

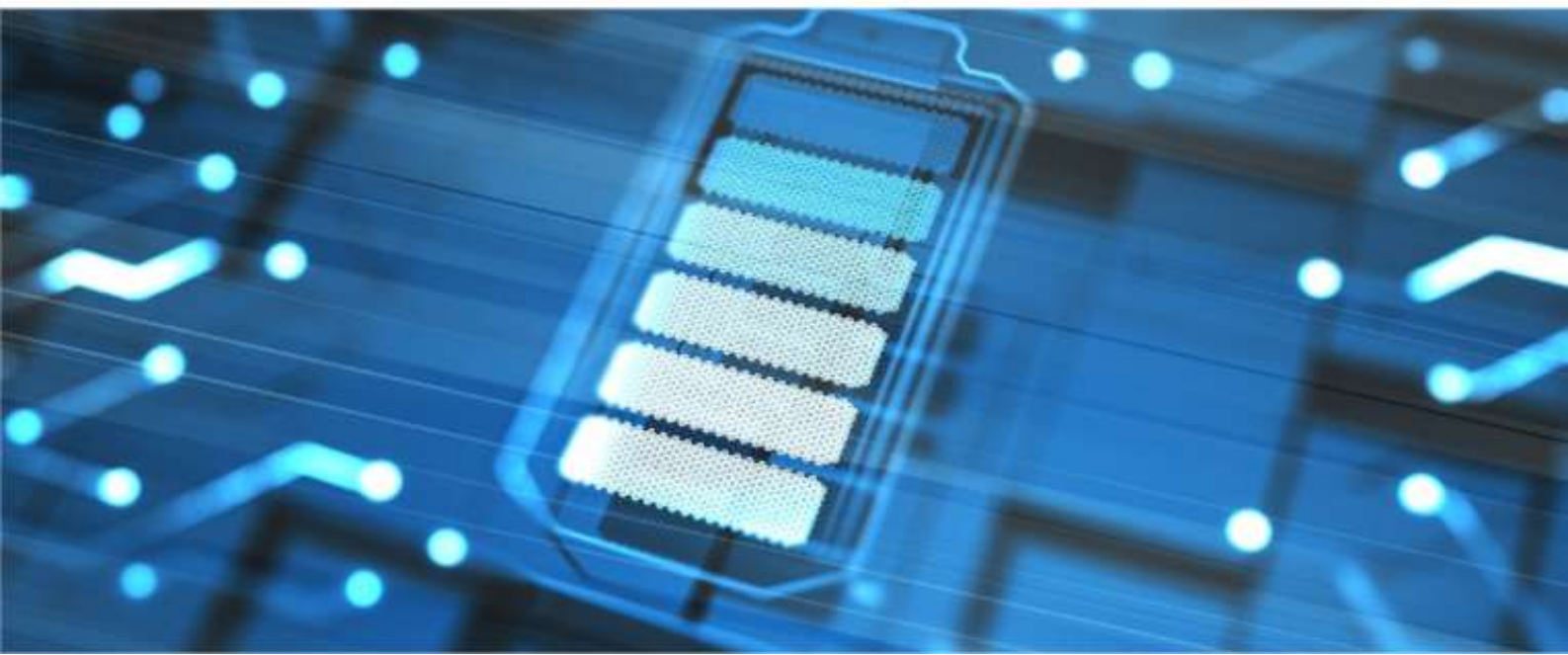
# Battery Technologies

Science & Applications



# Course Outline

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## Course Overview

The Battery Technologies Course provides an in-depth exploration of the science, engineering, and applications of modern battery systems. The course is structured into eight modules covering everything from battery chemistry and performance to cutting-edge simulations using Abaqus. Students will gain hands-on experience, analyze real-world case studies, and apply their learning in industry-relevant contexts such as electric vehicles, renewable energy storage, and smart cities.

The course is designed to equip learners with the skills and knowledge required to excel in the rapidly evolving battery technology industry.

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# Course Objectives

By the end of this course, students will:



## Understand the fundamentals

- **Understand the fundamentals** of battery technologies, including electrochemistry, design, and manufacturing.



## Analyze the performance

- **Analyze the performance** of various battery types, focusing on energy density, lifespan, and thermal management.



## Apply simulation techniques

- **Apply simulation techniques** to optimize battery performance using software such as Abaqus.



## Explore emerging technologies

- **Explore emerging technologies** in batteries and their applications in industries like electric vehicles and renewable energy.



## Develop practical skills

- **Develop practical skills** through hands-on projects and case studies that reflect real-world challenges.



## Understand the sustainability

- **Understand the sustainability** challenges associated with battery production and disposal, and learn about innovative recycling techniques.

# Target Audience

This course is ideal for:

- **Academicians and Educators** who wish to teach or specialize in battery technology at an advanced level.

- **Engineers and Scientists** who are looking to deepen their knowledge of battery technology and its applications in modern industries.

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- **Industry Professionals** working in electric vehicles, renewable energy, or smart grid technologies who want to improve their expertise in battery systems.



# Course Structure

Here's a comprehensive outline of **8-module Battery Technologies Course**

## Syllabus

### Module 1: Introduction to Battery Technology

- **Overview:** This module will introduce the basic principles of battery technology, exploring their applications, types, and importance in modern systems.
  - **Topics Covered:**
    - History and evolution of batteries
    - Basic principles of how batteries work
    - Importance and applications in electric vehicles (EVs), renewable energy systems, consumer electronics, and other industries
    - Current trends in battery technology and future outlook

### Module 2: Types of Batteries

- **Overview:** A detailed examination of the different types of batteries, their chemistry, structure, and applications.
  - **Topics Covered:**
    - Lead-acid, nickel-cadmium (NiCd), nickel-metal hydride (NiMH), lithium-ion, and other types of batteries
    - Chemical reactions in various types of batteries
    - Advantages, disadvantages, and applications of each type
    - Battery chemistry and performance

### Module 3: Battery Electrochemistry and Design

- **Overview:** Understanding the chemistry behind battery operation and the design of different battery components.
  - **Topics Covered:**
    - Basics of electrochemistry: electrode potentials, cell voltage, Faraday's laws of electrolysis
    - Anatomy of a battery: electrodes, electrolytes, separators, casing, and packaging
    - Battery design, including cylindrical, prismatic, and pouch cells

## Module 4: Battery Performance and Optimization

- **Overview:** Evaluation of the KPIs of batteries and strategies to optimize their usage.
  - **Topics Covered:**
    - Measuring energy density, cycle life, efficiency, and state of charge (SOC)
    - Impact of temperature, charge/discharge speed, and electrode materials on performance
    - Losses during charging and discharging and their impact on battery life
    - Battery management systems (BMS), cell balancing, and state of health (SOH) estimation

## Module 5: Battery Manufacturing and Safety

- **Overview:** Exploring the processes involved in the manufacturing of batteries and addressing safety concerns.
  - **Topics Covered:**
    - Manufacturing processes, including slurry preparation, coating, drying, and calendaring
    - Types of cell geometries: button cells, cylindrical cells, prismatic cells
    - Safety features and thermal runaway prevention in lithium-ion batteries

## Module 6: Simulation of Battery Systems Using Abaqus

- **Overview:** This module focuses on cell-level multiscale, multiphysics analysis of battery performance using the Abaqus software.
  - **Topics Covered:**
    - Simulation of electrochemical performance based on porous electrode theory
    - Modeling thermal effects from ionic diffusion, electrical conduction, and entropy
    - Mechanical effects due to lithiation-induced swelling
    - Coupling between electrochemical, thermal, and mechanical processes

## Module 7: Applications of Batteries in Emerging Fields

- **Overview:** Delving into how batteries are revolutionizing various industries and their future.
  - **Topics Covered:**
    - Batteries in electric vehicles
    - Batteries in renewable energy systems
    - Large-scale energy storage systems and residential battery sizing
    - New battery innovations, such as lithium-sulfur, lithium-oxygen, and redox-flow

## Module 8: Sustainability and Future Trends in Battery Technology

- **Overview:** Examining the environmental impact of batteries and forecasting future trends.
  - **Topics Covered:**
    - Environmental concerns related to battery production, usage, and disposal
    - Recycling and material recovery processes
    - Next-generation battery technologies and challenges
    - Future research directions and emerging battery materials

## Course Outcomes



- **Identify and differentiate** between various battery chemistries and their applications.
- **Simulate battery systems** using advanced software tools to predict performance and identify optimization opportunities.
- **Evaluate battery performance** in real-world scenarios using performance metrics such as cycle life, state of charge, and energy efficiency.
- **Apply sustainability principles** to the design, manufacturing, and recycling of batteries.
- **Design and implement** battery management systems (BMS) to enhance safety, performance, and longevity.
- **Develop and simulate models** for batteries, enabling real-time monitoring and performance prediction.



# Course Assessment

Students will be assessed through a combination of:

## Key Findings



- **Quizzes and Tests** after each module to ensure understanding of core concepts.



- **Simulation Projects** where students will apply their learning in hands-on tasks using Abaqus.



- **Case Study Analyses**, focusing on real-world applications of battery technology in sectors like electric vehicles and renewable energy.

- **Capstone Project**, where students will conceptualize, design, and simulate a battery system in a real-world context.

- **Peer Evaluations** in group-based projects and discussions to foster collaborative learning.



## Key Features of the Course:



- **Hands-on Projects:** Develop models and simulate real-world scenarios.
- **Industry-Focused Case Studies:** Examine implementations in manufacturing, electric cars, and other devices.
- **Expert Lectures:** Insights from industry leaders and experienced professionals.
- **Collaborative Learning:** Access to a virtual platform for networking and peer discussions.
- **Capstone Project:** Real-world project application, from conceptual design to deployment.

# Summary

This Battery Technologies Course provides a comprehensive understanding of the science and applications behind modern battery systems.

By equipping learners with practical skills and knowledge, the course fosters a generation of professionals ready to contribute to the rapidly advancing battery technology industry.

