

Battery Engineering Laboratory

The Battery Engineering Teaching and Learning Laboratory provides a state-of-the-art, hands-on environment where students, researchers, and industry professionals can gain practical knowledge and experience in battery systems, with a strong emphasis on eMobility applications such as Electric Vehicles (EVs). Our lab is dedicated to exploring and optimizing the performance of modern battery technologies, particularly Lithium-Ion (Li-ion) batteries, which are central to the advancement of clean energy solutions and sustainable transportation. Through a blend of experimental testing, simulation, and theoretical study, we prepare the next generation of engineers to solve real-world challenges in battery technology, energy storage, and electric mobility.

Our lab's curriculum combines theoretical learning with practical experience in critical areas like Battery Management Systems (BMS), State of Charge (SOC) and State of Health (SOH) estimation, electrochemical analysis, and thermal management. This interdisciplinary approach ensures that students develop a comprehensive understanding of battery systems and their applications in eMobility.

1. Measurement of Battery Cell Parameters, Including Internal Resistance



The lab provides a detailed and systematic approach to measuring the key parameters that define the performance and efficiency of Li-ion batteries. By using advanced testing equipment, students gain hands-on experience in evaluating battery cells, focusing on their electrical and thermal characteristics—essential for applications in Electric Vehicles (EVs) and energy storage systems.

Detailed Internal Examination: Students measure internal resistance and analyze battery performance under different load conditions, which is crucial for understanding how batteries perform in high-demand applications like EVs.

Comparative Structural Analysis: By comparing various battery chemistries (such as NMC, LFP, etc.), students learn how to optimize battery selection based on application-specific needs (e.g., driving range, charge time, or energy efficiency).

Material Composition Assessment: Students evaluate the impact of electrode and electrolyte materials on battery efficiency, performance, and lifespan, providing insights into cutting-edge battery chemistries for electric vehicles.

Internal Resistance Measurement: Internal resistance is key to understanding a battery's energy efficiency and its impact on the overall performance of electric mobility systems. This hands-on exercise helps students measure internal resistance and its correlation with charge/discharge cycles.

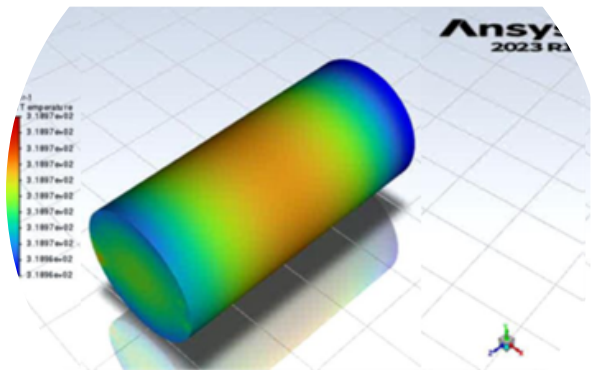
Battery Capacity Evaluation: Controlled discharge tests allow students to predict real-world performance, such as energy consumption in EVs, based on battery capacity.

Thermal Characteristics: Students learn to assess heat generation during battery operation, which is critical for optimizing thermal management systems in EVs, ensuring safety, and improving battery lifespan.

2. Estimation of State of Charge (SOC) and State of Health (SOH) Using MATLAB/Simulink and

Estimation of thermal properties of battery/cell using Ansys

A critical component of the lab is the accurate estimation of SOC and SOH, two essential parameters for battery management and performance monitoring in eMobility applications. By using MATLAB/Simulink simulations alongside experimental testing, students gain valuable insight into how these parameters influence the overall battery life and vehicle performance.



Simulation of Battery Behavior: Students use MATLAB/Simulink to simulate battery behavior under different operating conditions, including varying load, temperature, and voltage, which helps estimate SOC and SOH accurately.

SOC Estimation: By using techniques like coulomb counting, voltage-based methods, and impedance spectroscopy, students estimate the remaining charge in a battery, a key factor for managing driving range in EVs.

SOH Estimation: SOH estimation, including the analysis of internal resistance and capacity degradation, helps students understand how battery aging affects performance, providing critical insights for predicting battery replacement and maintenance schedules in eMobility systems.

Experimental Validation: Controlled charge/discharge cycles are conducted to validate simulation models against real-time battery performance, ensuring accuracy in predicting battery behavior.

Voltage and Current Estimation: By analyzing voltage and current profiles, students can assess the efficiency of charge/discharge processes, which directly impacts the energy consumption and heat

generation in EVs.

Thermal Management Analysis: The lab also focuses on the importance of managing heat during charge/discharge cycles. Students analyze heat generation and explore cooling systems to ensure safe battery operation in EVs.

3. Equivalent Circuit Modeling of Li-ion Cells via EIS and Temperature Chamber



The lab offers students the opportunity to explore advanced techniques like Electrochemical Impedance Spectroscopy (EIS) and equivalent circuit modeling to study the impedance characteristics of Li-ion cells, which are fundamental for understanding their electrical and thermal behavior. Students also investigate the impact of environmental factors such as temperature and humidity on battery performance, providing a comprehensive understanding of how real-world conditions affect battery efficiency and longevity.

EIS Testing with SQUIDSTAT Potentiostat: Students gain hands-on experience with SQUIDSTAT potentiostats to measure battery impedance, allowing them to explore the relationship between impedance and performance metrics such as internal resistance and charge/discharge efficiency.

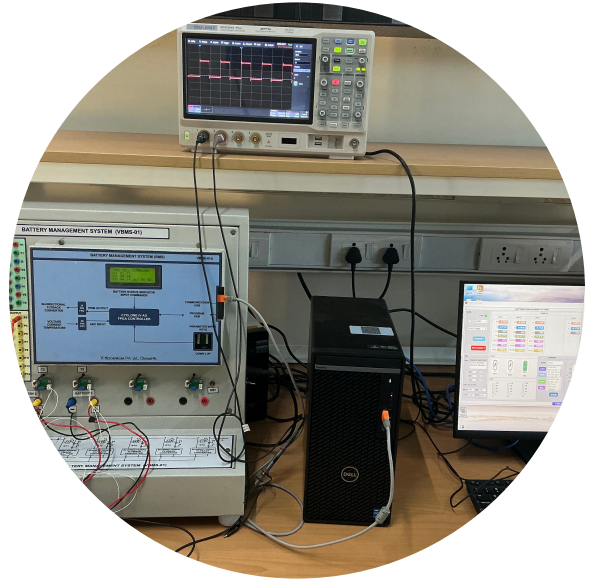
Impact of Humidity: Students study how varying levels of humidity affect battery performance, including charge/discharge efficiency, internal resistance, and cycling stability. This research is particularly relevant for ensuring battery reliability in diverse climates for EVs and portable electronics.

Performance Degradation: The lab provides an opportunity for students to evaluate how exposure to moisture affects long-term battery health, which is critical for improving the durability and reliability of batteries in real-world applications.

Enhancing Battery Durability: Students investigate strategies to improve the resilience of Li-ion batteries, particularly in high-humidity environments, ensuring that EVs and other devices perform optimally in varying weather conditions.

4. Functionality Study of Battery Management Systems (BMS)

Battery Management Systems (BMS) play a pivotal role in optimizing battery performance by continuously monitoring key parameters, ensuring safety, and extending battery life. The lab offers hands-on experience in understanding how BMS are designed, tested, and implemented in eMobility applications like EVs.



Voltage Monitoring: Students learn to monitor individual cell voltages to ensure that they remain within safe operating limits, preventing overcharging or overdischarging, which can lead to battery degradation or failure.

Current Monitoring: By tracking charge and discharge currents, students gain insight into how to prevent overcurrent situations that can damage batteries or reduce their lifespan.

Temperature Monitoring: Effective temperature monitoring is crucial for preventing overheating and freezing, especially in EV applications where battery performance is highly sensitive to temperature changes.

SOC and SOH Estimation Algorithms: Students implement algorithms for real-time SOC and SOH estimation, ensuring efficient energy use and extending the battery's life in EVs.

Cell Balancing: Hands-on experience with balancing techniques ensures that voltage levels across all cells remain equalized, which is critical for optimizing battery health and performance in EVs.

The **Battery Engineering Teaching and Learning Laboratory** is at the forefront of providing cutting-edge education and training in the rapidly evolving field of **battery technology** for **eMobility**. The lab's comprehensive curriculum is designed to equip students with the practical skills and theoretical knowledge required to tackle the challenges of battery development, optimization, and management for Electric Vehicles and energy storage systems.

Students have access to advanced tools and techniques, including simulation software (Altair tools, MATLAB/Simulink, COMSOL), cutting-edge testing equipment (SQUIDSTAT Potentiostat, thermal chambers), and real-world experimental setups. This unique combination of education and

hands-on learning ensures that students are well-prepared to drive innovation in the growing field of electric mobility and sustainable energy.
