

## **E – DRIVETOUR**

### ***Beyond the Border of Electric Vehicles: an Advanced Interactive Course***

Erasmus+ Programme: Knowledge Alliances

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#### **D1.2 Experiment Specifications**

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#### **Revision and history chart:**

VERSION	DATE	EDITORS	COMMENT
V 0.1	31/03/20	IHU	First draft version
V 0.2	12/05/20	IHU	1 <sup>st</sup> version with courses prepared
V 0.3	20/06/20	IHU	Review and upload on Google Drive
V 1.0	31/08/20	IHU	Final version
V 1.1	31/12/22	IHU	Revised Final version

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## **1 Executive summary**

The main objective of this document is to define the EDRIVETOUR project experiment specifications that set the foundations that will further enable the implementation of the laboratory activities in the project.

The experiments that were initially stated in the proposal will have their specifications defined in order to be further elaborated in WP3. This will allow the educators to also identify the tools (software/hardware) that will be used and provide a comprehensive list necessary for the procurement process.

In total, 13 laboratory experiments are defined & their specifications extracted to accompany the courses stated in Task 1.1.

The current version of the document is established as the deliverable about the E-DRIVETOUR experiment specifications and will be considered as the reference point for all project activities (Application Requirements & Specifications –WP1, Academic Curriculum Development –WP2, Development of Reconfigurable Laboratory Apparatus –WP3 and Integration, Deployment & Benchmarking – WP4).

The generated experimental specification forms are included in the Annex of this deliverable and they contain all the necessary information for the implementation of each course as standalone and the set of courses as a complete curriculum.





## 2 Objectives of the report

### 2.1 Purpose of the Document

The main objective of this document is to define the specifications for the reconfigurable interactive laboratory equipment of the E-DRIVETOUR project. The course-accompanying laboratory experiments are necessary for the students' hands-on experience and understanding of important course topics. The necessary laboratory apparatus together with any teaching software for the two educational periods (time slots 1 and 2) will be developed based on being reconfigurable in order to be easily adjusted to the teacher's needs and interactive for the students. Another important aspect that will be developed is the laboratory teaching material for the educators. This, along with the course syllabus, will be designed for a universal understanding to cater teachers across the EU. Experiment/Laboratory work accompanies many courses, throughout the two educational periods (Timeslot 1 & Timeslot 2). Thus, they provide the necessary knowledge & experience to the students for dealing with the two Intermediate Projects following each educational period. The description of the course experiments and the main teaching material/equipment requirements are the final outcome of this deliverable.

### 2.2 Scope of the Document

This document is aimed to define the project foundations; to create the necessary inputs for the two intermediate projects' devices specifications in T1.3. In addition, the extraction of the experiment specifications will enable the implementation of the Development of the Reconfigurable Laboratory Apparatus (in WP3). It is clear that the work performed in this task will support the rest of project activities in WP1 and WP3.

### 2.3 Structure of the Document

The document includes the following contents:

- In *chapter 2*, the introductory section is provided, highlighting the scope and objective of the deliverable
- Following, *chapter 3*, presents the project laboratory program and describes the main lab characteristics to be defined as the essential requirements
- In *chapter 4*, a detailed list and a general description of the hardware to be used during the laboratory sessions are presented.
- Chapter 5 presents the main software packages, free of or requiring licences, that will be needed for the laboratories' support
- In *Chapter 6*, the teaching material to be presented for the laboratory courses is described in detail.





- *Chapter 7* describes the connection of Task 1.2 and the specific Deliverable with the forthcoming activities
- *Chapter 8* is a conclusion of the present document
- Following chapter 8, the bibliographical references of the present document are listed

Finally, Annexes I and II contain the supportive information towards the definition of the project foundations, namely:

Annex I - Course Syllabus Template Form

Annex II – Courses' Syllabus





### **3 Conclusions**

As an activity to define the EDRIVETOUR Experiment Specifications, D1.2 provides the description of the requirements for the individual curriculum laboratories. This document is the outcome of the work in Task 1.2 about Experiment Specifications and tool (hardware/software) definition.

Following the definition of the necessary experiments, to accompany the course syllabus, the consultation with the EDRIVETOUR educators enabled the extraction of the specifications.

Crucial parameters of each course like the experiment content, equipment used, the learning outcomes, the objectives and competences acquired by the students as well as the teaching methods and assessment methodology are clearly defined. The developed experiment syllabus form outlines the specifications and offers valuable guidance on the development of WP3. The hardware/software list collects the tools needed to run all the experiments and offers a concentrated view of the procurement needs of the project.

The document together with all its attachments will set the foundations for the forthcoming WPs and especially WP3 which requires the development of the actual experiment teaching material.





## 4 ANNEX I – Courses syllabus

The following files are attached as integral part of the present document.

- *TS1.2 - NI LabVIEW Training.pdf*
- *TS1.3 - Automotive Energy Sources.pdf*
- *TS1.4 - Lightweight Materials.pdf*
- *TS1.6 - Data acquisition and EV Sensors.pdf*
- *TS1.8 - Electric Motors & Motor Drives for EVs.pdf*
- *TS1.9 – Autonomous Vehicles.pdf*
- *TS1.12 - Intermediate Project 1.pdf*
- *TS2.1 - EV System Modelling and Simulation.pdf*
- *TS2.2 – EV Energy Storage Systems.pdf*
- *TS2.3 - EV Charging Systems.pdf*
- *TS2.4 - Mechanical Drivetrains for EVs.pdf*
- *TS2.5 - Control System Development.pdf*
- *TS2.8 - EV On Board Diagnostics, Troubleshooting & Maintenance.pdf*
- *TS2.9 - Life Cycle Assessment of EV's.pdf*
- *TS2.12 - Intermediate Project 2.pdf*







## NI LabVIEW Training

Teaching Period			Course Code		
First Term			TS1.2		
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
6		16		3	1
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
1.04	English	Cerca Trova (CT)			

### Prerequisites

It is recommended that the participants have some understanding about computer control or experience with any programming language. In addition, understanding electricity and electrical quantities (voltage, current, resistance) is required.

The lab exercises should take place in computer class under supervision using mainly SELV (Separated or safety Extra-Low Voltage) and/or PELV (Protected Extra-Low Voltage) equipment in order to prevent any electrical danger.

### Content (Syllabus Outline)

The experiments will be conducted in teams of two to perform the tasks. The lab experiments will be aimed to control NI cDAQ hardware via NI LabVIEW software. In principle the tasks are to establish physical connection with the NI cDAQ hardware via Ethernet or USB and take measurements. During the experiments at least five experimental tasks will be proposed for the students to solve, for instance measuring temperature, resistance, conductivity, pressure, salinity etc. The tasks are presented to students in round-robin fashion meaning that every team will be working on a different task in order to reduce the number of specialized lab equipment for each task. Depending on the number of learning stations at least two teams could be assigned with the same task without generating too high bottle neck for waiting.

Experimental tasks for TS1.2 will consists of measuring different physical parameters via NI cDAQ equipment as well as simulation in NI LabVIEW software. Lab task manual will be presented for students for each task. Every task will have a preparatory and implementation phase. During the preparatory phase students will seat themselves behind the learning stations and prepare the principle of the solution as an algorithm and be able to explain different software as well as hardware concepts used. In addition, prepare the NI LabVIEW program in advance to reduce the NI cDAQ hardware utilization time in the implementation phase. More precisely develop NI





LabVIEW software for acquiring physical measurement results and to generate a suitable visual layout of the results. Moreover the measured results should be filtered and stored in suitable manner, thus considering the possible options in this phase (Excel, Matlab etc.).

In the implementation phase, students will connect the NI cDAQ hardware and the necessary sensors/actuators to take the measurements. Preferred connection type is Ethernet in order to avoid moving NI cDAQ hardware around and to prevent the USB connection to wear out.

For each experiment task a report must be prepared and submitted via the e-Learning platform. The report must consist the analysis of the initial algorithm/plan for the experiment and the final solution (preparation time, possible errors, needed modifications etc.) and data analysis.

### **Objectives and Competences**

The objective is to give students insight of the possible uses of NI LabVIEW and hands-on experience with NI cDAQ hardware. Use different sensors (temperature, resistance, pressure etc.) to obtain actual numerable results from sensors. Indirectly students gain teamwork experience and algorithmic thinking and preparation for task solving.

### **Intended Learning Outcomes**

Students that will successfully attend the lab exercises will be able to:

- recognize and describe the structure of a program created in NI LabVIEW
- employ the essential elements of a NI LabVIEW program
- calculate the parameters required by elements of a simple LabVIEW program
- satisfactorily develop a simple LabVIEW program
- analyse, design and develop a simple LabVIEW program according to predefined needs
- convert physical sensor results to numerable value

### **Learning and Teaching Methods**

The theoretical background needed to support the laboratory exercise will be presented in Web and In-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Finally, each team will write a report to demonstrate and evaluate the results of their experiment and compare their results among other group results.

### **Assessment**

Assessment consists of two parts with both contributing 50% for the final grade. First part consists of questions about LabVIEW functionalities and second part is solving practical task using LabVIEW software.

### **Main Hardware/Software Per Station**

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## E – DRIVETOUR

### *Deliverable 1.2 Experiment Specifications*

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For each learning station: 1x PC, 1x NI LabVIEW (License), 1x NI cDAQ 4-slot chassis, 1x NI-9219 Universal Analogue Input Module, 1x NI-9205 Voltage Input Module, 2x J-Type Thermocouples & 2x interdigitated electrode resistivity sensors, 2x pressure sensor, 2x salinity, 2x ultrasonic, 2x infrared receiver, 2x infrared LED, 1x ToF

#### **Learning Stations**

**10**

#### **Students per Station**

**4**

#### **Basic Literature**

- Online NI LabVIEW tutorials (<http://www.ni.com/gettingstarted/labviewbasics/>)
- NI LabVIEW "Help" contents.





## Automotive Energy Sources

Teaching Period			Course Code		
First Term			TS1.3		
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
10	2	4		6	2
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.96	English	International Hellenic University (IHU)			

### Prerequisites

It is recommended that the participants have understanding of basic electrotechnics.

### Content (Syllabus Outline)

The 4 hour laboratory will technically educate the students through the fundamental measurements on various automotive energy sources used in Vehicle Electrification. Initially, measurements will be performed on sole cells of various types. Then, the students will have to develop a battery pack out of the cells combining them in series and in parallel and using appropriate connectors and cables. The specifications of the battery pack will be extracted by means of the battery cell ones. Voltages and currents under charging or discharging procedures, with various electric loads will be measured and characterized in order to reveal the behavior of the sources. Automotive energy sources that will be used are Li based batteries used in small scale electric vehicles, like bicycles, tricycles, scooters or karts as well as high tension commercial ones, and also ultracapacitors packages.

Finally, battery simulations will be made with simple yet accurate battery models in Matlab/Simulink and the results will be compared with measurements.

### Objectives and Competences

The objective is to introduce the students to the way a battery pack is composed out of battery cells and to perform core measurements in order to estimate the basic battery pack specifications. Objective of the lab is also the simulation of battery packs by means of simple battery models and understanding of their differences. Corresponding competences are to be acquired by the students.





#### Intended Learning Outcomes

Students that will successfully attend the lab exercises will be able to:

- recognize and describe the construction of various automotive energy sources
- solve problems with different energy sources
- measure the characteristics of an automotive energy source
- analyze the structure of an energy source
- perform battery simulations by means of simple battery models

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in the in-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory invigilators will guide each step of the lab work and assist the students as needed. Finally the students will write a small report (as part of homework) to demonstrate and evaluate the results of their experiment and compare their results among other group results.

#### Assessment

Assessment of the laboratory will be performed by means of the student report on the measurements and simulation procedures and results. Weighting factor: 100%

#### Main Hardware/Software Per Station

For each learning station: 1x PC, 1x Matlab/Simulink (License), Li-ion Battery cells, LiFeYPO<sub>4</sub> Battery cells, Ultracapacitor cells, Battery connectors and cables, 1 multimeter and 1 Current clamp meter

#### Learning Stations

**10**

#### Students per Station

**4**

#### Basic Literature

- M. Ehsani, Y. Gao and A. Emadi, "Modern Electric, Hybrid Electric and Fuel Cell Vehicles", fundamental, theory and design, 2nd ed., CRC Press: Boca Raton, 2010. ISBN: 978-1420053982
- Vehicle Electrification course materials at the Department of Industrial Engineering and Management of the International Hellenic University, Greece





## Lightweight Materials

Teaching Period			Course Code		
First Term			TS1.4		
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
6		4		3	1
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.56	English	International Hellenic University (IHU)			

### Prerequisites

Basic knowledge of NI LabVIEW is considered mandatory. Lectures of TS1.4 Lightweight Materials should be completed.

Special materials, like carbon and glass fabrics, resin, special tooling (vacuum pump, vacuum tapes, vacuum bag) and personnel protective equipment, and measuring instrumentation (NI cDAQ-9174 slot chassis, modules NI-9219 and NI-9205, thermocouples and resistivity sensors). The laboratory exercise should be implemented in a well-ventilated space with at least 5 benches for preparing coupons and measurement devices. First AID kits and fire extinguishing equipment should be present along with face masks, one-use gloves, laboratory robes.

### Content (Syllabus Outline)

During the laboratory exercise students will have to work in teams to prepare composite coupons. The composite manufacturing will be monitored by NI cDAQ equipment controlled and programmed by the students. Preparatory actions include reading the exercise teaching material, reading the MSDS of the materials that will be used and getting prepared to produce code under NI LabVIEW programming language capable of acquiring and storing data such as temperature and resistance/conductance measurements from thermocouples and resistive/conductive sensors. The students will connect the measurement system online and upload the live data on the e-Learning platform.

The laboratory exercise will be consisted by the preparatory and the implementation phase. During the preparatory phase the students, will assemble the data acquisition apparatus interfacing the provided temperature & conductance sensors. The S/W code will be programmed & delivered for assessment. The students prepare the required materials to assemble the composite structure and start the polymerization process.





The process will be monitored online via the e-Learning platform and the students will be able to record the temperature variations of the coupon due to the exothermic reaction and at the same time detect the increase in the resistance of the material as the polymerization progresses & completes. The data collected will be stored and uploaded in the online database, available for further analysis. A report will be generated presenting all the results and the analysis of the overall process for assessment.

#### Objectives and Competences

The objective is to aid the students understand the new construction materials that are used nowadays widely in the automotive industry and also to broaden their experience in sensors & a data acquisition system to monitor an on-going process such as chemical reaction. It is believed that the combination of fabrication of a composite material along with real time monitoring of the process will strengthen the ability of the students to identify the crucial role of IoT in industrial applications.

#### Intended Learning Outcomes

Students that will successfully attend the laboratory exercise be able to:

- handle composite materials precursors and prepare composites according to specifications
- evaluate the measured values of measured properties of the composite materials
- calculate, measure or suggest proper test method to evaluate the condition or physical property of a composite material
- design and control S/W for data acquisition proper for the case of monitoring a fabrication process.
- to measure physical phenomena by designing a sensor based measurement system.

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented In-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory invigilators will guide each step of the lab work and assist the students as needed. Finally the students will write a small report (as part of homework) to demonstrate and evaluate the results of their experiment and compare their results among other group results.

#### Assessment

The students will be assessed in final written exams, assessing the students through exercises solution and multiple choice questions, theoretical and practical. Lab reports will also be assessed. Assessment = Exam (70%) + Lab (30%). Lab exercise report 10% + 10% S/W assessment + 10% coupon assessment = 30% of the overall assessment for the case of TS1.4.

#### Main Hardware/Software Per Station

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1x PC, 1x NI LabVIEW (License), 1x NI cDAQ-9174 4-slot chassis, 1x NI-9219 Universal Analogue Input Module, 1x NI-9205 Voltage Input Module, 2x J-Type Thermocouples & 1x interdigitated electrode resistivity sensor.

#### Learning Stations

**10**

#### Students per Station

**4**

#### Basic Literature

1. F.C. Campbell, "Lightweight Materials: Understanding the Basics", 2012, ISBN: 9781615038497
2. William D. Callister Jr. , "Materials Science and Engineering: An Introduction", 1998, ISBN: 9780471179450
3. Defense, d. o. (2002). "Composite materials handbook-volume 3. Polymer matrix composites materials usage, design and analysis". Air Force Institute of Technology. MIL-HDBK-17-3F Volume 3 of 5 - 17 JUNE 2002
4. Yi, Xiao-Su, Du, Shanyi, Zhang, Litong, "Composite Materials Engineering, Volume 1 & 2, Fundamentals of Composite Materials", ISBN: 9789811056963
5. Krishan K.Chawla, "Composite materials: Science and Engineering", 3<sup>rd</sup> Edition, Springer, 2012, ISBN 978-0-387-74365-3 (ebook)







## Data Acquisition and EV Sensors

Time Slot		Course Code			
Time Slot 1 (TS1)		TS1.6			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
6	0	4	0	3	1
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.56	English	International Hellenic University (IHU)			

### Prerequisites

Students are recommended to have understanding of basic theory of electricity or physics

### Content (Syllabus Outline)

An experimental setup will be designed and given to the students. This setup, based on essential NI platforms and LabVIEW software will comprise the most common sensor types found on an EV (Temperature, Strain, Accelerometer, Pressure, Hall-Effect & Voltage and Current sensors, Encoders, Resolvers etc). The students will use the available NI hardware to connect to each sensor depending on the type (Analogue or Digital) and collect, plot & store data. Special care will be taken of the connection of the sensors to the appropriate hardware ports, settings required in order to adjust the sensor characteristics to the data acquisition software and of course sensor calibration.

### Objectives and Competences

The objectives of this course is the student

- to be in the position to understand the connectivity of EV sensors with the EV powertrain control modules
- to realize the necessity for calibration of sensors

Competences

- ability to connect and calibrate sensors in a data acquisition system





#### Intended Learning Outcomes

Students that will successfully attend the course will be able:

- to gain broad understanding of how sensors work and convey a physical change to information
- to develop complex instrumentation system

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in the in-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory invigilators will guide each step of the lab work and assist the students as needed. Finally the students will write a small report (as part of homework) to demonstrate and evaluate the results of their experiment.

#### Assessment

Assessment of the laboratory will be performed by means of the student report on the measurements procedures and results. Weighting factor: 100%. This will be the final laboratory grade and the 30% of the overall course grade.

#### Main Hardware/Software Per Station

For each learning station: 1x PC, 1x NI LabVIEW (License), 1x NI cDAQ-9174 4-slot chassis, 1x NI-9219 Universal Analogue Input Module, 1x NI-9205 Voltage Input Module, Digital Signal Input Module, 1x High Voltage sensor, 1x current sensor, 1x Resolver, 1xEncoder.

#### Learning Stations

**10**

#### Students per Station

**4**

#### Basic Literature

- T. Denton, Electric and Hybrid Vehicles. Taylor & Francis Ltd, 2016. ISBN: 9781138842373
- Basu A.K., Tatiya S., Bhattacharya S. (2019) Overview of Electric Vehicles (EVs) and EV Sensors. In: Bhattacharya S., Agarwal A., Prakash O., Singh S. (eds) Sensors for Automotive and Aerospace Applications. Energy, Environment, and Sustainability. Springer, Singapore. [https://doi.org/10.1007/978-981-13-3290-6\\_7](https://doi.org/10.1007/978-981-13-3290-6_7)
- Fuad Un-Noor, Sanjeevikumar Padmanaban, Lucian Mihet-Popa, Mohammad Nurunnabi Mollah and Eklas Hossain, "A Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development", Energies 2017, 10, 1217. doi:10.3390/en10081217





- P. Dost, A. Bouabana and C. Sourkounis, "Measurement sensors in an electric vehicles," *International Symposium on Power Electronics Power Electronics, Electrical Drives, Automation and Motion*, Sorrento, 2012, pp. 790-795. **DOI:** 10.1109/SPEEDAM.2012.6264618
- Shinji Kajiwara (November 5th 2018). Motion Dynamics Control of Electric Vehicles, *New Trends in Electrical Vehicle Powertrains*, Luis Romeral Martínez and Miguel Delgado Prieto, IntechOpen, DOI: 10.5772/intechopen.77261. Available from: <https://www.intechopen.com/books/new-trends-in-electrical-vehicle-powertrains/motion-dynamics-control-of-electric-vehicles>





## Electric Motors and Motor Drives for EVs

Time Slot		Course Code			
Time Slot 1 (TS1)		TS1.8			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
12		4		6	2
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.96	English	International Hellenic University			

### Prerequisites

The students are suggested to have basic understanding of

- Electromechanical energy conversion
- Fundamentals of electric circuits
- Essential electrical measurements

### Content (Syllabus Outline)

The lab sessions of the course aim to provide to the students a "hands-on" experience as regards the operating principles of the main types of electric motors. It will be conducted in two parts, one part (2 hours) examining the operation of DC and AC induction motors and the other (2 hours) examining the operation of permanent magnet motors. Experimental work will take place that aims to present key features of the machines such as the derivation of curves (torque-speed, current-speed, etc), the design of controllers and the facilitation of calculations based on the data received (e.g. power, efficiency, power factor etc). Students will be asked to perform the experiments in small groups and elaborate on the results obtained explaining their correlation to the theoretical behaviour of the machines.

### Objectives and Competences

- Provide practical experience as regards the connection and operation of electric machines
- To facilitate the consolidation of theory by comparison with experiments
- To help students develop analytical skills based on experimental data.





#### Intended Learning Outcomes

Students that will successfully complete the course will be able to:

- to describe the fundamental principles of different types of electrical machines and the operating principles of the individual parts of a motor control system.
- to recognize the electromechanical parameters of a motor control system.
- to design speed and torque controllers.
- to troubleshoot motor control system.
- to become safety aware in motor testing
- to choose appropriate motor control system based on its characteristics

#### Learning and Teaching Methods

The lab sessions will be organised in 2 slots of 2 hours each, the first one will be dedicated to the operation of DC and AC induction motors and the second to the operation of permanent magnet machines

#### Assessment

Students will be asked to provide reports with their lab experiments results also containing calculations based on data acquired. Weighting Factor: 100%

#### Main Hardware/Software Per Station

The students will use the cDAQ chassis with a NI-9264 for Voltage output, a NI-9207 for Voltage & Current & a NI-9213 Temperature Modules to design a speed control loop. They will also use AC induction and DC motors set up to develop basic curves and torque control.

#### Learning Stations

8

#### Students per Station

5

#### Basic Literature

1. John G. Hayes, G. Abas Goodarzi, "Electric Powertrain", John Wiley and Sons Ltd, 2018. ISBN: 978-1-119-06364-3
2. Stephen J. Chapman, "Electric Machinery Fundamentals", McGraw Hill, 2011. ISBN: 978-0073529547





## Autonomous Vehicles

Time Slot		Course Code			
Time Slot 1 (TS1)		TS1.9			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
9		6		7.5	2.5
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
1	English	International Hellenic University (IHU)			

### Prerequisites

The students are suggested to have basic understanding of programming at any language (Python, C/C++, Matlab)

### Content (Syllabus Outline)

The lab sessions of the course aim to provide the students a “hands-on” experience for the basic mechanisms of path planning algorithms (Grassfire, Dijkstra, A Star) in order to accomplish a point-to-point movement in graphs and grids. An introduction to the python programming language along with basic exercises will be provided to the students. Step by step execution of the planning algorithms will take place at the lab and a planning algorithm will be developed at the python programming language (4 hours Lab Exercises). As a last step, the instructor will introduce the use of the Robot Operating System-ROS (ROS Basics, ROS teleoperation techniques) in autonomous vehicles’ applications. ROS will be used for discussing and implementing a publish-subscribe method to control a robot at a simulation environment and as a framework that controls a real-world robotic vehicle (2 hours Lab Exercises).

### Objectives and Competences

- Provide practical experience as regards the use of the python programming language, path planning algorithms and autonomous vehicles
- To facilitate the consolidation of theory by comparison with experiments
- To help students develop analytical skills based on experimental data.





#### Intended Learning Outcomes

Students that will successfully attend the course will be able to

- recognize the hardware and software components of an autonomous vehicle
- satisfactorily present a state-of-the-art architecture for developing an autonomous vehicle application
- to develop path planning algorithms and control a robotic vehicle in a simulation and a real-world environment

#### Learning and Teaching Methods

The lab sessions will be organized in 3 slots of 2 hours each, the first one will be dedicated to the use of the python programming language and the components that are necessary for implementing path planning algorithms, the second will analyze path planning algorithms in a step-by-step procedure and implement a path planning algorithm at the lab and finally, the third will use the ROS framework in order to run a publish subscribe protocol at simulation mode and move an autonomous vehicle chassis.

#### Assessment

Students will be asked to provide reports with their lab experiments results also containing calculations based on data acquired. Weighting Factor: 100%

#### Main Hardware/Software Per Station

The students will use a computer running the python programming language and a Raspberry PI in order to run the ROS framework and the publish subscribe protocol, and a vehicle chassis (the chassis will indicatively include tire wheels with DC Gear Motor, a 2 Channel DC Motor Driver Module, DC-DC Step-Up Power Supply and a single slot battery case).

#### Learning Stations

2

#### Students per Station

4

#### Basic Literature

- Teacher's notes
- Python Programming Language <https://www.python.org/about/gettingstarted/>
- Planning Algorithms <http://lavallo.pl/planning/>
- Tutorial: Robot Operating System (ROS) <http://wiki.ros.org/ROS/Tutorials>
- Book: ROS Robot Programming <https://community.robotsource.org/t/download-the-ros-robot-programming-book-for-free/51>





## Intermediate Project 1

Time Slot		Course Code			
Time Slot 1 (TS1)		TS1.12			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text" value="40"/>	<input type="text"/>
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
<input type="text" value="1.6"/>	<input type="text" value="English"/>	<input type="text" value="International Hellenic University (IHU)&lt;br/&gt;Kazimierz Pulaski University of Technology and Humanities&lt;br/&gt;in Radom (UTHR)"/>			

### Prerequisites

All courses of TS1.

### Content (Syllabus Outline)

During the end of time slot 1 the participating students will be divided in international groups and will have the chance to produce small projects on scaled electric vehicle powertrains based on the available for the project software. The students working in groups will built or work on a small scale replica of an EV using all the appropriate components. The vehicle will be able to travel and wirelessly transmit sensor information regarding currents, voltages, speed, distance travelled and in some cases auto avoid obstacles. The students will first assemble the EV replica and write control code. A descriptive manuscript, a possible experimental structure and a small presentation will be the deliverables of each project group. The outcome of the project will have to be delivered by the beginning of the time slot 2. Detailed description will be presented in manuscript D1.3.

### Objectives and Competences

The objective of the specific course, which is basically laboratorial, is to enhance the gained knowledge of the students on the subjects taught in time slot 1 and integrate knowledge acquired during the overall educational program, through the utilization of all laboratory devices in order to produce a scaled electric vehicle system based on the available software.







#### Intended Learning Outcomes

Students that will successfully attend the course will be able:

- to recognize the essential requirements for the solution of an automotive engineering problem
- to calculate the parameters required to produce a problem solution
- to satisfactorily present a simple LabVIEW program
- to design and develop an automotive control system for a scaled vehicle
- to cooperate with distant teams and share knowledge

#### Learning and Teaching Methods

The working hours of the students will be devoted to laboratory occupation for the preparation of their deliverables. Student tutors will play a supervisory role.

#### Assessment

The students will be assessed in groups according to the quality of their deliverables.

#### Main Hardware/Software Per Station

It will be defined in D1.3

#### Learning Groups

**8**

#### Students per Group

**5**

#### Basic Literature

Basic literature from TS1 courses.





## EV System Modelling and Simulation

Time Slot		Course Code			
Second Term		TS2.1			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
6		9		3	1
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.8	English	University of Technology and Humanities in Radom, Poland			

### Prerequisites

The basics of NI LabView programming are required. It is also recommended that students have knowledge of the operation of electric drives, sensors and the basics of vehicle dynamics.

### Content (Syllabus Outline)

Systems that have been studied in previous courses are presented in simple mathematical terms and then converted into simple models. This applies to systems such as power supply, vehicle dynamics, energy management. During the laboratory exercises, students develop their electric vehicle model. Then the models are used in system simulations through appropriate software packages. Students examine the impact of changing model parameters and simulation parameters on results. An important part of the exercise is the correct interpretation of the simulation results.

### Objectives and Competences

The objective is to provide students with the necessary knowledge to understand the operation and be able to modify electric vehicle systems.

Competences to be acquired by students are the ability to select the appropriate electrical system based on its implementation requirements and configuration modification to meet specific application needs. Students will understand and appropriate interpret the simulation results.





#### Intended Learning Outcomes

Students that will successfully attend the course will be able

- to recognize and describe a simulation model of a system
- • to satisfactorily present the results of a system's simulation
- to develop the model of a given system and perform a computer simulation based on it

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in In-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Finally, each student will write a report to demonstrate and evaluate the results of their model simulation and formulate the conclusions.

#### Assessment

The students will be assessed according to the laboratory exercise report, analysing and commenting on the model simulation results.

#### Main Hardware/Software Per Station

Software: NI LabView (Control Design and Simulation Module)

#### Learning Stations

**40**

#### Students per Station

**1**

#### Basic Literature

1. LabVIEW Control Design and Simulation Module Help: <http://zone.ni.com/reference/en-XX/help/371894J-01/>
2. Tutorial: Getting Started with Simulation: <http://zone.ni.com/reference/en-XX/help/371894J-01/>
3. Kai Velten: Mathematical Modelling and Simulation, Introduction for Scientists and Engineers. <https://mcdu.files.wordpress.com/2017/03/velten-mathematical-modeling-and-simulation.pdf>





## EV Energy Storage Systems

Time Slot		Course Code			
Second Term		TS2.2			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
6		6		3	1
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0,64	English	Kazimierz Pulaski University of Technology and Humanities in Radom (UTHR) eProInn - Inteligg PC (INT)			

### Prerequisites

TS1.1 Introduction to Vehicle Electrification  
TS1.2 NI Labview Training  
TS1.3 Automotive Energy Sources

### Content (Syllabus Outline)

As energy plays the central role in the workings of EVs, an understanding of the basic principles of energy – conservation, measurement, conversion and transfer – is of paramount importance. The charge and the discharge dynamics of four battery types and an ultracapacitor pack are validated experimentally along with monitoring the energy produced by a solar panel and its consumption by an electric motor. The experiments will be carefully set up, critical parameters, like voltage and currents, will be measured for all battery packs and comparison will be made.

### Objectives and Competences

#### Objectives

- to clarify to the students the meaning of battery load
- to force the students to compare different types of batteries through experimentation
- to reveal the characteristics of an operated energy storage system

#### Competences

- management of energy storage systems
- distinction of energy storage devices according to their characteristics
- ability to characterise energy storage systems according to their performance





#### Intended Learning Outcomes

Students that will successfully attend the course will be able:

- to describe the difference between storage systems
- to calculate generated power & consumption
- to analyse the health of a storage system and be able to troubleshoot
- to create a closed loop control & measurement system

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in in-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Finally, each team will write a report to demonstrate and evaluate the results of their experiment and compare their results among other group results.

#### Assessment

The students will be assessed according to the laboratory exercise report, analyzing and commenting on the experimental results. Weighting factor: 100%.

#### Main Hardware/Software Per Station

For each learning station: 1x PC, 1x NI LabVIEW (License), 1x NI cDAQ 4-slot chassis, 1x NI-9264 for Voltage output, a NI-9207 for Voltage & Current Modules, 2xLEM Voltage Transducers, 4xLEM Current Transducers will be used to design to measure & compare the energy profiles.

#### Learning Stations

2

#### Students per Station

5

#### Basic Literature

1. Battery, Ultracapacitor, Fuel Cell, and Hybrid Energy Storage Systems for Electric, Hybrid Electric, Fuel Cell, and Plug-In Hybrid Electric Vehicles: State of the Art', *EEE Transactions on Vehicular Technology*, vol. 59, no. 6, pp. 2806-2814, July 2010, doi: 10.1109/TVT.2010.2047877.
2. Electrochemical Energy Storage for Green Grid, doi.org/10.1021/cr100290v | *Chem. Rev.* 2011, 111, 3577–3613.
3. Battery energy storage technology for power systems—An overview, *Electric Power Systems Research* 79 (2009) 511–520





## EV Charging Systems

Time Slot			Course Code		
Second Term			TS2.3		
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
21	3	6		12	4
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
1,84	English	International Hellenic University (IHU) University of Technology and Humanities in Radom, Poland eProInn – Ezee Europe (EZEE) Hellenic Institute of Transport (HIT)			

### Prerequisites

TS1.1 Introduction to Vehicle Electrification  
 TS1.2 NI Labview Training  
 TS1.3 Automotive Energy Sources

### Content (Syllabus Outline)

The students will have the opportunity in this laboratory to design the power electronics behind a small scale charging station and use simulation tools to simulate the charging and discharging cycles. The students will have to design and develop a small charging station of two or more single phase sockets. Charging of a small electric vehicle through these sockets will be controlled by simple and easy to use devices, like the Raspberry PI. The charging station must have the ability to provide current and energy consumption through appropriate meters. The overall system will have to be expandable in order to be able to communicate with mobile applications, implemented by the students in the frame of Intermediate Project 2.

### Objectives and Competences

#### Objectives

- To get the students in touch with all critical circuits of a charging station
- To reveal the role of charging station control and communication with the user

#### Competences

- Insight to the power electronics for charging stations
- Be able to program a simple charging station's control module





#### Intended Learning Outcomes

Students that will successfully attend the course will be able:

- to describe how a charging station system operate
- to distinguish the difference in charge station technologies
- to design & troubleshoot power electronics and use simulation tools

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in in-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Finally, each team will write a report to demonstrate and evaluate the results of their experiment and compare their results among other group results.

#### Assessment

The students will be assessed according to the laboratory exercise report, analyzing and commenting on the experimental results. Weighting factor: 100%

#### Main Hardware/Software Per Station

MATLAB/Simulink will be used for designing and simulating electronic circuits for EV charging. Per learning station: 1xPC, 1 Raspberry PI, 1xRelay Module - 4 Channel 5V, 2 single phase sockets, 1xindustrial looking box, cables, wires and connectors.

#### Learning Stations

2

#### Students per Station

5

#### Basic Literature

1. <https://www.tuv.com/greater-china/en/electric-vehicle-charging-system-testing.html>
2. <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1996-15.pdf>
3. Lecturer's own teaching/research material
4. Modeling of an electric vehicle charging station for fast DC charging, 2012 IEEE International Electric Vehicle Conference, Greenville, SC, 2012, pp. 1-6, doi: 10.1109/IEVC.2012.6183232.
5. Open Charge Point Protocol 2.0.1, <https://www.openchargealliance.org/downloads/>
6. A DIY Charging Point for an Electric Car: Perspective, Protocol & Prototype, <https://www.eliftech.com/blog/48-a-diy-charging-point-for-an-electric-car-perspective-protocol-and-prototype>





## Mechanical Drivetrains for EVs

Time Slot		Course Code			
Second Term		TS2.4			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
9		4		4.5	1.5
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.7	English	UTH Radom, HIT			

### Prerequisites

Before laboratory all students should know the most common safety rules necessary for working with chassis dynamometer. Fundamental knowledge on vehicles construction is also recommended

### Content (Syllabus Outline)

The laboratory exercise will use a chassis dynamometer and vehicles equipped with a conventional drivetrain system and a hybrid or electric one equipped with planetary gear box. Students will work together in small group. They will prepare the vehicle for the test. In the next step they will measure the power, torque and power losses. Then, based on the results obtained, they will determine the mechanical efficiency of the drivetrain system for a vehicle equipped with internal combustion engine and manual gear box, as well as for a hybrid or electric vehicle with a planetary gear box. Each student will collect individual measurement data for both kinds of tested vehicles. The results will be presented in individual reports and then compared with each others.

### Objectives and Competences

The objective is to provide students the necessary knowledge and practical skills to understand and perform measurements of selected parameters of vehicles drivetrain. In particular, students will gain practical experiences with chassis dynamometer measurements. They will extend the engineering knowledge on vehicles drivetrain constructions and factors affecting the quality of measurements carried out on the chassis dynamometer.







#### Intended Learning Outcomes

Students that will successfully attend the laboratory will be able to

- prepare vehicles and chassis dynamometer for tests
- measure power and torque of vehicles including power losses in drivetrain
- calculate of mechanical efficiency of vehicles drivetrain

#### Learning and Teaching Methods

Fundamental, theoretical background of laboratory will be presented during conventional lectures. All sources of knowledge necessary for the following laboratory will be available by the e-learning platform. During laboratory exercises all students will participate in practical work focused on the chassis dynamometer measurements. After laboratory, each student will prepare a report based on individual measurement data.

#### Assessment

As mentioned above, based on the test results all students will prepare individual laboratory report. The report will be assessed by teacher taking into account the quality of all necessary parts such as: theoretical background, calculations, figures, tables and conclusions.

#### Main Hardware/Software Per Station

chassis dynamometer, tested vehicles, personal computers equipped with software necessary for fundamental mathematical calculations: Matlab, Mathcad, Excel or equivalent

#### Learning Stations

**1**

#### Students per Station

**10**

#### Basic Literature

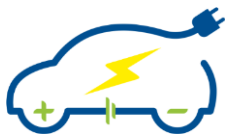
- Olszewski M. Evaluation of 2004 Toyota Prius HED System. U.S. Dept. of Energy 2005, [https://www.engr.uvic.ca/~mech459/Pub\\_References/890029.pdf](https://www.engr.uvic.ca/~mech459/Pub_References/890029.pdf)
- Masrur A. et al. Hybrid Electric Vehicles with Practical Perspectives. Wiley, 2011, ISBN: 978-1-118-97056-0
- Soyulu S. Electric Vehicles. The Benefits and Barriers. InTech 2011, ISBN: 978-953-307-287-6
- Heisler H. Advanced Vehicle Technology. Butterworth-Heinemann. 2002, ISBN: 9780750651318
- Ehsani M. et al. Modern Electric, Hybride Electric, and Fuel Cell Vehicles. CRC 2005, ISBN 0-8493-3154-4
- Guzzella L., Sciarretta A. Vehicle Propulsion Systems. 2nd edition. Springer 2007, ISBN 978-3-642-35912-5
- Górski K. Smigins R.: Selected Physicochemical Properties of Diethyl Ether/Rapeseed Oil Blends and Their Impact on Diesel Engine Smoke Opacity. Energy&Fuels. 32(2), 2018. <https://pubs.acs.org/doi/full/10.1021/acs.energyfuels.7b03225?src=recsys>





- Skrzek T. Effect of diesel fuel injection parameters on performances and efficiency of a turbocharged dual-fuel compression ignition engine operating on propane. IOP 2018(421), <https://iopscience.iop.org/article/10.1088/1757-899X/421/4/042073/pdf>
- Asok K.Sen, Longwic R., Litak G., Górski K.: Analysis of cycle-to-cycle pressure oscillations in a diesel engine. Mech Syst Signal Process. 22(2), 2008. [https://www.researchgate.net/publication/223214093\\_Analysis\\_of\\_cycle-to-cycle\\_pressure\\_oscillations\\_in\\_a\\_diesel\\_engine](https://www.researchgate.net/publication/223214093_Analysis_of_cycle-to-cycle_pressure_oscillations_in_a_diesel_engine)





## Control System Development

Time Slot		Course Code			
Time Slot 2 (TS2)		TS2.5			
Lectures In-class	Lectures Web	Lab Exercises	Practice	Home Work	Exams
9		6		4.5	1.5
ECTS Credits	Language	Lecturer			
0.84	English	International Hellenic University (IHU) University of Technology and Humanities in Radom (UTHR)			

### Prerequisites

Students are recommended to have acquired Basic knowledge of electric machines and Fundamentals of Control Systems

### Content (Syllabus Outline)

A laboratory setup emulating a control system in an automobile will be used to teach students about closed loop control. This setup will include actuators, sensors, motors & rotary encoders connected to a 4-slot cDAQ chassis with a NI-9264 for Voltage output & a NI-9207 for Voltage & Current Modules. The students will have to experiment themselves with the correct setup of the system and its response under closed and open loop control situation. NI LabVIEW and its components will play critical role in this experimentation.

### Objectives and Competences

- Develop students' knowledge of control principles
- Understand principles of operation of speed and torque control systems
- Develop practical skills in automatic control

### Intended Learning Outcomes

Students that will successfully attend this course will be able to:

- to describe about closed loop control
- to create & analyse PID profiles to optimise an operation
- to create simple closed loop control algorithms





#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in in-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Finally, each team will write a report to demonstrate and evaluate the results of their experiment and compare their results among other group results.

#### Assessment

The students will be assessed according to the laboratory exercise report, analyzing and commenting on the experimental results. Weighting factor: 100%

#### Main Hardware/Software Per Station

For each station: 1x PC, 1x NI LabVIEW (License), 1x NI cDAQ 4-slot chassis, 1x NI-9219 Universal Analogue Input Module, 1x NI-9205 Voltage Input Module, 2x wheel speed sensors, 2x electromagnetic actuators

#### Learning Stations

2

#### Students per Station

4

#### Basic Literature

- Richard C. Dorf, Robert H. Bishop, "Modern Control Systems", Pearson ISBN-13:978-0-13-602458-3
- Bimal K. Bose, "Power Electronics and Variable Frequency Drives", IEEE Press, <https://www.semanticscholar.org/paper/Power-Electronics-And-Variable-Frequency-Drives-And-Kazmierkowski/e2ece06ea38a57e206b183746c37e8b94d42a55b>





## EV On Board Diagnostics, Troubleshooting & Maintenance

Time Slot		Course Code			
Second Term		TS2.8			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
6		3		3	1
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.5	English	University of Technology and Humanities in Radom, Poland			

### Prerequisites

It is required that students have knowledge of the operation of electric drives, sensors and the data acquisition. The basics of NI LabView programming are also required.

### Content (Syllabus Outline)

Students will learn methods and tools for detecting damage in EV and HEV cars. The laboratory will consist of three parts. In the first exercise simulation and detection of CAN bus faults will be performed. The second exercise contain EV fault diagnostics with NI toolkit and CAN Interface device. The third part is using commercial diagnostic scan tools for HEV and EV diagnostics.

### Objectives and Competences

The objective is to provide the students the necessary knowledge connected with the maintenance, fault detection and troubleshooting of the EVs. The competences expected to be acquired by the students are the ability to connect with the CAN Bus protocol architecture to send & receive data and to troubleshoot common ECU faults from defective sensors & sub-systems.





#### Intended Learning Outcomes

Students that will successfully attend the course will be able:

- to recognize and describe an EV fault under On-board Diagnostics system and its implementation in EVs
- to maintain a simplified EV
- to estimate faults of the electric vehicle power network
- to satisfactorily present a fault in electric vehicle and its solution

to analyze and develop an EV troubleshooting procedure

#### Learning and Teaching Methods

The theoretical background needed to support the laboratory exercise will be presented in In-class lectures and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Finally, each team will write a report to demonstrate and evaluate the results of their experiment and compare their results among other group results.

#### Assessment

The students will be assessed according to the laboratory exercise report, analyzing and commenting on the experimental results.

#### Main Hardware/Software Per Station

Three different stations

1. Demonstration stand (or car), oscilloscope, multimeters for observing signals in CAN bus.
2. Demonstration stand (or car), Software: Automotive Diagnostic Command Set for vehicle diagnostics, NI Devices: CAN-USB Interface for data logging, CAN interface for vehicle diagnostics.
3. Demonstration stand (or car), Bosch KTS-570 Scan Tools with dedicated software ESI[tronic].

#### Learning Stations

**3**

#### Students per Station

**5**





#### **Basic Literature**

1. Johansson K.H., Torngren M., Nielse L.: Vehicle Applications of Controller Area Network. [https://people.kth.se/~kallej/papers/can\\_necs\\_handbook05.pdf](https://people.kth.se/~kallej/papers/can_necs_handbook05.pdf)
2. CAN - Automotive Diagnostic Command Set User Manual <http://www.ni.com/pdf/manuals/372139d.pdf>
3. Corrigan, Steve: Introduction to the Controller Area Network (CAN). Texas Instruments, 2008. <http://www.ti.com/lit/an/sloa101b/sloa101b.pdf>
4. Course materials at the Department of Mechanical Engineering of the UTHR, Radom Poland.





## Life Cycle Assessment of EVs

Time Slot		Course Code			
Second Term		TS2.9			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
3		2		1.5	0.5
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
0.28	English	CERTH/HIT			

### Prerequisites

None

### Content (Syllabus Outline)

The course is an introduction to a practical application of the LCA. The students will be familiarized with a free access well-known software. The course is aiming to the introduction of a systemic tool for evaluating the environmental impact related to goods and services. LCA includes technical surveys of all product life cycle stages, from material acquisition and manufacturing to use and end-of-life. By linking processes within the system from cradle to grave, a model will be made of how the flows are connected and influence each other. The result is an inventory of inflows to the system in terms of natural resources and outflows in terms of emissions to the surrounding natural system. The students will work independently and build their own simplified models and evaluate/commend the inflow and outflow results.

### Objectives and Competences

The objective of this experiment is to analyze the environmental impacts, specifically energy use and CO<sub>2</sub>-equivalent emissions, of passenger vehicles.

The competences expected to be acquired by the students are the ability to identify and comprehend the different phases of a vehicle life: from production to decommissioning, as well as their potential effects to environment.







#### Intended Learning Outcomes

Students that will successfully attend the course will be able to:

- to calculate the life cycle of energy sources and the impact to environment
- to perform a simple life cycle analysis using an appropriate software

#### Learning and Teaching Methods

The laboratory exercise will be presented in In-class lecture and the respective teaching materials will be available at the e-Learning platform. Laboratory supervisors will guide each step of the lab work and assist the students as needed. Each student will write a report to demonstrate and evaluate the results of his/her experiment.

#### Assessment

The students will be assessed according to the laboratory exercise report, analyzing and commenting on the simulation results. Weighting Factor: 100%

#### Main Hardware/Software Per Station

OpenLCA will be used as open source and free software for conducting Life Cycle Assessment studies. It plays in the same league as commercial LCA software, such as SimaPro, GaBi, or Umberto, but offers distinct differences.

#### Learning Stations

**40**

#### Students per Station

**1**

#### Basic Literature

1. openLCA 1.10 Comprehensive User Manual. Software Version: 1.10.2, Manual Version: February 2020, Authors: Dr A. Ciroth, C. Di Noi, T. Lohse, M. Srocka.
2. <http://www.openlca.org/learning>
3. ISO 14040:2006. Environmental management — Life cycle assessment — Principles and framework
4. Electric vehicles from life cycle and circular economy perspectives. TERM 2018: Transport and Environment Reporting Mechanism (TERM) report, EEA, Denmark, 2018, ISSN 1977-8449. <https://www.eea.europa.eu/publications/electric-vehicles-from-life-cycle/download>
5. Energy Efficiency and Conservation Authority. Life Cycle Assessment of Electric Vehicles, Final Report, 243139-00, Australia, November 2015. <https://apo.org.au/sites/default/files/resource-files/2015-11/apo-nid58940.pdf>
6. eLCAR: Guidelines for the LCA of electric vehicles. Technical Report, January 2013. [https://www.researchgate.net/publication/291135663\\_eLCAR\\_Guidelines\\_for\\_the\\_LCA\\_of\\_electric\\_vehicles](https://www.researchgate.net/publication/291135663_eLCAR_Guidelines_for_the_LCA_of_electric_vehicles)





## Intermediate Project 2

Time Slot		Course Code			
Time Slot 2 (TS2)		TS2.12			
<b>Lectures In-class</b>	<b>Lectures Web</b>	<b>Lab Exercises</b>	<b>Practice</b>	<b>Home Work</b>	<b>Exams</b>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text" value="40"/>	<input type="text"/>
<b>ECTS Credits</b>	<b>Language</b>	<b>Lecturer</b>			
<input type="text" value="1.6"/>	<input type="text" value="English"/>	<input type="text" value="International Hellenic University (IHU)&lt;br/&gt;Kazimierz Pulaski University of Technology and Humanities&lt;br/&gt;in Radom (UTHR)"/>			

### Prerequisites

All courses of TS1 and TS2.

### Content (Syllabus Outline)

The Intermediate Project 2 will be connected with the Intermediate Project 1 course. The students will have to develop simple Augmented Reality (AR) or wireless connection code based on the equipment provided by the partner institutions. The code will be connected to some of the courses. The code will be simple enough as for example developing blank geometrical drawings in the AR space. Similarly with Intermediate Project 1, a tutor will be assigned to each group of students in order to assist them complete their project. A descriptive manuscript, the code and a small presentation will be the deliverables of each project group. Each intermediate project will have to be delivered by the beginning of the practical experience period. Detailed description will be presented in manuscript D1.3.

### Objectives and Competences

The objective of the specific course, which is basically laboratorial, is to enhance the gained knowledge of the students on the subjects taught in time slot 2 and integrate knowledge acquired during the overall educational program, through the development of Augmented Reality or wireless technology code.





#### Intended Learning Outcomes

Students that will perform the specific project, will be able

- to recognize and describe the basic instructions of the AR programming language
- to recognize and describe the elementary structure of an AR code
- to satisfactorily present a simple AR code
- to analyze, design and develop an AR code creating simple geometrical drawings
- to analyze, design and develop a simple marker-based AR application
- to analyse, design and develop a sensor system based on LabVIEW®

to cooperate with distant teams and share knowledge

#### Learning and Teaching Methods

The working hours of the students will be devoted to laboratory occupation for the preparation of their deliverables. Student tutors will play a supervisory role.

#### Assessment

The students will be assessed in groups according to the quality of their deliverables.

#### Main Hardware/Software Per Station

It will be defined in D1.3

#### Student Groups

**8**

#### Students per Group

**5**

#### Basic Literature

All educational material provided in the frame of the other TS1 and TS2 courses.

