INTERNATIONAL EFFICIENCY CHALLENGE

ELECTRIC VEHICLE

TECHNICAL DESIGN REPORT GUIDE

TEAM ID:		
TEAM NAME:		
TEAM CAPTAIN:		
TEAM CAPTAIN'S UNIVERSITY:		
VEHICLE NAME:		
CATEGORY:	☐ **ELECTROMOBILE**	☐ **HYDROMOBILE**

1. Report Format Requirements

The report is prepared in A4 format, 12 points, Arial, line spacing is 1.15 and top-bottom and side margins are 2.5 cm, with a maximum of 150 pages. The use of the cover page, table of contents and bibliography is not obligatory in the report. The Jury edits, evaluates and scores the report (if necessary) in accordance with the above-mentioned format requirements. After the format conditions are met (A4 format, 12 pt, Arial, line spacing is 1.15 and bottom-top and side edges are 2.5 cm), reports that do not comply with the upper-page limit are deducted from 10 points per page and a maximum of 350 points in total.

Page Exceeding Penalties	*Points to be Deducted*
1 page	*10 points*
Max page out penalty	*350 points*

2. Vehicle Specifications Table

*In the event that the tables submitted in the application and the technical design report are identical and applied to the vehicle, the team gets **100 points**.*

Feature	Unit	Value
Length	mm	
Width	mm	
Height	mm	
Chassis	material	
Shell	material	
The brake system	hydraulic disc, front, rear, hand brake	
Motor	type	
Motor driver	self-designed, ready-made product	
Motor power	kW	
Motor efficiency	%	
Engine weight	kg	
Battery cell chemistry	type	
Battery pack nominal voltage	V	
Battery pack capacity	Ah	

Battery pack Maximum voltage	V	
Battery pack energy	Wh	
Fuel cell power	kW	
Number of hydrogen cylinders	#	
Hydrogen cylinder pressure	bar	
Super capacitor	yes/no	
You must fill in the fields related to your category.		

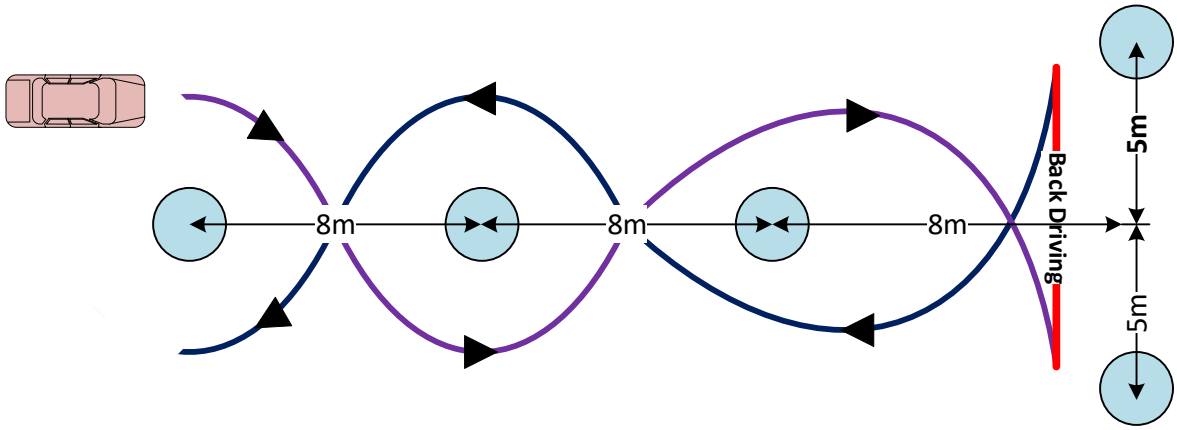
3. Vehicle Dynamic Testing

It is mandatory for the teams to upload a video to show that their vehicle is ready to be driven according to the manoeuvre described in the Chapter 5.1 of Efficiency Challenge Electric Vehicle Rules.

*If it is determined that the vehicle does not move and/or cannot perform the desired maneuvers in the uploaded video, a **30 Wh** penalty will be applied to the teams.*

Video shall show that the vehicle can make the manoeuvres specified in the video in the attached link[1] within 120 seconds on a small track of 50 meters, which is given in below Figure.
The vehicle should move by means of electric motor(s) using energy it acquires from its on board energy sources. The vehicle must not be moved by pushing. Furthermore, video shall show (with provided additional view of display unit) that Battery Management System works properly and shows the required information specified in Chapter 5.3.1. of Efficiency Challenge Electric Vehicle Rules during the manoeuvres.

Teams can upload their video to one of the open access share points. One of the team members has to show the date at the beginning of the video via pointing the latest "Bilim ve Teknik" journal.



[1] https://www.youtube.com/watch?v=rfv51rzslVg

4. Braking Test Video

It is mandatory for the teams to upload a video to show that their vehicles are ready to drive, teams show that they have come to a complete stop by braking while having a minimum cruising speed of 10 km/h. To show the braking performance, the video should be taken from inside and outside the vehicle during braking. In the video, the point to start braking and the point where the vehicle stops must be indicated by pointers such as traffic cones, delineators, etc.

If it is determined that the vehicle does not move and/or cannot perform the desired movement in the uploaded video, a penalty of 30 Wh will be applied to the teams.

The vehicle should move by means of the electric motor(s) using the energy it acquires from its onboard energy sources. Braking performance will not be performed by pushing the vehicle.

Teams can upload their video to one of the open-access share points.

5. Pre-Technical Control Videos

5.1 Motor Video

A short introduction of the designed engine, in which parameters such as power, voltage, speed, etc. are specified. Briefly explaining what the engine type is and why it was chosen. Briefly explaining how the design and production stages are carried out. Short videos of design and production process steps (eg. conceptual design process, analysis processes, production processes, testing processes, etc.).

5.2 Motor Driver Video

The pre-technical control video must comply with the requirements specified in section 5.3.3 of the rules book. It is mandatory for all teams, regardless of domestic or ready-made product.

The video should provide information on the following topics.

- *The motor driver is placed in the vehicle with a suitable box and is available for disassembly and inspection when requested*
- *Input/output connectors of motor driver and cabling between other sub-components (motor, battery, etc.)*
- *Showing motor driver can move the motor in both directions*
- *Showing motor driver can rotate the motor at different speeds and keep it constant at a desired speed*

5.3 Battery Management System Video

The pre-technical control video must meet the requirements specified in Section 5.3.3 of the Rulebook. The pre-technical control video on battery management systems (BMS) is mandatory for all teams, regardless of whether the product is domestic or ready made.

- *The video should include information on the following items:*
- *The electrical connections between the battery and the BMS and the connectors used for this purpose should be shown. The physical structure of the BMS and its specifications should be presented.*
- *The current sensors should be shown, their specifications, and the method of connection should be presented.*
- *The temperature measurement method and sensors should be presented.*
- *The balancing methodology should be explained, including the details of the components used for this purpose.*
- *ICEs and microcontrollers used in BMS, and their specifications and responsibilities in the system should be presented.*

5.4 Energy Management System Video

Teams shall present the device physically and describe how the power is flowing. While the power converters (DC/DC) are operating, output voltage and current should be measured with an instrument and shown in the video.

5.5 Embedded Recharging Unit Video

The device shall be presented physically and the circuit topology, power level, voltage-current ratings and control method should be explained. Device should be supplied from the grid and as a load, preferably vehicle battery, if not possible a resistor bank at least 500W should be used. While the device is operating, output voltage and current readings should be presented.

5.6 Battery Packaging Video

The pre-technical control video must comply with the requirements specified in the battery packaging section of the rules book. It is mandatory for all teams, regardless of domestic or ready-made product.

The following should be included in the video:

- *Selection criteria and packaging of cells*
- *How serial and parallel connections are determined*
- *Pack assembly before and after the insertion of the cells*

- *Spot welding process*
- *How the thermal analysis of the battery pack is realized*
- *Battery pack cooling system details*

5.7 Electronic Differential Application Video

Teams shall present a simple demo of a domestically designed electronic differential application within the video. During the demonstration, the maneuver detailed in the Vehicle Dynamic Testing Part shall be applied and reference signals to traction motors will be displayed via a digital interface integrated on vehicle console. The display should be clear and easily perceptible.

5.8 Vehicle Control Unit Video

Video submission is mandatory for teams that will develop VCU domestic, but not for teams using ready-made or not carrying domestic product functions. Vehicle control unit video must comply with the following requirements.

a) *Physical representation of the VCU circuit design*
b) *Main functions that VCU performs*
c) *Information transferred to the user and the monitoring center*
d) *Instant display of the data transferred to the monitoring center on the vehicle screen*

5.9 Insulation Monitoring Device Video

Teams shall present a simple demo of a domestically designed isolation monitoring application within the video. During the demonstration, insulation monitoring device which is connected to the vehicle is tested by connecting various resistance values to the positive and negative terminal of the car battery to the car chassis. The insulation resistance should be measured accordingly and should be shown in the screen. . It should also be observed that when the resistance value falls below the critical level, the system gives a warning.

5.10 Steering System Video

It is mandatory for the teams to upload a video to *show that their vehicles are ready to drive. Teams must turn their steering wheel a full turn to the right, then a full turn to the left, then a full turn to the right, and finally a full turn to the left to show that their vehicle is ready to drive(Fig.1). Video recording should be taken from inside and outside the vehicle during these maneuvers. The video should not be interrupted during the maneuvers, videos that are paused or the recording is closed and restarted will be considered invalid.*

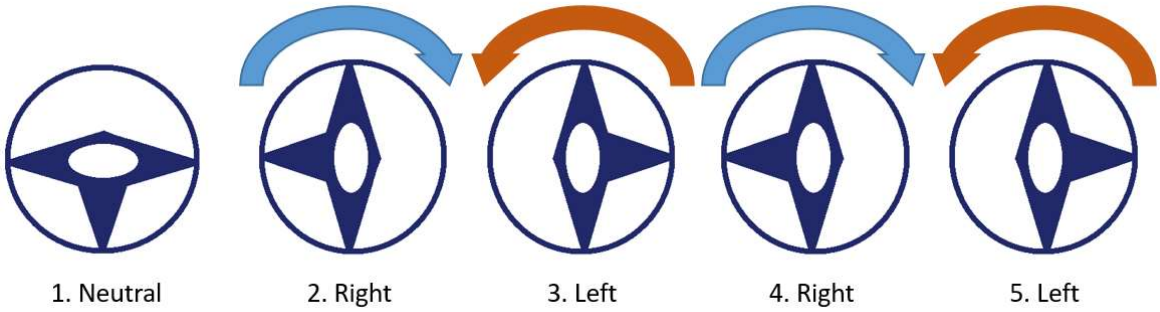


Figure.1: Steering Wheel test manoeuvre

If it is determined that the vehicle does not move and/or cannot perform the desired movement in the uploaded video, a penalty of 30 Wh will be applied to the teams. Teams can upload their video to one of the open-access share points.

5.11 Door Mechanism Video

The team is requested to prepare a video proving that the door can be opened and closed with the door handle from both inside and outside of the vehicle.

5.12 Brake System Video

It is mandatory for the teams to upload a video to show that their vehicle's braking system is ready to drive. The braking system equipment must be installed on the vehicle through the video recording. The brake system master cylinder, dual circuit line, brake pedal, brake disc, and calipers should be included in the video.

5.13 Hydrogen System (Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders) Video (For Hydromobile Only)

Starting from the metal hydride cylinders, along the hydrogen line including the fuel cell, all parts (temperature and gas sensor, temperature gauge, flasher, fuel cell) should be

taken into account by the team and the rules given in the 15th title of the International EC Racing Rules Guide (15. Hydrogen System - Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders) and the 20th title of the Technical Design Report (Hydrogen System - Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders) should be considered for Pre-Technical Control Videos. Satisfactory explanations are also expected about the displayed equipment simultaneously during the video shooting.

Also in the video, according to the current state of the vehicle; indication that the fuel cell is working, the temperature of the metal hydride cylinders measured by the thermocouple can be read on the temperature indicator located in the pilot cabin, if possible, when the temperature read by the sensor exceeds the value stated in the rules book (for example, T>55 °C), the solenoid valve cuts the gas flow (for this, the safety rules should be followed, lighters and fire tools should definitely not be used, temperature test can be done by carefully and appropriately touching the tip of the sensor to hot water placed in a glass at an appropriate distance from the metal hydride cylinders) and it is expected that the flasher will work. The hydrogen gas sensor and its location inside the vehicle are expected to be shown in the video, but for safety reasons, the gas sensor test (2% hydrogen by volume) is not expected to be shown in the technical design video. These tests will be carried out during the pre-race technical controls.

5.14 Telemetry Video

The video content should contain a demo which the screenshots of the monitoring center application are briefly explained, along with the visuals of the equipment (electronic cards/screens, etc.) included in the telemetry system. It should be sent together with the exported file of the recorded data in the desired format (.csv).

6. Domestic Sub-Components

In this section, the teams are asked to mark the domestic sub-components they designed. If there has been a change in the domestically status of the parts according to the Progress Report, it is requested to indicate this for the relevant title.

Teams that cannot make the parts specified in II.1.a can participate in the race for 15 Wh penalty points for each missing piece. However, in order for a team to complete the

technical controls and participate in the race, it must make at least two of the mandatory sub-parts locally. It is recommended that the teams targeting the Domestic Product Award and the Technical Design Award should also make the following sub-parts locally. 2 Wh award points will be given for each local sub-part. (Rules, II. TECHNICAL RULES, 1. Being Domestic)

1. Motor	**Mandatory for Electromobile/Hydromobile**	☐
2. Motor driver	**Mandatory for Electromobile/Hydromobile**	☐
3. Battery management system (BMS)	**Mandatory for Electromobile/Hydromobile**	☐
4. Embedded recharging unit	**Mandatory for Electromobile**	☐
5. Energy management system (EMS)*	**Mandatory for Hydromobile**	☐
6. Battery packaging	**Optional**	☐
7. Electronic differential application	**Optional**	☐
8. Vehicle control unit (VCU)	**Optional**	☐
9. Fuel cell*	**Optional**	☐
10. Fuel cell control system (circuit)*	**Optional**	☐
11. Insulation monitoring device	**Optional**	☐
12. Steering system	**Optional**	☐
13. Door mechanism	**Optional**	☐
14. Braking System	**Optional**	☐

** Hydromobile category only*

7. Motor

*All the teams are required to prepare their motors themselves. The teams that make this product domestically will get a maximum of **400 points** depending on the design. The teams that perform domestic motor design and production are responsible for the following items during the technical inspections:*

1) *Awareness regarding electrical and mechanical features.*
2) *Submitting information on magnetic and thermal analysis.*
3) *Submitting visual information such as photos and videos about production stages.*
4) *Submitting information related to test methods and results (You might be requested to simulate raw documents)*

If designed by the team, detailed information should be given on the following topics. ***Additionally, the raw documents (original files) to show the simulation/design***

process and calculation results must be sent with the report in a compressed file (i.e. .zip, .rar). Otherwise it will not be considered as domestic even if a domestic product motor is presented at technical inspections. All the designs and simulations must be the teams' own work, i.e., magnetic and/or thermal analyses provided by the manufacturer of any part of the system will not be accepted. The

teams might be asked to run their source files related to the magnetic and thermal analyses and to show the sketches of their design.

a) Design Calculations

- *Detailed design information*
- *Design steps with its equations*
- *Motor Design limitations (if any)*
- *If use a commercial design software, reports will be shared with your comments*
- *Motor selection details such as motor type, power, speed etc. (for ready-made motors)*

b) Magnetic Analysis Studies

- *Magnetic calculation steps and its equations*
- *If use a commercial design software (Maxwell, Femm, etc.), results will be shared with your comments*
- *FEA (Finite Element Analysis) results*

c) Mechanical Analysis Studies

- *Detailed mechanical design information*
- *Mechanical calculations with its equations*
- *Mechanical Design limitations (if any)*
- *FEA results (if any)*

d) Thermal Analysis Studies

- *Cooling methodology*
- *Thermal calculation steps with its equations*
- *Thermal Design limitations (ambient temperature, insulation class etc.)*
- *CFD or FEA results (if any)*

e) Production Studies

- *Production steps*
- *Technical drawing*

f) Motor Test Results and Efficiency

- *Motor test reports (depends on EN60034-1)*

g) Comparison Table

		Previous Design	Current Design
Motor Type	**:**		

Motor Phase Voltage	**:**		
Motor Power	**:**		
Motor Speed	**:**		
Motor Dimensions	**:**		
Motor Weight	**:**		
Motor Efficiency	**:**		
Motor Main Dimension	**:**		
Stator Dimension	**:**		
Rotor Dimension	**:**		
Winding Scheme	**:**		
Motor Optimization	**:**		
Magnetic Design and Analysis Model	**:**		
Thermal Design and Analysis Model	**:**		
Mechanical Design and Analysis Model	**:**		
Motor Test Methods and Results	**:**		

8. Motor Driver

*It is suggested to produce motor driver themselves for all the teams. Teams that have produced this product domestically will get a maximum of **300 points** depending on the design.*

If the motor driver is a ready-made product, information should be given about the working principle of the driver used. Input/output connectors of the driver and its connections with other sub-components (Motor, battery, VCU etc.) should be shown. Information should be given about the protection functions in the motor driver. Ready-made product specifications table should be filled.

The teams that perform domestic motor driver design and production are responsible for the following items during the technical inspections:

1) *Physically illustrating the motor driver.*
2) *Providing information regarding simulation studies and control algorithms.*
3) *Providing circuit schematic and PCB drawings.*
4) *Submitting information related to test methods and results (You might be requested to simulate raw documents)*

If designed by the team, detailed information should be given on the following topics. ***Additionally, the raw documents (original files) of the simulation and design process and results must be sent with the report in a compressed file (i.e. .zip, .rar). Otherwise it will not be considered as domestic even if a domestic motor driver is presented at technical inspections. All the designs and simulations must be the teams' own work, i.e., simulation results, PCB schematics or embedded code provided by the manufacturer of any part of the system will not be accepted. The teams might be asked to run their source files related to the simulation results, PCB schematics or embedded code and to show the sketches of their design.***

a) *Circuit Design*
- *Step-by-step design of motor drive circuit*
- *Analytical expression of designed circuit (inverter, control board etc)*
- *Component selection (IC, transistors, resistors, inductors, capacitors, etc.)*
- *Parameter adjustment (component values)*
- *Information about converter module and control unit*
- *Power consumption calculation*

b) *Control Algorithm*
- *Concept and type of drive control (analog/digital control, FOC, DTC, V/f control, etc.)*
- *Control block scheme*
- *Information about feedback sensors (open loop/closed loop)*

c) *Simulation Studies*
- *Software programme (Matlab Simulink, Altium Designer, Proteus, etc.)*
- *Simulation parameters (Sampling time, resolution time, etc.)*
- *Schematic drawing*
- *Simulation steps*
- *Simulation results of power electronic converter and analysis of switching losses in modelling circuit*
- *Simulation results of motor drive method and their interpretation*

d) *PCB Studies*
- *PCB design software tool*
- *Designing a PCB layout and its schematics*
- *Gerber file for fabrication data*
- *Picture of printed circuit board*

e) *Production Studies*
- *Production steps*
- *Electrical pre-test results of circuit board before soldering*

- *Adding a picture regarding soldering process*
- *Adding a table regarding economic cost*
- *Electrical test*
- *Showing the motor driver box and giving information about its dimensions*

f) Motor Driver Efficiency

- *Power losses calculation*
- *Efficiency value in percent*

g) Motor Driver Protection

- *Providing information regarding short circuit protection*
- *Providing information regarding over-temperature protection*
- *Providing information regarding over-current protection*

h) Bill of Materials

- *Adding bill of each material*

i) Comparison Table

		Previous Design	Current Design
Switch	**:**		
Driver IC	**:**		
Controller IC	**:**		
Control Algorithm	**:**		
Protection Circuit	**:**		
Electric Circuit Design	**:**		
Printed Circuit Board Design	**:**		
Printed Circuit Board Production	**:**		
Simulation Studies	**:**		
Dimension (PCB / boxed hardware)	**:**		
Power / Current / Voltage	**:**		
Efficiency	**:**		

j) Ready-made Product Specifications Table

Characteristic		Description/Values
Manufacturer Part No	**:**	
Rated current (A)	**:**	
Rated voltage (V)	**:**	
Frequency of operation (kHz)	**:**	
Current limit (A)	**:**	
Driving/Control method	**:**	

Weight (kg)	**:**		
Dimension (Length x Width x Height)	**:**		
Efficiency (%)	**:**		
Operating temperature range	**:**		
Programmable	**:**	**Yes** ☐	**No** ☐
Regenerative braking mode	**:**	**Yes** ☐	**No** ☐
Over-voltage protection	**:**	**Yes** ☐	**No** ☐
Under-voltage protection	**:**	**Yes** ☐	**No** ☐
Over-current protection	**:**	**Yes** ☐	**No** ☐
Over-heat protection	**:**	**Yes** ☐	**No** ☐
HALL protection	**:**	**Yes** ☐	**No** ☐
Phase winding disconnect protection	**:**	**Yes** ☐	**No** ☐

9. Battery Management System (BMS)

*All the teams are required to design and implement their BMS themselves. The teams that produce this product domestically will get a maximum of **200 points** depending on the design.*

All the teams are responsible for the following items during the technical inspections:

1) *Physically illustrating the BMS.*
2) *Submitting overall information related to BMS design and working principles.*
   - *V, I, and T measurements*
   - *V, I, and T protections*
   - *Thermal Controller*
   - *Cell Balancing and its algorithm*
   - *Communication system and communication protocol*
   - *SOC Estimation Algorithm*

All the teams should provide detailed information about BMS including diagrams, schematics, pictures, datasheets, and connection details to BMS:

a) *Voltage, Current, and Temperature Measurement Methods and Details*
b) *Balancing Method*
c) *SOC Estimation Algorithm*
d) *Control Algorithm*
e) *Circuit Design*
f) *Simulation Studies*
g) *Printed Circuit Studies*

h) *Production Studies*

i) *Comparison Table*

		Previous Design	Current Design
Battery Packing Design	**:**		
Output Voltage	**:**		
Output Current	**:**		
Balancing Method (active or passive)	**:**		
Circuit Design Type	**:**		
SOC Estimation Algorithm	**:**		
Control Algorithm	**:**		
Domestic or Not	**:**		

10. Embedded Recharging Unit

*All the Electromobile teams are required to prepare their embedded recharging unit themselves. Teams that make this product domestically will get a maximum of **200 points** depending on the design. Teams using ready-made products will be able to get a report score up to 50 points if the product is in working condition to charge the batteries and is on the vehicle during the race.*

During technical inspections, testing of the embedded recharging unit will be done by measuring the current and voltage values at output terminals.

If designed by the team, detailed information should be given on the following topics:

a) *Circuit Design*
b) *Simulation Studies*
c) *Printed Circuit Studies*
d) *Production Studies*
e) *Test Results*
(While the converter is operating, output voltage-current waveforms and switching waveforms of power transistor (Vds, Vgs)can be included. While measuring the signals, isolated voltage probes can be used or the oscilloscope can be supplied over an isolation transformer for safety)
f) *Comparison Table*

		Previous Design	Current Design
Circuit Topology	**:**		
Power	**:**		
Output Voltage Range	**:**		
Output Current Ripple	**:**		
Input Power Factor	**:**		

Power Conversion Efficiency	**:**		
PWM Controller IC	**:**		
Protection Circuits / Components	**:**		
PCB Size	**:**		

11. Energy Management System (EMS) (Hydromobile category only)

*All the Hydromobile teams are required to prepare their EMS themselves. Teams that produce this product domestically will get a maximum of **300 points** depending on the design.*

A software and hardware that optimises power flow between the energy sources and the load can be regarded as an EMS.

Teams that develop a domestic EMS will be responsible for the following items during technical inspections:

1) *Demonstrating the EMS product physically,*
2) *Providing general information about the EMS design and operating principles,*
3) *Measuring and showing the current and voltage values at which the DC-DC converters operate.*

If designed by the team, detailed information should be given on the following topics.

a) *Control Algorithm*
   (Energy flow diagram between fuel cell, battery and vehicle should be provided)
b) *Circuit Design*
c) *Simulation Studies*
d) *Production Studies*
e) *Test Results*
   (Input-output current and voltage waveforms and power transistor voltage waveforms (Vds, Vgs) should be included)
f) *Comparison Table*

		Previous Design	**Current Design**
Circuit Topology	**:**		
Power	**:**		
Input Voltage Range	**:**		
Output Voltage Range	**:**		
Power Conversion Efficiency	**:**		

PWM Controller IC	**:**		
Semiconductor Power Switches	**:**		
Protection Circuits / Components	**:**		
PCB Size	**:**		

12. Battery Packaging

In this section, describe your design that you are planning to implement. Please use system diagrams, tables, algorithms, schematics, pictures and videos to describe your design. If available, hyperlinks to the multimedia files related to the product can also be provided here.

Detailed information should be given on the following topics.

a) *Characteristics of the Cells:*
   - *Electrical characteristics of the cells (maximum charge-discharge currents, maximum and minimum voltage limits, etc.)*
   - *Thermal characteristics of the cells (optimum operating temperature, thermal runaway point, etc.)*
   - *Mechanical properties of the cells (Cell geometry, cell alignment in modules/pack, etc.)*

b) *Characteristics of the Package:*
   - *Output voltages, energy, charge/discharge powers, weight, size etc.*

c) *Properties of the Case Materials:*
   - *Electrical properties of the case materials (dielectric constant, etc.):*
   - *Thermal properties of the case materials (melting point, thermal conductivity, etc.):*
   - *Mechanical properties of the case materials (Tensile strength, impact resistance, etc.):*

d) *Thermal Analysis of the Battery Modules / Pack*

e) *Housing and Insulation of Modules / Pack:*
   Housing and insulation designs inside a module should be explained, if the battery pack is composed of battery modules. Otherwise the housing and insulation of cells inside battery pack should be explained. The material selection, design and production of bus bars between modules should also be explained.

f) *Battery Cooling System Design*

g) *Precharge Circuit Design (if exists)*

13. Electronic Differential Application

*Teams that produce this product domestically will get a maximum of **150 points** depending on the design.*

a) *System Topology*
b) *Control Algorithm*
c) *Simulation Studies*
d) *Test Results*
e) *Comparison Table*

		Previous Design	Current Design
System Topology (Used Sensors, Control Units, Actuators etc.)	**:**		
Vehicle Model (Kinematic Model, Simple Dynamic Model, Full Vehicle Model etc.)	**:**		
Control Algorithm	**:**		
Considered Exceptional Cases and Proposed Design Solutions (Low Adhesion, Split Friction (Mu), Weight Transfer, Acceleration /Deceleration on Curves etc.)	**:**		
Applied Simulation Scenarios	**:**		
Performance Results for Simulation Scenarios	**:**		
Applied Test Scenarios	**:**		
Performance Results for Test Scenarios	**:**		

14. Telemetry System

*Teams that perform this unit domestically will receive a maximum of **150 points** depending on the design.*

In the Telemetry system section, define your applied design. Please use system diagrams, tables, algorithms, diagrams, images and videos to describe your design. Teams will be scored based on the items listed below.

- *Briefly explain the technical features of the telemetry module hardware that indicate that they meet the requirements.*
- *Explain data flow and system diagrams sent/received from data sources to telemetry monitoring software.*
- *Explain the data format to be transferred and recorded in the telemetry system. Indicate the data format and units clearly.*
- *Briefly describe the telemetry monitoring center application architecture and technologies used.*

Hyperlinks to module-related multimedia files may also be provided here, if any available.

15. Vehicle Control Unit (VCU)

*Teams that produce this component domestically will get a maximum of **150 points** depending on the design.*

Teams can get points according to functions in VCU. As described in the rules, each function given below are the main functions that teams can develop for their own VCU. Achieving 3 (three) main functions on just one mainboard will be sufficient to be encountered as domestic part. Teams will get more points if more functions are performed domestically and properly working.

a) *Motor Torque Control*
b) *Regenerative Breaking Optimization*
c) *Vehicle Energy Management System*
d) *Management of Vehicle Communication System*
e) *Diagnostic*
f) *Monitor Vehicle Condition and Warn the User etc.*
g) *Telemetry*
h) *Comparison Table*

		Previous Design	Current Design
VCU Functions	**:**		
Controller IC	**:**		
Number of VCU I/O	**:**		

Electronic Circuit Design	:		
Printed Circuit Design	:		
Printed Circuit Manufacturing	:		
Software Algorithm	:		
Experimental Study	:		
Size (PCB / Box)	:		

16. Insulation Monitoring Device

*Teams that produce this product domestically will get a maximum of **150 points** depending on the design.*

a) *Circuit Design*
b) *Simulation Studies*
c) *Printed Circuit Studies*
d) *Production Studies*
e) *Test Results*
(Measurements for different leakage resistances should be given)
f) *Comparison Table*

		Previous Design	Current Design
Micro Controller IC	:		
Measuring Accuracy at 50kΩ	:		
Measuring Accuracy at 200kΩ	:		
Measuring Accuracy at 1MΩ	:		
Does the system give warning under 10kΩ resistance?(Y/N)			

17. Steering System

*Teams that produce this component domestically will get a maximum of **150 points** depending on the design.*

<u>If teams design their steering system domestically, they should describe design and production steps clearly. They should give detailed design result with their own comments. Teams should describe and calculate following design properties;</u>

a) *CAD model. (150 points)*

b) *Angle and distance values of your vehicle's front geometry. (Camber angle, Caster angle, toe distance) (60 points)*

c) *Calculation of steering ratio. (10 points)*

d) *Calculation of turning radius according to the bicycle model and the outer wheel center. (10 points)*

e) *Show the values that should be taken by the inner and outer steer angles according to the Ackerman geometry. (10 points)*

f) *Plot the inner wheel and outer wheel steer angles according to the steering angle in the same graph for theoretical and real situation. Adams Program can be used to calculate theoretical values. In addition, the maximum steer angles of the wheels relative to the largest steering angle of the steering wheel should be indicated on the graph. The graph should include the steer angles both left and right turns. (50 points)*

g) *The steering wheel must have at least 180 degrees (90 to left, 90 to right) of rotation. There must be at least 1 cm clearance between the wheels and any part on the body during the rotation of the wheels. (10 points)*

18. Door Mechanism

*Teams that produce this component domestically will get a maximum of **150 points** depending on the design.*

As described in rules, following items are the main calculations that teams shall perform and report for door mechanism to be encountered as domestic part.

a) *Each of the parts in the door system must have a 3D CAD drawing, and also a 3D assembled CAD drawing of the entire system must be prepared. The CAD file must be delivered with an .stp extension. (50 points)*

b) *Calculations or analysis for the choice of hinge locations and dimensions based on the door geometry and physical properties shall be reported. (50 points)*

c) *Report shall be prepared that the door can satisfy following specifications;*

   i. *The vehicle must have 2 doors that shall open on both sides of the vehicle, the dimensions of the doors must be the same, and the surface area of the doors must be at least 0.4 m^2. (10 points)*

   ii. *Use of a seal between door and vehicle body is mandatory. (10 points)*

   iii. *The door must be able to be locked by means of a key, and the door cannot be opened by the movement of the door handle without unlocking it with the key. (10 points)*

   iv. *The door must be able to be closed only by pushing, without any intervention with the door handle. (10 points)*

v. *When the door is closed, a 0.2-cm-thick object must not be able to enter between the door and body. (10 points)*

19. Braking System

*Teams that produce this component domestically will get a maximum of **150 points** depending on the design.*

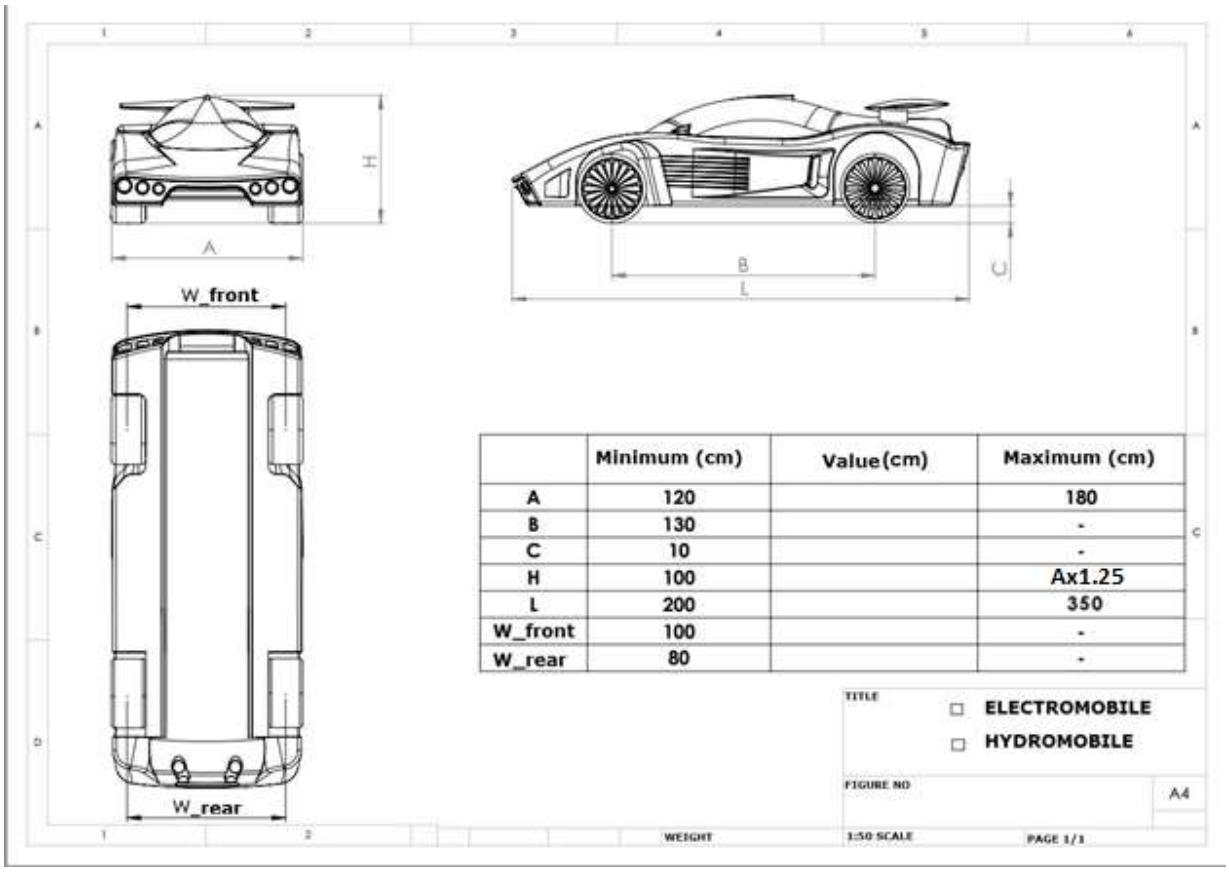
<u>If teams design their braking system domestically, they should describe design and production steps clearly. They should give detailed design result with their own comments. Teams should describe and calculate following design properties;</u>

a) *CAD model of all parts and braking circuit diagram. (150 points)*
b) *Front brake and rear brake caliper force calculations. (15 points)*
c) *Calculations of the front and rear brake center forces.(15 points)*
d) *Hydraulic pressure calculations of the front and rear brake circuit. (15 points)*
e) *Calculations of brake pedal ratio and pressure increase on master cylinder. (15 points)*
f) *Calculations of the total braking force transmitted to the brake master cylinder. (15 points)*
g) *Speed graph under Mean Fully Developed Deceleration. (15 points)*
h) *Longitudinal load transfer calculations and graphics during braking. (15 points)*
i) *Dynamic axle loads calculations and curves. (15 points)*
j) *Braking force distribution curve. (15 points)*
k) *Front and rear-wheel braking torque calculations during braking. (15 points)*

20. Mechanical Details

*Teams that provide sufficient information will get a maximum of **150 points** depending on the design.*

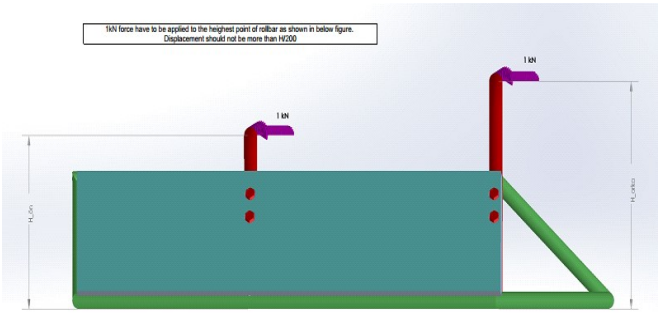
a) *Technical Drawings (30 points)*



	Minimum (cm)	Value(cm)	Maximum (cm)
A	120		180
B	130		-
C	10		-
H	100		Ax1.25
L	200		350
W_front	100		-
W_rear	80		-

As in the example above, technical drawings of the finished vehicle from the side, front, and back are required (you can review this in detail by double-clicking on the figure above). A technical drawing of the lower parts is not required. Measurements must be given in a table, as in the figure above.

b) Strength Analysis (30 points)



For strength analysis, below described item and illustrated above must be calculated manually or by a computer program (you can review this in detail by double-clicking on

the figure above). Other calculations prepared by the teams that do not provide this information as expected will not be considered.

- *When a point load of 1 kN is applied between the upper point of the roll cage and the lowest point, the displacement in the horizontal direction must be calculated. It should not exceed H/200. Calculations must be made for both the front and rear roll cages (H: the height difference between the lower and upper point).*

c) *Outer Shell Production (30 points)*
It must be explained briefly with illustrations how the product was produced. If it was produced by an external company, the cost and method of production must be explained.

d) *Energy Consumption Calculation (30 points)*
Taking into account the front area, wheel friction, and internal losses of vehicles, the teams must calculate the energy consumption necessary to complete a 4000-m flat track at 50 km/h.
Teams shall calculate the necessary motor power to climb a hill that has 6% slope with a constant speed of 50km/h
Teams shall calculate the continues speed that vehicle reach with a 1.5kW electric motor at a hill which has a slope of 6%.

e) *Cost Calculation (30 points)*
A bill of materials and the cost of the vehicle must be presented in detail in a table.

21. Hydrogen System (Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders) (Hydromobile category only)

In addition to the rules written here, the teams must also pay attention to the other rules specified in the "International EC Racing Rules Guide 2022". Especially "15. HYDROGEN SYSTEM (Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders)" should be paid attention to and the details should be written under the relevant sub-headings given below in the technical design report. Other parts of the rules guide concerning hydromobile vehicles should also be checked.

21.1 Fuel Cell

*Teams that produce the fuel cell for hydromobile vehicles themselves will receive maximum 5**00 points** depending on the locality rate and product design. Teams using commercial items will receive maximum **50 points.** Teams that manufacture the fuel cell themselves must provide the design of each part, design calculations, fuel cell electrical efficiency calculations, performance test results, polarization curve and wiring diagram. Teams using commercial products should provide detailed technical specifications of the fuel cell, polarization curve, results of tests and wiring diagram.*

Teams that will use the fuel cell to be supplied by TENMAK should specify this separately.

21.2 Fuel Cell Control System

*Fuel cell control system for hydromobile vehicles will receive maximum **300 points.** Teams using commercial products will receive maximum **50 points.** The fuel cell control system should be given schematically and explained in detail.*

21.3 Hydrogen Line and Metal Hydride Cylinders

*Teams that complete the hydrogen line and metal hydride cylinders as specified will receive maximum **100 points** from this section**.** Within the scope of the safety rules specified in the International EC Racing Rules Guide, it is expected that the design, connection, technical drawing and/or photographs of the finalized in-vehicle placement of all system elements are expected to be submitted. Official product documents regarding the conformity of the all hydrogen connection line elements (protection shield, safety and the position of the tanks, pressure relief valve, safety valve and its location, solenoid valve, regulator, flame trap or check valve, hydrogen sensor, thermocouple, the location where the hydrogen flow meter to be given during the race will be placed, the location of the water vapour hose coming out of the fuel cell, the pipe to be used, the valves and the fittings) starting from the metal hydride hydrogen tanks to the fuel cell (See 2022 International EC Racing Rules Guide Chapter 15. HYDROGEN SYSTEM) are expected*

to be declared. Connection design and location details of hydrogen sensor, thermocouple and flasher etc. should be given.

A sample flow diagram for the hydrogen line and its elements should be given in detail. Instead of copy-pasting the diagram given as an example in the rules guide, the diagram drawn by the team itself should be shared.

Teams that will use metal hydride hydrogen tanks that will be supplied by TENMAK should indicate this. If metal hydride hydrogen tanks will be provided by the team, detailed technical information, safety precaution, vehicle interior layout, protection shield and fixation status, connections, etc. should be provided.

22. Vehicle Electric Scheme

*Teams that provide sufficient information will get a maximum of **50 points** depending on the design.*

It is mandatory to provide an A4 drawing (21 × 29.7 cm) illustrating all power circuits of the electrical equipment of the vehicle. The drawing must include the battery, fuses, circuit breakers, power control buttons, capacitors, motor control tools, motor or motors, charge unit, connection cables, and so on. A second drawing must also clearly illustrate the components within the vehicle as viewed from above.

23. Unique Design by Team

*Team designs regarded as original can receive a maximum of **100 points.***

			Scoring			
			Electromobile		Hydromobile	
			Domestic	Ready-made	Domestic	Ready-made
1	**Vehicle specifications table**		100		100	
2	**Vehicle dynamic testing video**		-	-	-	-
3	**Braking testing video**		-	-	-	-
4	**Motor**	If designed by team, details mandatory; if ready-made product, please explain briefly	400	50	400	50
5	**Motor driver**	If designed by team, details mandatory; if ready-made product, please explain briefly	300	50	300	50
6	**Battery management system (BMS)**	If designed by team, details mandatory; if ready-made product, please explain briefly	200	50	200	50
7	**Embedded recharging unit**	If designed by team, details mandatory; if ready-made product, please explain briefly	200	50	200	50
8	**Energy management system***	If designed by team, details mandatory; if ready-made product, please explain briefly	-	-	300	50
9	**Battery packaging**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	50	150	50
10	**Electronic differential application**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	0	150	0
11	**Telemetry System**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	50	150	50
12	**Vehicle control unit (VCU)**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	50	150	50
13	**Insulation monitoring device**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	0	150	0
14	**Steering system**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	50	150	50
15	**Door mechanism**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	50	150	50

16	**Braking System**	If designed by team, details mandatory; if ready-made product, please explain briefly	150	0	150	0
17	**Mechanical details**		150		150	
18	**Fuel cell***	Details are mandatory if designed by the team; If it is a commercial product, please briefly describe it.	-	-	500	50
19	**Fuel cell control system***	Details are mandatory if designed by the team; If it is a commercial product, please briefly describe it.	-	-	300	50
20	**Hydrogen Line and Metal Hydride Cylinders***	The scoring of this sub-section will be done by considering part "17.3. Hydrogen Line and Metal Hydride Cylinders".	-	-	-	100
21	**Electric scheme**		50		50	
22	**Original design**		100		100	
	TOTAL		**2700**		**3650**	

**Hydromobile category only*

Domestic Product Awards:

In order to receive the Domestic Product Awards, at least 1000 points must be obtained over the total points of the titles subject to domesticity in the Technical Design Report.

	Electromobile	Hydromobile
Motor	400	400
Motor Driver	300	300
Battery Management System (BMS)	200	200
Embedded Recharging Unit	200	200
Energy Management System (EMS)*	-	300
Battery Packaging	150	150
Electronic Differential Application	150	150
Telemetry System	150	150
Vehicle Control Unit (VCU)	150	150

Insulation Monitoring Device	150	150
Steering System	150	150
Door Mechanism	150	150
Braking System	150	150
Fuel Cell*	-	500
Fuel Cell Control System*	-	300
Domestic Product Awards Evaluation:	**A minimum of 1000 points must be obtained out of a total of 2300.**	**A minimum of 1000 points must be obtained out of a total of 3400.**

TITLES THAT ARE NOT INCLUDED IN THE TECHNICAL DESIGN REPORT SCORING

Pre-technical control videos included in the Technical Design Report will be evaluated independently of the Technical Design Report score.

Pre-Technical Control Videos Scoring Table:

Each title is evaluated out of 100 points. The team with the highest score is entitled to receive the pre-technical control video award.

		Electromobile	**Hydromobile**
1	Motor Video	100	100
2	Motor Driver Video	100	100
3	Battery Management System Video	100	100
4	Energy Management System Video*	-	100
5	Embedded Recharging Unit Video	100	100
6	Battery Packaging Video	100	100
7	Electronic Differential Application Video	100	100
8	Vehicle Control Unit Video	100	100
9	Isolation Monitoring Device Video	100	100
10	Steering System Video	100	100
11	Door Mechanism Video	100	100
12	Braking System Video	100	100

13	Hydrogen System Video*	-	100
14	Telemetry Video	100	100