ENGINEERING SCIENCES

Programme Code: ENGG03

Programme Outcome:

The courses in engineering sciences aim to provide the research scholars a broad overview of the subjects which are relevant for their research programs in the area of cyclotron and beam technology. The students are equipped with in-depth knowledge of skill set required for research work. The courses cover advanced topics in the above-mentioned areas. The courses are deigned to help students understand the various aspects of their field of research, foster a sense of enquiry, independent thinking about the solutions to the problems that define their areas of research.

DETAILED COURSE STRUCTURE

CORE Courses						
Sr. No	**Subject Title**	**Course Code**	**Hours**			**Credits**
			L	**T**	**P**	
1	Artificial Intelligence & Machine Learning	VECES-701-E	24	6		2
2	Computer Architecture	VECES-702-E	24	6		2
3	Advanced RF System	VECES-711-E	24	6		2
4	Advanced Power Electronics	VECES-721-E	30	8	15	3
5	Cryogenics Engineering	VECES-731-E	30	8	15	3
6	Introduction to Nuclear Physics, Nuclear Radiation, Detection and Applications	VECES-401-F	20	5	15	2
	CORE TOTAL		152	39	45	14

CORE COURSES COORDINATOR

Chief Coordinators:

Dr. Nabhiraj P Y (E-Mail: *npy@vecc.gov.in*, Ph: 033-23183201)

Course	Coordinators	Contact
Artificial Intelligence & Machine Learning	**Dr Biswajit Sarkar**	**bsarkar@vecc.gov.in Ph: 033-23184744**
Computer Architecture	**Dr Tapas Samanta**	**tsamanta@vecc.gov.in Ph: 033-23184729**
Advanced RF System	**Dr Anuraag Misra**	**anuraag@vecc.gov.in Ph: 033-23183216**
Advanced Power Electronics	**Dr Anirban De**	**ade@vecc.gov.in Ph: 033-23184145**
Cryogenics Engineering	**Dr Pranab Bhattacharyya**	**pbhatt@vecc.gov.in Ph: 033-23184106**
Introduction to Nuclear Physics, Nuclear Radiation, Detection and Applications	**Dr Parnika Das**	**parnika@vecc.gov.in Ph: 033-23182381**

CORE COURSES

VECES-701-E: Artificial Intelligence & Machine Learning (24L+ 6T)

Coordinators: Dr Biswajit Sarkar
bsarkar@vecc.gov.in

Course Details:

- **Introduction to Artificial Intelligence**
  Historical perspective, philosophy, Turing Test, Physical Symbol Systems, Intelligent Agent, Percept Action Cycle, Concept of Rationality for building rational agent, Bounded Rationality Agent and Environment Classification.

- **Problem Solving through Search**
  Concept of state space, search through a state space, formulation of a search problem, examples of search problem, uniformed search methods (breadth first search, depth first search, iterative deepening depth first search, uniform cost search), informed search methods (concept of heuristics, greedy best first search, A*, admissibility of heuristics for optimal A* solution)

- **Game Playing**
  2 player games, MinMax Algorithm, Alpha Beta Pruning

- **Reasoning**
  Propositional Logic, Resolution Refutation Method, Reasoning in First Order Logic

- **Evolutionary algorithms**
  Genetic algorithms: Chromosome representation, encoding, decoding, Genetic operators: Selection, Crossover, Mutation, Elitism, Schema Theorem, Multi-objective evolutionary algorithms, applications in search and optimization. Recent advances in Evolutionary Computing (e.g., Particle Swarm Optimization).

- **Introduction to Machine Learning**
  Definition of learning systems. Learning Paradigms, Function Approximation, training, validation and testing, generalization, bias-variance dilemma.

- **Artificial Neural Network Concepts**
  Neurons and biological motivation. Linear threshold units. Perceptrons: representational limitation and gradient descent training. Multilayer networks and back propagation.

- **Introduction to Deep Learning**
  Convolution Neural Networks: Architectures, convolution / pooling layers. Recurrent Neural Networks: LSTM, GRU. Auto encoders, Adversarial Generative Networks.

Course Outcomes:

This course will introduce the students to the domain of Artificial Intelligence and Machine Learning (AI & ML). The course will expose the students to the key paradigms, algorithms and methods that are commonly employed for building intelligent problem solving techniques. By the end of this course, the student will be able to devise methods appropriate for building intelligent systems and also implement such methods.

References:

1. Stuart J. Russel and Peter Norvig, Artificial Intelligence: A Modern Approach, Pearson Education India (2015)
2. Elaine Rich and Kevin Knight, Artificial Intelligence, McGraw Hill Higher Education (1991)
3. David E. Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning Addison Wesley (1989)
4. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley (2010)
5. Tom M. Mitchell, Machine Learning, McGraw Hill Education; (2017)
6. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer (2011)

VECES-702-E: Computer Architecture (24L+ 6T)

Coordinators: Dr Tapas Samanta
tsamanta@vecc.gov.in

Course Details:

- **Introduction to Computer architecture**
  Parts of computer, computing model, parallel computer, flynn's taxonomy, memory and storage architecture

- **Modern processors**
  Instruction set architecture, RISC, CISC, processor cycles. Pipelined architecture, pipeline hazards, memory and cache architecture. Linear and non-linear pipeline processor, latency, collision free scheduling, optimization. Instruction pipeline design, Dynamic instruction scheduling, brunch handling, register flow technique, out-of-order execution. Superscalar architecture, Vector processors. MP architecture. Multi core architecture. GPU Architecture, CPU-GPU integration.

- **Parallel computing**
  Computer cluster: Message passing architecture, Backend connectivity, Infiniband, 10G Ethernet, HPC cluster, HA cluster. Grid computing architecture, middleware, resource management. Cloud architecture. Memory architecture for parallel computer, shared memory, distributed memory, uniform & non-uniform memory access.

Course Outcomes:

By the end of this course, the student will be able to understand the modern processors, memory system and IO systems. The course will also help them in understating the performance issues for computing system. It will give them clear idea about the various computing resources and how they are operated to perform the task.

References:

1. Advanced Computer Architecture: Kai Hwang, McGraw Hill

2. Computer Architecture: A quantitative approach, J. L. Hennessy, D. A. Patterson, Morgan Kaufman

3. Modern processor design, J. P. Shen and M.H. Lipasti, McGraw Hill.

VECES-713-E: Advanced RF System (24L+ 6T)

Coordinators: Dr Anuraag Misra
anuraag@vecc.gov.in

Course Details:

- **Statics and DC**
  Circuit theory and EM, Coulombs Law and Electric Field Electric Scalar Potential, Gauss Law, Conductors in the Electrostatic Field, Dielectrics in the Electrostatic Field

- **Magnetics and electromagnetic**
  Magnetic Field in a Vacuum, Magnetic Fields in Materials. Electromagnetic Induction and Faradays Law, Inductance, Energy and Forces in the Magnetic Field,

- **Maxwell's equations and Transmission Lines**
  Maxwells Equations, The Skin Effect, Uniform Plane Waves, Reflection and Refraction of Plane Waves. Transmission Lines, waveguides, stripline, microstrip line

- **RF basic Concepts**
  S-parameters, Smith Chart, Impedance matching, Transmission Line transformers, RF measurements: Power, Frequency, VSWR, Phase noise, Spurious, Harmonics, Impedance

- **RF Resonators**
  Series and Parallel Resonant Circuits, Transmission Line Resonators, Cavity Resonators, Introduction to Quality factor, Shunt Impedance

- **Power Dividers, Directional Couplers, Circulators and Isolators**
  Basic Properties of Dividers and Couplers, The Wilkinson Power Divider, Bethe Hole Coupler, The Quadrature (90◦) Hybrid, Coupled Line Directional Couplers, Circulators and Isolators

- **Active RF and Microwave Devices**
  Schottky Diodes, PIN Diodes, RF MOSFET , Frequency synthesizers, Multipliers , Oscillators , Mixers, and Low noise amplifiers

- **RF Power Amplifier**
  Vacuum Tube (triode and Tetrode), IOT, Klystron, Solid State Power Amplifier

- **RF for Accelerators**
  Different types of Accelerating cavities, RF power Coupler, Cavity Tuning, Amplitude and Phase Control

- **RF measurements**
  RF power measurement and scattering parameters measurements using vector network analyzer, spectrum analyzer and RF power meters.

Course Outcomes:

The course is intended to provide a thorough understanding of EM theory and RF-microwave. It includes various conceptual and computational aspects of RF-microwave. The course also focuses on RF technology used in accelerators applications. The key topics will be covered through a series of lectures, tutorials, technical discussions and hands-on experiments using RF test and measuring instruments.

References:

1. IIT Kanpur Course on Microwave engg. https://www.iitk.ac.in/ee/courses-stream-wise-list#rf
2. Syllabus | Electromagnetics | Electrical Engineering and Computer Science | MIT OpenCourseWare
3. CERN Accelerator School notes
4. Microwave Measurements, Edward L Ginzton

VECES-721-E: Advanced Power Electronics (30L+8T+15P)

Coordinators: Dr Anirban De,
ade@vecc.gov.in

Course Details:

- **Solid-State Devices**
  Review of SCR, driving circuits and protection; Modern semiconductor devices: Power Diodes, BJT, MOSFET, GTO, IGBT, their operating characteristics, Gate Drive; Heat sink design.

- **Phase Controlled Converters**
  Review of single-phase controlled converters, effect of load and source impedances, effect of freewheeling diode; Three-phase converters, fully controlled and half controlled converters, twelve-pulse converter; Multi-pulse converters using transformer connections; Dual converter.

- **Linear voltage regulators**
  basic structures, advantages and disadvantages;

- **Improved Quality Converters**
  Power factor improvement techniques, PWM converter, voltage source converter, current control methods.

- **DC-DC Converters**
  Review of voltage and current commutated choppers; basic DC-DC converters (Buck, boost, buck-boost), derived DC-DC (Cuk, SEPIC, Quadratic) converters, Txf isolated DC-DC converters (Forward, Flyback, push-pull, bridge)

- **Basic Resonant Converters**
  Soft switching principles, ZVS, ZCS, ZVZCS Resonant Load Converters: Variable frequency series and parallel resonant converters (Resonant Switch Converters (quasi resonant): Half and full wave operations and control, PSFB Converter.

- **Inverters**
  Review of three-phase voltage source inverters, voltage and frequency control; Harmonic reduction techniques, PWM inverters, Space Vector Modulation; Multi-level inverters, configurations: Diode clamped, flying capacitor and cascade multilevel inverters, applications; Current source inverter, commutation circuits, transient voltage suppressing techniques; DC link resonant converters, operation and control.

- **Switched mode voltage regulator**
  specifications, block diagram, Modeling approach, assumptions and approximations.

- Dynamic models and transfer functions of hard switched converters in CCM and DCM modes.

- Regulator design example.

- **Tutorial 1-4:** Phase Controlled Converters; Linear voltage regulators; Converters; Inverters
- **Assignment 1-4:** Phase Controlled Converters; Converters; Inverters; Regulator design

Course Outcomes:

By the end of this course, the student will be able to understand the basic features of advanced power electronic converters, their design principles and properties of related devices that have evolved through generations. It might be expected that a student undergoing this course will be able to apply the principles in developing techniques and equipment in the field.

References:

1. First Course on Power Electronics by Ned Mohan
2. Fundamentals of Power Electronics by Robert W. Erickson, Dragan Maksimović
3. Resonant Power Converter by Kazimierczuk
4. Power Electronics by P.S. Bhimbra
5. Power Electronics by P. C. Sen

VECES-732-E: Cryogenics Engineering (30L+8T+15P)

Coordinators: Dr Pranab Bhattacharyya,
pbhatt@vecc.gov.in

Course Details:

- **Introduction to cryogenics**
  - **Cryogenic fluids:** T-S diagram - Nitrogen, Helium, etc.
  - **Material properties at Cryogenic temperature:** Yield strength & ultimate strength, Fatigue strength, Impact strength, Hardness & ductility, Elastic modulus, etc.

- **Liquefaction of gas & refrigeration systems**
  Basics of refrigeration/liquefaction, Production of low temperature, Ideal thermodynamic cycle, Various liquefaction cycles like Linde Hampson, Linde Dual, Claude, Kapitza, Collins, etc.

- **Cryo-coolers**
  Fundamentals of cryo-coolers, Stirling, Pulsed Tube & GM Cryo-coolers, Regenerators, heat exchangers, compressors, etc.
- **Cryogenic insulations**
  Fundamentals of insulation, Types of insulation like expanded foam & powder insulation, multi-layer insulation, etc.

- **Cryogenic instrumentation**
  Need of cryogenic instrumentation, Measurement of thermo-physical properties like temperature, pressure, liquid level, etc., various types of sensors and their working principles, special precautions for installation of cryogenic sensors, vacuum and cryogenic feed-through, etc.

- **Safety measures in cryogenics**
  Introduction, basic hazards and their cause, protection from hazards, cryogenic safety systems.

- **Application of cryogenics**
  Superconductivity, Superconducting RF cavity, Space & Defense applications, Nuclear Magnetic Resonance Spectroscopy, Industrial and medical applications, Electronics filed, Fuels research, Biological application, Food industry, etc.

Course Outcomes:

By the end of this course, the student will be able to (a) Calculate heat load of cold system, (b) Design and calculate safety relief requirement, (c) design insulation system for cold system, (d) understand the thermodynamics and working principle of cryogenics plant, (e) understand working principle of different parameter sensor for cryogenic application.

References:

1. Cryogenic Systems by R Barron
2. Cryogenic Engineering by Thomas M Flynn
3. Advances in Cryogenic Engineering by Timmerhaus K D Timmerhaus

VECES-401-F: Introduction to Nuclear Physics, Nuclear Radiation, Detection and Applications (20L+5T+15P)

Coordinators: Dr Parnika Das,
parnika@vecc.gov.in

Course Details:

- **Introduction to Nuclear physics**
  Basic Physical Attributes of Nuclei: Mass, Size, Nuclear charge, density distribution, Nuclear spin and magnetic moment, quadrupole moment; Stable and unstable nuclei, alpha, beta and gamma decay, isotopes, isobars, isomers; Basic Idea on Nuclear models, quantum mechanical picture, Shell model and Collective model; Nuclear Reaction, Elastic scattering, Inelastic scattering, Fusion, Fission etc.

- **Nuclear Radiation and Detection**
  Nuclear radiation and interaction with matter; Introduction to nuclear detectors, gas detectors, solid state detectors, scintillator detectors;

- **Applications**
  Accelerators and Reactors; Medical Application; Industrial applications

- Radiation safety and shielding

- **Lab work 15 Hours.**

Course Outcomes:

By the end of this course, the student will be able to basic idea about the nucleus, its properties and concepts of nuclear forces, binding energies etc. The students will know about the nuclear radiations, particle as well as electromagnetic and techniques of detection and measurements. Finally a student will have an idea about production and application of nuclear radiations in different areas.

References:

1. Concepts of nuclear physics by Cohen, Bernard L.
2. Basic ideas and concepts in nuclear physics: an introductory approach by: Heyde, K.