



MINOR DEGREE PROGRAM  
IN  
**Automotive Electronics  
and E-Mobility**

OFFERED BY

**DEPARTMENT OF ELECTRICAL ENGINEERING**

INSTITUTE OF ENGINEERING & MANAGEMENT

School of

University of Engineering and Management, Kolkata

## Minor Specialization Syllabus — Automotive Electronics and E-Mobility

### Program me overview

The Department of Electrical Engineering (IEM Kolkata, Salt Lake Campus) offers the Minor in Automotive Electronics and E-Mobility across six semesters, one course per semester from Semester 3 to Semester 8.

| Semester | Course code | Course title                                      | L-T-P           | Credits | Contact hrs/week | Type (Theory/Lab /Project)             |
|----------|-------------|---------------------------------------------------|-----------------|---------|------------------|----------------------------------------|
| 3        | MINOR301AE  | Autotronics and EV Power Electronics              | 4-0-0           | 4       | 4                | Theory                                 |
| 4        | MINOR401AE  | Vehicle Control, Diagnostics and EV Fundamentals  | 4-0-0           | 4       | 4                | Theory                                 |
| 5        | MINOR501AE  | EV Sensors and Automotive Embedded Systems        | 3-0-0           | 3       | 3                | Theory                                 |
| 6        | MINOR601AE  | Energy Storage and EV Charging Infrastructure     | 3-0-0           | 3       | 3                | Theory                                 |
| 7        | MINOR701AE  | Autonomous Vehicles and Project Phase I           | 3-0-0 + Project | 3       | 3                | Theory + Project Phase I               |
| 8        | MINOR801AE  | Connected Vehicles, E-Mobility Policy and Project | 3-0-0 + Project | 3       | 3                | Theory + Project Phase II / Internship |
| Total    |             |                                                   |                 | 20      |                  |                                        |

### Programme-level details

- Offering department: Department of Electrical Engineering (EE), IEM Kolkata – Salt Lake Campus

### Semester 3 — MINOR301AE: Autotronics and EV Power Electronics

MINOR301AE is a theory course with 27 teaching hours across four modules: Modules 1–3 follow the 12-week NPTEL *Autotronics* course (IIT Indore) and Module 4 follows Coursera *Powering the Drive: Unveiling EV Electronics*.

| Field                | Details                                         |
|----------------------|-------------------------------------------------|
| Course code          | MINOR301AE                                      |
| Course title         | Autotronics and EV Power Electronics            |
| Course category      | Minor Specialization                            |
| L-T-P                | 3-0-0                                           |
| Credits              | 4                                               |
| Contact hours/week   | 3                                               |
| Total teaching hours | 27                                              |
| Prerequisites        | Basic Electrical Engineering; Basic Electronics |

### Course objectives

1. **Describe** the system approach to automotive control and instrumentation, signal flow and conversion, multiplexing and engine management.
2. **Explain** the operating principles of automotive sensors, MEMS devices, actuators and transmission mechatronics for electric and hybrid vehicles.
3. **Apply** sensor and actuator knowledge to engine, chassis and by-wire subsystems.
4. **Analyse** vehicle control strategies and EV power electronic converters, PWM control and motor-drive energy management.
5. **Evaluate** automotive faults using systematic, intelligent and IoT-enabled diagnostic methods.

**Course outcomes** — on completion, students will be able to:

| CO  | Statement                                                                                                                                                                          |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Explain automotive instrumentation — signal flow and conversion, multiplexing, measurement of vehicle parameters, display systems and engine management.                           |
| CO2 | Apply the working principles of automotive sensors, MEMS devices and actuators, including transmission mechatronics, steer-by-wire and intelligent braking, to vehicle subsystems. |
| CO3 | Analyse vehicle control strategies (air–fuel, ignition, transmission, hybrid, cruise, ABS) and EV power electronic converters, PWM control and motor-drive energy management.      |
| CO4 | Evaluate faults in automotive electronic, ignition, emission and sensor systems using systematic, intelligent and IoT-enabled diagnostics.                                         |

**CO–PO/PSO mapping** (3 = high, 2 = medium, 1 = low, blank = none)

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 1   |     | 1   |     |     |     |     |      |      |
| CO2 | 3   | 2   | 2   | 1   | 2   |     |     |     |     |      |      |
| CO3 | 3   | 3   | 3   | 2   | 2   | 1   | 1   |     |     |      |      |
| CO4 | 2   | 3   | 2   | 2   | 3   | 1   | 1   | 1   |     |      | 1    |

## Detailed syllabus

| Module                                                                    | Topics                                                                                                                                                                                                                                                                                                                                                  | Lecture hours |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 1: Automotive Instrumentation (NPTEL weeks 1–2)                    | System approach to control and instrumentation; electronic fundamentals; input/output signal flows and conversions; multiplexing; fuel quantity, coolant temperature, oil pressure and vehicle speed measurement; display devices and intelligent glass cockpit; engine management system.                                                              | 7             |
| Module 2: Automotive Actuators and Transmission Systems (NPTEL weeks 3–5) | Actuator operation; actuators for fuel injectors, gas recirculation and idle speed control; ABS actuators; electronic unit injectors; computer-controlled dampers; piezoelectric energy harvesters; transmission mechatronics for electric/hybrid 4-wheel and 2-wheel drives; steer-by-wire and intelligent braking.                                    | 7             |
| Module 3: Automotive Sensors and MEMS (NPTEL weeks 6–8)                   | Electromagnetic sensors; optical sensors; combustion knock sensors; variable-resistance sensors; tyre pressure sensing; temperature sensors; ride-height control sensors; manifold absolute pressure sensor; exhaust gas oxygen sensor; air flow sensors; accelerometers and other sensors for steer-by-wire.                                           | 7             |
| Module 4: EV Power Electronics and Drives (Coursera)                      | Role and significance of power electronics in EVs; key components — inverters, converters and DC-DC converters; power electronics topologies in EVs; pulse-width modulation (PWM); H-bridge and multilevel converters; control strategies and algorithms for efficient power conversion; motor drive systems; energy management and range optimisation. | 6             |
| <b>Total</b>                                                              |                                                                                                                                                                                                                                                                                                                                                         | <b>27</b>     |

## Text books

1. William B. Ribbens, *Understanding Automotive Electronics: An Engineering Perspective*, Butterworth-Heinemann, 8th Edition, 2017.
2. Tom Denton, *Automobile Electrical and Electronic Systems*, Routledge, 5th Edition, 2017.
3. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 3rd Edition, 2021.

## Reference books

1. Tom Denton, *Advanced Automotive Fault Diagnosis*, Routledge, 4th Edition, 2016.
2. Robert Bosch GmbH, *Bosch Automotive Electrics and Automotive Electronics*, Springer Vieweg, 5th Edition, 2014.
3. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press, 3rd Edition, 2018.

## Online resources (NPTEL / SWAYAM / MOOCs)

| PLATFORM | NAME OF THE COURSE                                                                                                                  | Hours |
|----------|-------------------------------------------------------------------------------------------------------------------------------------|-------|
| NPTEL    | <ul style="list-style-type: none"><li>• <a href="#">NPTEL — Autotronics, Prof. I. A. Palani, IIT Indore</a> (Modules 1–3)</li></ul> | 21    |

|          |                                                                                                                                      |   |
|----------|--------------------------------------------------------------------------------------------------------------------------------------|---|
| COURSERA | <ul style="list-style-type: none"> <li><a href="#">Coursera — Powering the Drive: Unveiling EV Electronics</a> (Module 4)</li> </ul> | 6 |
|----------|--------------------------------------------------------------------------------------------------------------------------------------|---|

#### Semester 4 — MINOR401AE: Vehicle Control, Diagnostics and EV Fundamentals

MINOR401AE is a theory course with 26 teaching hours across four modules: Modules 1–2 follow NPTEL *Autotronics* (IIT Indore) and Modules 3–4 follow Coursera *Electric Vehicle Sensors* (University of Colorado Boulder).

| Field                | Details                                           |
|----------------------|---------------------------------------------------|
| Course code          | MINOR401AE                                        |
| Course title         | Vehicle Control, Diagnostics and EV Fundamentals  |
| Course category      | Minor Specialization                              |
| L-T-P                | 3-0-0                                             |
| Credits              | 3                                                 |
| Contact hours/week   | 3                                                 |
| Total teaching hours | 26                                                |
| Prerequisites        | MINOR301AE (Autotronics and EV Power Electronics) |

#### Course objectives

1. **Recall** the types of electric vehicles and the architecture and components of automotive embedded systems.
2. **Explain** the operation of traction motors, traction inverters, EV transmissions and battery charging hardware.
3. **Apply** sensing principles to specify sensors for high-voltage current and voltage, torque, speed and temperature measurement in EVs.
4. **Design** a basic microcontroller-based embedded system that integrates automotive sensors and actuators.
5. **Assess** the impact of connectivity, autonomy, AI and cybersecurity on automotive embedded systems.

**Course outcomes** — on completion, students will be able to:

| CO  | Statement                                                                                                                                                           |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Explain the types of electric vehicles and the working of their major electrical components — synchronous traction motors, EV transmissions and traction inverters. |
| CO2 | Apply sensing principles to select and specify sensors for battery charging, high-voltage current and voltage, torque, speed and temperature measurement in EVs.    |
| CO3 | Design a basic automotive embedded system using a microcontroller, sensor data acquisition, actuator control and the embedded software development lifecycle.       |
| CO4 | Assess the role of embedded systems in electric, hybrid, connected and autonomous vehicles, including V2X, AI/ML and automotive cybersecurity.                      |

**CO–PO/PSO mapping** (3 = high, 2 = medium, 1 = low, blank = none)

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 1   |     | 1   |     | 1   |     |     |      |      |
| CO2 | 3   | 3   | 2   | 2   | 2   |     |     |     |     |      |      |
| CO3 | 2   | 3   | 3   | 2   | 3   |     |     |     | 1   | 1    |      |
| CO4 | 2   | 2   | 1   | 1   | 2   | 2   | 2   | 2   |     |      | 1    |

### Detailed syllabus

| Module                                                      | Topics                                                                                                                                                                                                                                             | Lecture hours |
|-------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 1: Vehicle Control Systems (NPTEL weeks 9–10)        | Air–fuel control; spark timing control; transmission control; clutch for AWD; hybrid vehicle control; series, parallel and split hybrids with feedback-based supervisory control; cruise control; ABS control; control of fuel systems.            | 7             |
| Module 2: Automotive System Diagnostics (NPTEL weeks 11–12) | Circuit testing; six-step approach; fault finding in emission-related and ignition systems; sensor system and intermittent fault diagnosis; intelligent collaborative diagnostic systems; IoT-enabled condition monitoring and diagnostic systems. | 6             |
| Module 3: How Electric Vehicles Work                        | How EVs differ from petrol and diesel vehicles; types of EVs; battery electric vehicle; hybrid electric vehicle; mild hybrid; plug-in hybrid; electric bus.                                                                                        | 6             |
| Module 4: Major Electrical Components of EVs                | AC synchronous motors; interior permanent magnet synchronous reluctance motor; power and torque in synchronous motors; transmissions in EVs; traction inverters.                                                                                   | 7             |
| <b>Total</b>                                                |                                                                                                                                                                                                                                                    | <b>26</b>     |

### Text books

1. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 3rd Edition, 2021.
2. Nicolas Navet, Françoise Simonot-Lion (Eds.), *Automotive Embedded Systems Handbook*, CRC Press, 2009.
3. Jon S. Wilson (Ed.), *Sensor Technology Handbook*, Newnes, 2005.

### Reference books

1. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press, 3rd Edition, 2018.
2. William B. Ribbens, *Understanding Automotive Electronics: An Engineering Perspective*, Butterworth-Heinemann, 8th Edition, 2017.
3. James Larminie, John Lowry, *Electric Vehicle Technology Explained*, Wiley, 2nd Edition, 2012.

### Online resources (NPTEL / SWAYAM / MOOCs)

| PLATFORM | NAME OF THE COURSE                                                                                                                                  | Hours |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| NPTEL    | <ul style="list-style-type: none"> <li><a href="#">NPTEL — Autotronics, Prof. I. A. Palani, IIT Indore</a> (Modules 1–2)</li> </ul>                 | 13    |
| COURSERA | <ul style="list-style-type: none"> <li><a href="#">Coursera — Electric Vehicle Sensors, University of Colorado Boulder</a> (Modules 3–4)</li> </ul> | 13    |

### Semester 5 — MINOR501AE: EV Sensors and Automotive Embedded Systems

MINOR501AE is a theory course with 27 teaching hours across four modules: Modules 1–2 follow Coursera *Electric Vehicle Sensors* (University of Colorado Boulder) and Modules 3–4 follow Coursera *Introduction to Automotive Embedded Systems* (Starweaver).

| Field                | Details                                                     |
|----------------------|-------------------------------------------------------------|
| Course code          | MINOR501AE                                                  |
| Course title         | EV Sensors and Automotive Embedded Systems                  |
| Course category      | Minor Specialization                                        |
| L-T-P                | 3-0-0                                                       |
| Credits              | 3                                                           |
| Contact hours/week   | 3                                                           |
| Total teaching hours | 27                                                          |
| Prerequisites        | MINOR401AE; basic Electrical Machines and Power Electronics |

### Course objectives

1. **Explain** EV configurations and the role of motor drives, power electronics and in-vehicle networks in EVs.
2. **Apply** vehicle dynamics models to compute tractive effort, power and energy requirements.
3. **Analyse** power electronic converters and PWM techniques for DC, induction, PMSM, SRM and BLDC drives.
4. **Develop** dynamic models and control schemes — V/f, sensed and sensorless vector control — for induction and PMSM drives.
5. **Evaluate** motor–drive technologies and in-vehicle network technologies (LIN, CAN, FlexRay, MOST, Automotive Ethernet) for EV applications.

**Course outcomes** — on completion, students will be able to:

| CO  | Statement                                                                                                                                                |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Apply vehicle dynamics modelling and simulation to determine tractive force, power and energy requirements of an EV.                                     |
| CO2 | Analyse power electronic converters and PWM schemes used in DC motor, induction motor, SRM and BLDC drives.                                              |
| CO3 | Develop dynamic models and control schemes (V/f, sensed and sensorless vector control) for induction motor and PMSM drives in rotating reference frames. |

| CO  | Statement                                                                                                                                                                                        |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO4 | Evaluate motor–drive technologies (IM, PMSM, SRM, BLDC) and in-vehicle networks (LIN, CAN/CAN-FD/CAN-XL, FlexRay, MOST, Automotive Ethernet, SerDes) for EVs on cost, speed and safety criteria. |

**CO–PO/PSO mapping** (3 = high, 2 = medium, 1 = low, blank = none)

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO1 | 3   | 3   | 2   | 2   | 2   |     | 1   |     |     |      |      |
| CO2 | 3   | 3   | 2   | 2   | 2   |     |     |     |     |      |      |
| CO3 | 3   | 3   | 3   | 3   | 3   |     |     |     |     |      |      |
| CO4 | 2   | 2   | 2   | 1   | 2   | 1   | 2   | 1   |     |      | 1    |

### Detailed syllabus

| Module                                                  | Topics                                                                                                                                                                                                                                                                                                      | Lecture hours |
|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 1: Battery Charging and High-Voltage Measurement | Battery charging (in-vehicle and external); battery modules; regenerative braking; high-voltage current measurement; high-voltage measurement.                                                                                                                                                              | 7             |
| Module 2: Sensors Critical to EV Performance            | Torque sensors; speed sensors; thermistors and on-board thermal sensing; selecting and specifying sensors for EV applications.                                                                                                                                                                              | 6             |
| Module 3: Foundations of Automotive Embedded Systems    | Role and key components of automotive embedded systems; microcontroller basics, selection and programming; embedded software development lifecycle, tools and languages; sensor technologies and integration; data acquisition from sensors; actuator types, integration challenges and control strategies. | 8             |
| Module 4: Advanced Topics and Future Trends             | Embedded systems in EVs and hybrids, including battery management; vehicle connectivity and V2X communication; foundations of autonomous driving; AI/ML and IoT in vehicles; automotive cybersecurity and layered security; embedded systems for sustainable mobility.                                      | 6             |
| <b>Total</b>                                            |                                                                                                                                                                                                                                                                                                             | <b>27</b>     |

**Laboratory / practical component:** Not applicable (theory course, 3-0-0).

### Text books

1. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 3rd Edition, 2021.
2. R. Krishnan, *Electric Motor Drives: Modeling, Analysis, and Control*, Prentice Hall, 2001.
3. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press, 3rd Edition, 2018.

### Reference books

1. B. K. Bose, *Modern Power Electronics and AC Drives*, Prentice Hall, 2002.

2. R. Krishnan, *Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and Applications*, CRC Press, 2001.
3. G. K. Dubey, *Fundamentals of Electrical Drives*, Narosa, 2nd Edition, 2001.
4. Dominique Paret, *Multiplexed Networks for Embedded Systems: CAN, LIN, FlexRay, Safe-by-Wire*, Wiley, 2007.

**Online resources (NPTEL / SWAYAM / MOOCs)**

| PLATFORM | NAME OF THE COURSE                                                                                | Hours |
|----------|---------------------------------------------------------------------------------------------------|-------|
| COURSERA | <a href="#">Coursera — Electric Vehicle Sensors, University of Colorado Boulder</a> (Modules 1–2) | 13    |
| COURSERA | <a href="#">Coursera — Introduction to Automotive Embedded Systems, Starweaver</a> (Modules 3–4)  | 14    |

**Semester 6 — MINOR601AE: Energy Storage and EV Charging Infrastructure**

MINOR601AE is a theory course with 25 teaching hours across five modules: Modules 1–3 follow the Coursera Battery Technologies specialization, and Modules 4–5 follow NPTEL *Charging Infrastructure* (Prof. Apurv Kumar Yadav, IIT Roorkee).

| Field                | Details                                       |
|----------------------|-----------------------------------------------|
| Course code          | MINOR601AE                                    |
| Course title         | Energy Storage and EV Charging Infrastructure |
| Course category      | Minor Specialization                          |
| L-T-P                | 3-0-0                                         |
| Credits              | 3                                             |
| Contact hours/week   | 3                                             |
| Total teaching hours | 25                                            |
| Prerequisites        | MINOR501AE; basic Power Electronics           |

**Course objectives**

1. **Describe** the principles of electrochemical energy storage and conversion and the definitions and measurement methods for cell performance.
2. **Explain** the components and characteristics of lithium-ion cells — electrodes, electrolytes and current collectors.
3. **Apply** EV charging standards, procedures and communication protocols for AC Type 2 and DC CCS2 charging.
4. **Analyse** AC-DC and isolated DC-DC converter topologies used in EV chargers.

5. **Evaluate** (L5 Evaluate) alternative battery chemistries, supercapacitors, battery pack designs and lithium recycling for EV use.

**Course outcomes** — on completion, students will be able to:

| CO  | Statement                                                                                                                                                                                                    |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Explain electrochemical energy storage principles, performance definitions and measuring methods, and the components and characteristics of commercial lithium-ion cells.                                    |
| CO2 | Evaluate sodium-ion, Li-air, Li-S and other battery chemistries, supercapacitors, battery pack designs and lithium resources and recycling for EV applications.                                              |
| CO3 | Analyse AC-DC (boost-derived, bridgeless, three-phase) and isolated DC-DC (phase-shift full bridge, dual active bridge) converters for EV chargers, including modelling, losses, soft switching and control. |
| CO4 | Apply EVSE classifications, charging standards, charging procedures and communication protocols (AC Type 2, DC CCS2) to EV charging infrastructure.                                                          |

**CO–PO/PSO mapping** (3 = high, 2 = medium, 1 = low, blank = none)

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 1   |     | 1   |     | 1   |     |     |      |      |
| CO2 | 2   | 3   | 2   | 2   | 1   | 1   | 3   | 1   |     |      | 1    |
| CO3 | 3   | 3   | 3   | 2   | 2   |     |     |     |     |      |      |
| CO4 | 2   | 2   | 2   | 1   | 2   | 2   | 1   | 1   |     |      | 1    |

### Detailed syllabus

| Module                                                                    | Topics                                                                                                                                                           | Lecture hours |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 1: Electrochemical Energy Storage Fundamentals (battery weeks 1–2) | Introduction to electrochemical energy storage and conversion; definitions of cell performance parameters; measuring methods.                                    | 5             |
| Module 2: Lithium-Ion Battery Technology (battery weeks 3–5)              | Lithium batteries; basic components of lithium-ion batteries — electrodes, electrolytes and current collectors; characteristics of commercial lithium-ion cells. | 7             |
| Module 3: Sodium-Ion Cells and Battery Pack Design (battery weeks 6–7)    | Sodium-ion rechargeable cells; introduction to battery pack design.                                                                                              | 5             |

| Module                                                                     | Topics                                                                                                                     | Lecture hours |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 4: Introduction to EV Charging Systems (NPTEL Module 1)             | EVSE for on-board chargers; EVSE for off-board chargers; charging infrastructure challenges; classification and standards. | 4             |
| Module 5: Charging Procedure, Protocols and Communication (NPTEL Module 4) | Charging procedure and communication; AC Type 2 charging system; DC CCS2 charging system.                                  | 4             |
| <b>Total</b>                                                               |                                                                                                                            | <b>25</b>     |

**Laboratory / practical component:** Not applicable (theory course, 3-0-0).

#### Text books

1. Thomas B. Reddy (Ed.), *Linden's Handbook of Batteries*, McGraw-Hill, 4th Edition, 2011.
2. Robert W. Erickson, Dragan Maksimović, *Fundamentals of Power Electronics*, Springer, 3rd Edition, 2020.
3. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 3rd Edition, 2021.

#### Reference books

1. Gianfranco Pistoia (Ed.), *Lithium-Ion Batteries: Advances and Applications*, Elsevier, 2014.
2. Ned Mohan, Tore M. Undeland, William P. Robbins, *Power Electronics: Converters, Applications, and Design*, Wiley, 3rd Edition, 2003.
3. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press, 3rd Edition, 2018.

#### Online resources (NPTEL / SWAYAM / MOOCs)

| PLATFORM | NAME OF THE COURSE                                                                                                                     | Hours |
|----------|----------------------------------------------------------------------------------------------------------------------------------------|-------|
| COURSERA | [Battery technology source course name and link — to be added]<br>(Modules 1–3)<br><br><a href="#">Battery Technologies   Coursera</a> | 17    |
| NPTEL    | <a href="#">NPTEL — Charging Infrastructure, Prof. Apurv Kumar Yadav, IIT Roorkee</a> (Modules 4–5)                                    | 8     |

#### Semester 7 — MINOR701AE: Autonomous Vehicles and Project Phase I

MINOR701AE has two parts: a theory component of 23 teaching hours across four modules — Modules 1–4 follow the University of Toronto *Self-Driving Cars* specialization (Coursera) — and Project Phase I, which continues as Project Phase II in Semester 8.

| Field                     | Details                                                              |
|---------------------------|----------------------------------------------------------------------|
| Course code               | MINOR701AE                                                           |
| Course title              | Autonomous Vehicles and Project Phase I                              |
| Course category           | Minor Specialization                                                 |
| L-T-P                     | 3-0-0 (theory) + Project Phase I                                     |
| Credits                   | 3 (theory) + [project credits]                                       |
| Contact hours/week        | 3 (theory)                                                           |
| Total teaching hours      | 23                                                                   |
| Prerequisites             | MINOR601AE; basic Control Systems and Probability                    |
| Marks (CIE / ESE / Total) | Theory: 30 / 70 / 100; Project: see Project Phase I assessment below |

### Course objectives

1. **Explain** the requirements for autonomy, the hardware and software architecture of self-driving cars and their safety assurance.
2. **Apply** vehicle dynamic models, longitudinal and lateral controllers, state estimation and visual perception methods to autonomous-vehicle subsystems.
3. **Analyse** the impact of EV charging loads on the electricity grid.
4. **Evaluate** smart charging, time-of-use pricing, demand response and vehicle-to-grid (V2G) strategies.
5. **Develop** mission, behaviour and local motion planners for self-driving cars.
6. **Formulate** an e-mobility project problem, its objectives and methodology through Project Phase I.

**Course outcomes** — on completion, students will be able to:

| CO  | Statement                                                                                                                                                                               |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Explain the requirements for autonomy, self-driving hardware and software architectures, and safety assurance frameworks for autonomous vehicles.                                       |
| CO2 | Apply vehicle dynamic modelling, longitudinal and lateral control, least-squares and Kalman-filter state estimation, and visual perception techniques to autonomous-vehicle subsystems. |
| CO3 | Develop mission, behaviour and local motion planners, including occupancy grids and dynamic object interaction, for self-driving cars.                                                  |
| CO4 | Evaluate EV grid integration — charging impacts, smart charging, time-of-use pricing, demand response, load shifting and V2G — for grid support.                                        |

**CO–PO/PSO mapping** (3 = high, 2 = medium, 1 = low, blank = none)

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO1 | 2   | 1   | 1   |     | 1   | 2   | 1   | 1   |     |      |      |

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO2 | 3   | 3   | 2   | 2   | 3   |     |     |     |     |      |      |
| CO3 | 3   | 3   | 3   | 2   | 3   | 1   |     |     | 1   |      |      |
| CO4 | 3   | 3   | 2   | 2   | 2   | 2   | 3   | 1   |     |      | 1    |

### Detailed syllabus

| Module                                                      | Topics                                                                                                                                                                                                                                                      | Lecture hours |
|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 1: Introduction to Self-Driving Cars (UofT Course 1) | Terminology and levels of driving automation; requirements for autonomy; self-driving hardware — sensors and computing; software architecture; safety assurance for autonomous vehicles.                                                                    | 5             |
| Module 2: Vehicle Dynamics and Control (UofT Course 1)      | Kinematic and dynamic vehicle modelling; longitudinal speed control; lateral path-tracking control.                                                                                                                                                         | 6             |
| Module 3: State Estimation and Localization (UofT Course 2) | Least-squares estimation; Kalman filter, extended and unscented Kalman filters; IMU and GNSS sensing; LIDAR sensing; multi-sensor fusion for vehicle localization.                                                                                          | 6             |
| Module 4: Visual Perception (UofT Course 3)                 | Basics of 3D computer vision — camera models and calibration; visual feature detection, description and matching; visual odometry; neural networks for 2D object detection and semantic segmentation; perception of dynamic objects in the drivable region. | 6             |
| <b>Total</b>                                                |                                                                                                                                                                                                                                                             | <b>23</b>     |

**Project Phase I** — students, individually or in small groups under a faculty guide, identify an e-mobility problem (for example in EV powertrains, batteries, charging, grid integration, autonomous or connected vehicles), survey the literature, define objectives, and develop the methodology with a preliminary design or simulation. Deliverables: a synopsis, a Phase I report and a presentation. The work continues as Project Phase II in Semester 8.

### Text books

1. Rajesh Rajamani, *Vehicle Dynamics and Control*, Springer, 2nd Edition, 2012.
2. Sebastian Thrun, Wolfram Burgard, Dieter Fox, *Probabilistic Robotics*, MIT Press, 2005.
3. Sumedha Rajakaruna, Farhad Shahnia, Arindam Ghosh (Eds.), *Plug In Electric Vehicles in Smart Grids: Integration Techniques*, Springer, 2015.

### Reference books

1. Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2nd Edition, 2022.
2. Steven M. LaValle, *Planning Algorithms*, Cambridge University Press, 2006.

- Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 3rd Edition, 2021.

**Online resources** (NPTEL / SWAYAM / MOOCs)

| PLATFORM | NAME OF THE COURSE                                                                                                                                  | Hours |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| COURSERA | <a href="#">Coursera — Self-Driving Cars Specialization, University of Toronto</a><br>(Modules 1–4)<br><a href="#">Self-Driving Cars   Coursera</a> | 23    |

**Semester 8 — MINOR801AE: Connected Vehicles, E-Mobility Policy and Project**

MINOR801AE has two parts: a theory component of 24 teaching hours across four modules (connected vehicles and V2X; telematics, OTA and fleet platforms; Indian EV policy and incentives; standards for EVs, batteries and charging), and Project Phase II or an Industry Internship.

| Field                     | Details                                                      |
|---------------------------|--------------------------------------------------------------|
| Course code               | MINOR801AE                                                   |
| Course title              | Connected Vehicles, E-Mobility Policy and Project            |
| Course category           | Minor Specialization                                         |
| L-T-P                     | 3-0-0 (theory) + Project Phase II / Industry Internship      |
| Credits                   | 3 (theory) + [project credits]                               |
| Contact hours/week        | 3 (theory)                                                   |
| Total teaching hours      | 24                                                           |
| Prerequisites             | MINOR701AE; Project Phase I                                  |
| Marks (CIE / ESE / Total) | Theory: 30 / 70 / 100; Project: see project assessment below |

**Course objectives**

- Explain** connected-vehicle architectures and V2X communication technologies — DSRC and C-V2X.
- Apply** telematics, over-the-air (OTA) updates, IoT and cloud platforms to EV fleet management.
- Analyse** Indian EV policies, incentive schemes and AIS/BIS/IEC standards for EV and charging compliance.
- Evaluate** battery recycling, second-life use, life-cycle impact and business models for e-mobility.
- Design** an e-mobility solution through Project Phase II or an industry internship.

**Course outcomes** — on completion, students will be able to:

| CO  | Statement                                                                                                                                    |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Explain connected-vehicle architectures and V2X communication technologies (DSRC/IEEE 802.11p and C-V2X/PC5 and Uu) with their applications. |

| CO  | Statement                                                                                                                                 |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------|
| CO2 | Apply telematics, OTA software updates, IoT and cloud platforms to monitor and manage EV fleets.                                          |
| CO3 | Analyse Indian EV policy (FAME, PM E-DRIVE, state policies) and AIS/BIS/IEC standards for EV, battery and charging compliance.            |
| CO4 | Evaluate battery recycling and second-life options, life-cycle assessment, e-mobility business models and the chosen elective technology. |

**CO–PO/PSO mapping** (3 = high, 2 = medium, 1 = low, blank = none)

| CO  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| CO1 | 3   | 2   | 1   |     | 2   |     |     |     |     |      |      |
| CO2 | 3   | 2   | 3   | 1   | 3   |     |     |     | 1   | 1    | 1    |
| CO3 | 2   | 2   | 1   | 1   | 1   | 3   | 2   | 3   |     | 1    | 2    |
| CO4 | 2   | 3   | 2   | 2   | 2   | 2   | 3   | 1   |     |      | 3    |

### Detailed syllabus

| Module                                              | Topics                                                                                                                                                                                                                               | Lecture hours |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Module 1: Connected Vehicles and V2X                | Connected-vehicle architecture; V2V, V2I, V2P and V2N communication; DSRC (IEEE 802.11p, WAVE/IEEE 1609); C-V2X — LTE-V2X (PC5 and Uu interfaces) and 5G NR-V2X; V2X safety and traffic-efficiency applications.                     | 7             |
| Module 2: Telematics, OTA and Fleet Platforms       | Vehicle telematics units and data; over-the-air (OTA) software and firmware updates and their cybersecurity requirements; IoT architecture for EVs; cloud platforms for fleet monitoring, charging management and battery analytics. | 6             |
| Module 3: Indian EV Policy and Incentives           | FAME-I and FAME-II schemes; PM E-DRIVE scheme; PLI schemes for automobiles and advanced chemistry cell batteries; state EV policies; charging infrastructure guidelines.                                                             | 6             |
| Module 4: Standards for EVs, Batteries and Charging | Role of ARAI, BIS and IEC; AIS standards for EV safety and traction batteries; BIS/IEC charging standards (IS 17017, IEC 61851, IEC 62196); communication standards (ISO 15118); homologation and type approval.                     | 5             |
| <b>Total</b>                                        |                                                                                                                                                                                                                                      | <b>24</b>     |

**Project Phase II / Industry Internship** — students continue their Project Phase I work to design, build or simulate and validate an e-mobility solution, or complete an industry internship with an EV, battery, charging or automotive-electronics organisation. Deliverables: a mid-term review, a final report, a demonstration or presentation, and a viva-voce.

#### **Text books**

1. Radovan Miucic (Ed.), *Connected Vehicles: Intelligent Transportation Systems*, Springer, 2019.
2. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 3rd Edition, 2021.
3. James Larminie, Andrew Dicks, *Fuel Cell Systems Explained*, Wiley, 2nd Edition, 2003.

#### **Reference books**

1. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press, 3rd Edition, 2018.
2. Gianfranco Pistoia (Ed.), *Lithium-Ion Batteries: Advances and Applications*, Elsevier, 2014.
3. Official documents: Ministry of Heavy Industries PM E-DRIVE scheme guidelines; ARAI Automotive Industry Standards (AIS); BIS IS 17017; Battery Waste Management Rules, 2022.

#### **Online resources** (NPTEL / SWAYAM / MOOCs)

| PLATFORM | NAME OF THE COURSE                            | Hours |
|----------|-----------------------------------------------|-------|
| COURSERA | <a href="#">Supplementary video lecture 1</a> | 13    |

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