- Case studies on the consequences of non-compliance

**Weeks 5-7: Signal Integrity Fundamentals**

- Fundamentals of signal integrity in high-speed digital and mixed-signal designs
- Analysis of transmission line effects, reflections, and signal degradation

**Weeks 8-9: PCB Layout Considerations**

- PCB layout techniques for EMC and signal integrity
- High-speed routing guidelines, power distribution, and grounding strategies

**Weeks 10-11: EMI Mitigation Techniques**

- Strategies for minimizing electromagnetic interference (EMI)
- Filtering, shielding, and grounding techniques for EMI mitigation

**Weeks 12-13: Simulation Tools for Signal Integrity**

- Introduction to simulation tools for signal integrity analysis
- Hands-on exercises using simulation software to predict and optimize signal integrity

**Weeks 14-15: Project and Review**

- Final project: Design and simulate an electronic system with a focus on EMC and signal integrity
- Review of key concepts and applications

- Discussion of current trends and emerging technologies in EMC and signal integrity

**Reference Books**


1. Bogatin, Eric. *Signal and Power Integrity - Simplified*. Prentice Hall, 2017.
2. Montrose, Mark. *EMC and the Printed Circuit Board*. John Wiley & Sons, 2004.
3. Christopoulos, Christos. *Principles and Techniques of Electromagnetic Compatibility*. CRC Press, 2018.
4. Russ, Samuel. *Signal Integrity*. Springer Nature, 2022.


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# Appendix – II

# A Guide to Induction Program

# Appendix – II: A Guide to Induction Program

## Introduction

In its 49th meeting, held on 14th March 2017, AICTE approved a package of measures for further improving the quality of technical education in the country. This 3-week mandatory Student Induction Program (SIP) based on Universal Human Values (UHV) is one of these key measures.

The SIP is intended to prepare newly admitted undergraduate students for the new stage in their life by facilitating a smooth transition from their home and school environment into the college and university environment.

The present form of the Student Induction Program (SIP) has taken inspiration from and gratefully acknowledges the many efforts in this direction. In particular the Foundation Program at IIT Gandhinagar1 (July 2011) and the course in Universal Human Values and Professional Ethics2 (IIIT Hyderabad, 2005; AKTU Lucknow, 2009 and PTU Jalandhar, 2011; overall about 35 universities); and also, the mentorship, internship and apprenticeship programs3 of several institutions. The SIP amalgamates all the three into an integrated whole, which leads to its high effectiveness in terms of building a healthy lifestyle, creativity, bonding and character. It develops sensitivity towards self and one's relationships, builds awareness about others and society beyond the individual, and also in bonding with their own batch-mates and senior students as well as faculty members.

The purpose of this document along with accompanying details are to help institutions / colleges in understanding the spirit of the Induction Program and implementing it.

It is in line with the thoughts expressed in the NEP 2020:

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[1] IIT Gandhinagar places great emphasis on not only educating successful engineers of the future, but also creating well-rounded personalities, who contribute to society, are respectful of and can adapt to their surroundings, and prove themselves to be great thinkers and problem solvers in all avenues of life. In 2011, in line with this vision, It took the bold step to introduce a five week Foundation Program for incoming 1st year UG students. It involved activities such as games, art, etc.; also science and other creative workshops as well as lectures by eminent resource persons. To enable undivided attention on this, normal classes were scheduled only after this program was over.

[2] The foundation course was started in 2005 at IIIT Hyderabad. In 2009, UP Technical University (now AKTU) introduced it in all academic programs across their 550 colleges. From there on, it has been included in the curriculum of many universities, particularly in technical universities, in quite a natural manner, filling a long-felt need. After AKTU, it was IKG-Punjab Technical University in 2011, then Royal University of Bhutan in 2012 and so on. By 2020, more than 40 universities in India and both universities of Bhutan have been offering this foundation course. Since 2017, it has been a compulsory credit course in AICTE's model curriculum for all UG courses. Faculty from all departments are involved in conducting the course. The content is universal, rational, verifiable and leading to harmony. The mode is a self-exploration (and not sermonising or lecturing). Faculty are to be prepared beforehand. The results have been quite encouraging.

[3] Many institutes setup mentor-mentee network under which 1st year students are divided into small groups, each assigned to a senior student as a Student Buddy, and to a faculty member as a Faculty Mentor. Thus, a new student has their guidance through regular interactions. They can discuss their aims and aspirations as well as concerns whether social, psychological, financial, academic, or otherwise.

"*Education is fundamental for achieving* ***full human potential****, developing an* ***equitable and just society****, and promoting* ***National development***".

*"The purpose of the education system is to develop good human beings capable of rational thought and action, possessing compassion and empathy, courage and resilience, scientific temper and creative imagination, with sound ethical moorings and values".*

*"It aims at producing engaged, productive, and contributing citizens for building an equitable, inclusive, and plural society as envisaged by our Constitution".*

*"Education must build character, enable learners to be ethical, rational, compassionate, and caring, while at the same time prepare them for gainful, fulfilling employment".*

*"The curriculum must include basic arts, crafts, humanities, games, sports and fitness, languages, literature, culture, and values, in addition to science and mathematics, to develop all aspects and capabilities of learners; and make education more well-rounded, useful, and fulfilling to the learner".*

So, when new students join an institution, they are to be welcomed and oriented to the institute, its vision, people, purpose, culture and values, policies, programs, rules and regulations etc. through a well-planned 3-week interaction before regular classes start.

Education aims at developing the students to their full potential, so that they are able to participate meaningfully not only in their profession, but also in their family, society and their natural environment. That requires the development of their values as well as skills.

Engineering colleges were established to train graduates in their respective branch/ department of study, be ready for the job market, but also have a holistic outlook towards life and have a desire and competence to work for national needs and beyond. The graduating student must have the knowledge and skills in the area of his study. However, s(he) must also have a broad understanding of society and relationships. Besides the above, several meta-skills and underlying values are needed. Character needs to be nurtured as an essential quality by which s(he) would understand and fulfil his/her responsibility as an engineer, a family member, a citizen etc.

The same applies to all other branches of study – be it professional, vocational or any other area of academic. The graduating student must be a good human being and have the skills in their area of study.

Each family, institution, region, community etc. have evolved their way of life, their cultures over a period of time. The new students are going from one culture to another. Today, a major issue is that one culture tends to be opposed to other cultures. This is because their basic assumptions, and therefore thoughts, are different. Even though there are commonalities at the core value level, the conflict is at the level of expression and details.

With this situation, it is imperative to

- Articulate the essence or core aspects of human culture and civilization, i.e. understand universal human values like trust and respect, love and compassion
- Appreciate the various expressions, different approaches taken in different regions

Our effort is in the context of the whole humanity. However, when it comes to exemplifying these essential concepts, we will have to take to local or national expressions.

In SIP, we want to provide an exposure to essence in the context of the whole humanity first. Then we can take a representative cross-section of all cultures as expressions of this essence. A yardstick to evaluate these various options is provided to guide the student towards a humanistic culture founded on the truth and universal human values like love and compassion.

*For example:* We want to live with fulfilment as a society. This part is common, universal.
*To exemplify this, we may expose students to traditional Indian culture and philosophy as well as contemporary western culture and thought.*

The intent is:

- Connecting the basic principles through specific examples
- To see and appreciate various cultures, to see the commonality amongst them, in the light of clarity about human culture and civilisation.
- To evaluate any specific example, system or culture, with a view to fill the gaps, rather than to criticise or reject it. Further, we can also be mutually enriching for other cultures.

# Student Induction Program (SIP)

With this background, the SIP has been formulated with specific goals to help students to:

- Become familiar with the ethos and culture of the institution (based on institutional culture and practices)
- Set a healthy daily routine, create bonding in batch as well as between faculty members and students
- Get an exposure to a holistic vision of life, develop awareness, sensitivity and understanding of the
  Self---family---Society---Nation---International---Entire Nature
- Facilitate them in creating new bonds with peers and seniors who accompany them through their college life and beyond
- Overcome weaknesses in some essential professional skills – only for those who need it (e.g. Mathematics, Language proficiency modules)

The SIP consists of different activities which includes meeting new students, socializing with teachers and other people in the university. Secondly associating with the Local area or city, knowing different departments, associating with the department heads, local stores and necessary shops for the survival at new place. Basically, getting information about the rules and regulations of the university which includes do's and don'ts. Other activities which may involve students in several creative, cultural and co- curricular activities through which they can explore themselves and get idea about their intrinsic desires and interests which may help them in the long run. In order to make it worth, at the initial level of joining of student various seminars, lectures by eminent personalities, sessions by the appointed mentor for the student is being done to make them more familiar with the university environment. It has been seen that student after schooling when moves towards further studies for either under graduation or post-graduation has got so many confusions and false knowledge about the college and the curriculum. They should know the basic idea about the fruits and prospects of the particular course and the university or institute in which they are entering. To have faith about their choices and to know that after completion, they will be well equipped with the values and skills which may aid to their future goals and let them work for their personal motives, society and the Nation's development.

The various modules or core areas recommended for the 3-week SIP are:

**SIP Module 1: Universal Human Values I (UHV I) 22 hours**

The purpose is to help develop a holistic perspective about life. A self-reflective methodology of teaching is adopted. It opens the space for the student to explore his/her role (value) in all aspects of living – as an individual, as a member of a family, as a part of the society and as a unit in nature. Through this process of self-exploration, students are able to discover the values intrinsic in them. The session-wise topics are given below:

| Session No. | Topic Title | Aspirations and Issues | Basic Realities (underlying harmony) |
|---|---|---|---|
| 1 | Welcome and Introductions | Getting to know each other | Self-exploration |
| 2 and 3 | Aspirations and Concerns | Individual academic, career… Expectations of family, peers, society, nation… Fixing one's goals | Basic human aspirations Need for a holistic perspective Role of UHV |
| 4 and 5 | Self-Management | Self-confidence, peer pressure, time management, anger, stress… Personality development, self-improvement… | Harmony in the human being |
| 6 and 7 | Health | Health issues, healthy diet, healthy lifestyle Hostel life | Harmony of the Self and Body Mental and physical health |
| 8, 9, 10 and 11 | Relationships | Home sickness, gratitude towards parents, teachers and others Ragging and interaction Competition and cooperation Peer pressure | Harmony in relationship Feelings of trust, respect… gratitude, glory, love |

| | | | |
|---|---|---|---|
| 12 | Society | Participation in society | Harmony in the society |
| 13 | Natural Environment | Participation in nature | Harmony in nature/existence |
| 14 | Sum Up | Review role of education Need for a holistic perspective | Information about UHV-II course, mentor and buddy |
| 15 | Self-evaluation and Closure | Sharing and feedback | |

**SIP Module 2: Physical Health and Related Activities 51 hours**

This module is intended to help understand the basic principles to remain healthy and fit and practice them through a healthy routine which includes exercise, games etc.

**SIP Module 3: Familiarization of Department/ Branch and Innovation 06 hours**

This module is for introducing and relating the student to the institution/department/branch; how it plays a role in the development of the society, the state, region, nation and the world at large and how students can participate in it.

**SIP Module 4: Visit to a Local Area 10 hours**

To relate to the social environment of the educational institution as well as the area in which it is situated through interaction with the people, place, history, politics…

**SIP Module 5: Lectures by Eminent People 06 hours**

Listening to the life and times of eminent people from various fields like academics, industry etc. about careers, art, self-management and so on enriches the student's perspective and provides a holistic learning experience.

**SIP Module 6: Proficiency Modules 06 hours**

This module is to help fill the gaps in basic competency required for further inputs to be absorbed. It includes effort to make student proficient in interpersonal communication and expression as well as awareness about linguistic and thereafter NLP.

**SIP Module 7: Literature / Literary Activities 30 hours**

Through the exposure of local, national and international literature, this module is aimed at helping the student learn about traditional as well as contemporary values and thought.

**SIP Module 8: Creative Practices 49 hours**

This module is to help develop the clarity of humanistic culture and its creative, joyful expression through practice of art forms like dance, drama, music, painting, pottery, sculpture etc.

**SIP Module 9: Extra Curricular Activities 06 hours**

This is a category under which things that are not placed in any of the above may be placed. Some clubs and hobby group may be made for each of the above categories, so that students may pursue them even after SIP.

The recommended hours to be allocated are given above. Depending on the available faculty, staff, infrastructure, playgrounds, class timings, hostellers and day scholars etc., the timetable for these activities may be drawn up. Of course, colleges may conduct an inaugural function at the beginning of the SIP; and they may also conduct a celebratory closing ceremony at the end of the SIP.

In particular, during the lockdown phase, appropriate care may be taken and some or all activities may be planned in distance-learning or on-line mode.

**Sample 3-week Activity List**

| | |
|---|---|
| **Week 1** | Inaugural Function<br><br>Regular SIP Activities (See Hours Plan) |
| **Week 2** | Regular SIP Activities (See Hours Plan) |
| **Week 3** | Regular SIP Activities (See Hours Plan)<br><br>Valedictory and Closing Ceremony (Celebration) |

**Implementation**

Every institution/college is expected to conduct the 3-week SIP under the guidance of the Director/Principal or Dean Students or a senior faculty member. For this, the institution is expected to make an SIP Cell / team, which will be responsible for planning, and then implementation of the SIP.

A UHV Cell is expected to be set up at each college and university. At the college, it will be managed by the UHV Convener / Coordinator under the chairpersonship of the director/principal. Faculty members and some students will be the members. They will coordinate the UHV activities like UHV-I during SIP, UHV-II, the faculty mentoring program and student buddy program throughout the student's association with the institute/college. The UHV Cell will work to incorporate human values in every aspect of education at the institute/college. Preparing UHV Faculty (Mentors) is one of its important activities.

**Follow up**

The SIP is only the beginning of the interaction with newly joined students.

An important part of the SIP is to associate one faculty mentor to every small groups of about 20 students; and also associate one senior student buddy to an even smaller groups of about 5 students for the guidance required for holistic development of the newly joined student throughout his/her time in the institution/college.

These activities are to be continued in the ongoing academic program along with other cultural activities through various student clubs which are largely be managed by students with the help of one or more faculty mentors. One of the main responsibilities of the faculty mentors would be helping the clubs to review their activities in alignment with human values.

**Assessing the Implementation and Impact**

The institution / college is expected to take feedback and prepare appropriate reports for assessing the impact and for further improvement of SIP. The basic feedback forms are included with the SIP Teaching Materials.

The SIP and its further follow up is expected to positively impact common graduate attributes like:

- Holistic vision of life
- Socially responsible behaviour
- Environmentally responsible work
- Ethical human conduct

Having Competence and Capabilities for Maintaining Health and Hygiene
Appreciation and aspiration for excellence (merit) and gratitude for all

AICTE will conduct periodic assessment to ascertain the implementation efforts and impact of the SIP and related activities.

**Faculty Development**

To ensure the implementation of SIP, and in particular to prepare the faculty, the National Coordination Committee for Student Induction (NCC-IP) has been formed. It offers various faculty development programs (FDPs) with the support from AICTE HQ and Regional Offices.

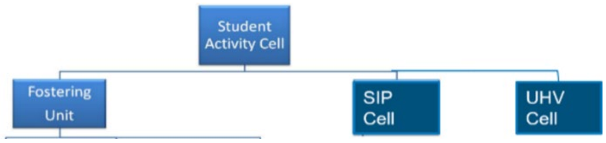
**UHV Faculty (Mentors):** Every institution is expected to prepare UHV Faculty in the ratio of 1:20 (1 faculty per 20 newly admitted students). Faculty from every teaching department are to be prepared. The basic preparation is participation in an 8-day FDP-SI (UHV).

**Faculty for other Modules**: Institutions/colleges generally have faculty, coaches, student clubs, alumni for these areas. FDP and comprehensive material will also be made available.

**Student Activity Cell (SAC) – SIP Cell, UHV Cell and Fostering Unit**

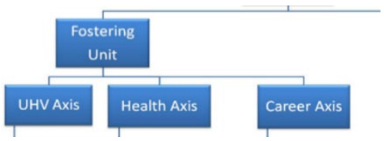
Student Activity Cell will have three cells or units:

- Fostering Unit – for coordinating various student clubs and activities in alignment with human values and IKS through various student clubs
- SIP Cell – for coordinating the annual SIP
- UHV Cell – for coordinating regular UHV activities, including UHV-I during SIP and UHV-II during future semesters, faculty mentoring and student buddy programs etc.



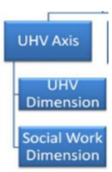

Each cell / unit will have some axis. E.g. the Fostering Unit will have 3 axis:

- UHV Axis – for UHV inputs and activities after the SIP
- Health Axis – for health oriented inputs and activities after SIP
- Career Axis – for career related inputs




Each axis will have one or more dimensions. E.g. the UHV Axis will have two dimensions:

- UHV Dimension
- Social Work Dimension




- Details of the clubs will be based on local conditions.

- Director or Principal or Dean of Student affairs will be the Chairman of Student Activity Cell

- SIP Cell (or Induction Unit) will be managed by faculty members with the help of student volunteers. 5 to 7 faculty members will be the members. The SIP Cell will be responsible for planning, organization, coordination and reporting of the annual Student Induction Program with the help of other faculty members and student volunteers

- UHV Cell will be managed by the UHV Convener / Coordinator under the chairpersonship of the director/principal. Faculty members and some students will be the members. They will coordinate the UHV activities like UHV-I during SIP, UHV-II 3rd/4th semester, faculty mentoring program and student buddy program throughout the student's association with the institute/college. UHV Cell will work to incorporate human values in every aspect of education at the institute/college. Preparing UHV Faculty (Mentors) is one of its activities

- Fostering unit will largely be managed by students with the help of one fostering unit faculty mentor. Student will be coordinators for axis, dimensions and clubs. Fostering unit will take support from induction unit as and when required. It will be responsible for coordinating various student clubs and activities in alignment with human values and Indian Knowledge System

**SIP Teaching Material and More Details**

The SIP Handbook as well as detailed guides and material for each of the modules is available on the AICTE website (http://www.fdp-si.aicte-india.org/download.php).

**Details and Reference Documents:**

- G012 SIP Handbook v2
- Teaching Material for UHV-I v2.1
- Teaching Material for SIP modules 2 to 9 v1
- G008 Facilitator (Mentor) Manual Version 2.1
- G911 UHV Cell, Nodal and Resource Centres
- G009 RP Development Process v2

***#Note: For CSE UG Students only***

The Department of Telecommunications, Ministry of Communication, Government of India is going to auction 5G spectrum shortly. The adoption of 5G will accelerate employment generation in telecom and technology industry. The 5G Technology will penetrate the entire telecom ecosystem of hardware, software and services that are critical for implementation of other futuristic technologies like Internet of Thing (loT), Machine-to-Machine **(M2M}** communication, edge computing etc. Innovative applications in various sectors like agriculture, transportation, power etc. will use and requires knowledge of inherent features of 5G. There will be huge requirement of market ready talent pool in 5G technology.

Considering the need for specialized courses and modules on SG Technology, National Telecommunication Institute for Policy & Research, Innovation & Training (NTIPRIT)-Department of Telecommunication, after due consultation with academia and industry, sent a proposal to AICTE vide No. 1-3/2020-NTI.TS-SD dated 09.03.2021 to include the following:

- A full Semester course on "Advanced Mobile Communications" for UG
- A 14-hour 5G awareness Program for UG Students;

## 5G Awareness Programme for UG students

## (14 hours) Course Title: Introduction to 5G

Topics to be covered

1. IMT2020 enhancements in comparison to IMT Advanced
2. 5G potential and applications
3. Usage scenarios: eMBB, URLLC, MMTC
4. Spectrum for 5G and spectrum sharing
5. Millimeter wave communication and small cells
6. New Radio: SA and NSA mode
7. Massive MIMO and beam forming
8. Multi-access edge computing
9. Software defined networks
10. Network slicing
11. Current state of deployment
12. Large cell scenarios: LMLC

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