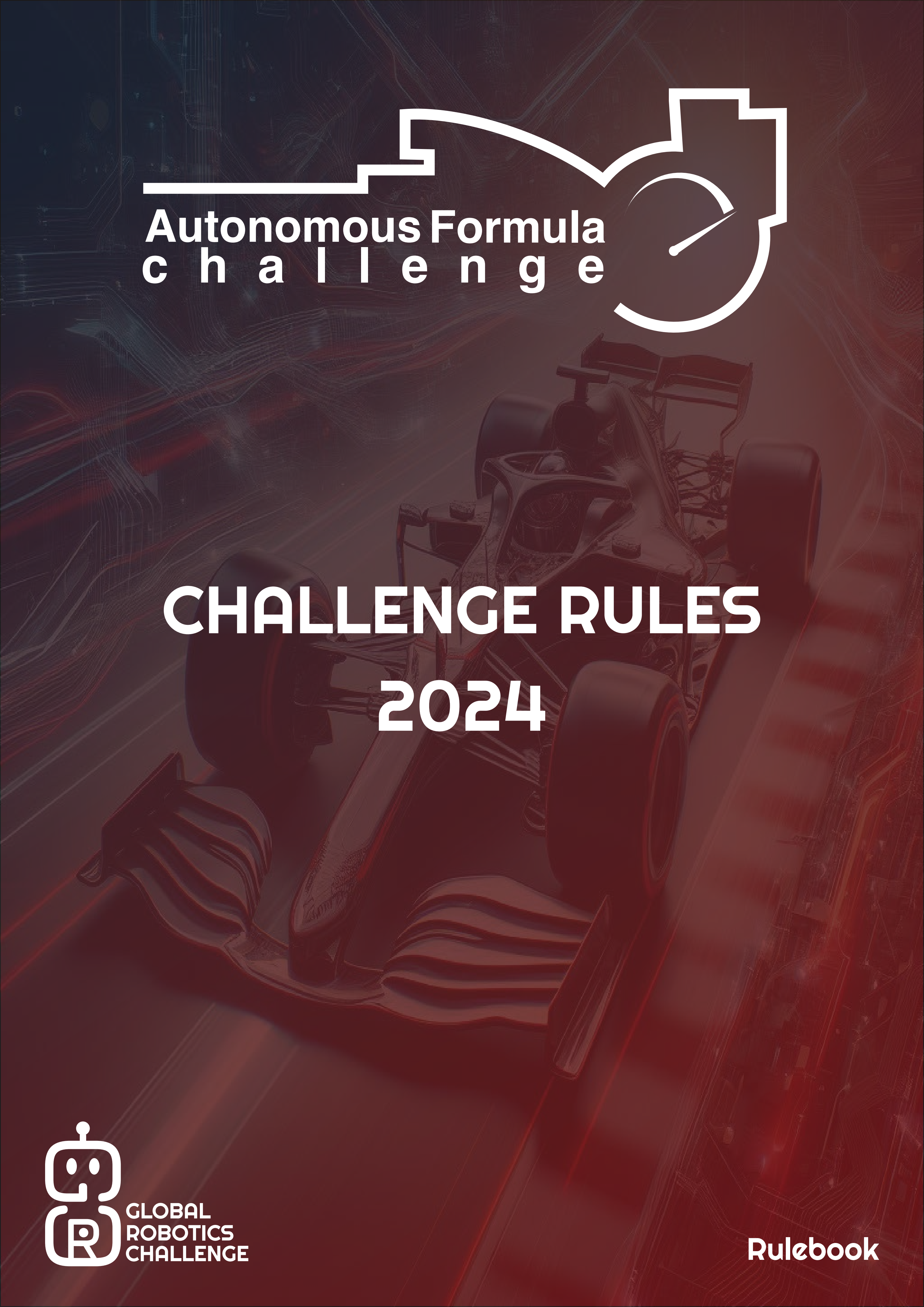
Autonomous Formula challenge



CHALLENGE RULES 2024

GLOBAL ROBOTICS CHALLENGE

Rulebook

About Autonomous Formula Challenge (AFC)

The small automatic car competition focuses on designing and developing autonomous vehicles that can perform specified tasks using artificial intelligence (AI) and technological knowledge. This competition challenges engineering students and school students to create innovative small cars capable of navigating and completing tasks without human intervention.

Participants are required to integrate AI algorithms and advanced technologies into their small cars to enable them to perceive their surroundings, make intelligent decisions, and execute actions accordingly. The competition seeks to promote the application of AI and technological advancements in the field of autonomous vehicles, fostering creativity and problem-solving skills among engineering students and school students.

The tasks assigned to the small automatic cars may vary based on the competition's theme and objectives. These tasks can include obstacle avoidance, path planning, object detection and recognition, following specific routes, responding to traffic signals, and executing precise manoeuvres. The small cars need to demonstrate efficient and reliable performance in completing these tasks while showcasing the capabilities of AI and technological knowledge.

Participants are expected to demonstrate their understanding of AI principles, sensor integration, control systems, and software development. They are required to design and implement robust algorithms that enable the small cars to process sensor data, make intelligent decisions in real-time, and execute precise actions to accomplish the assigned tasks.

The competition provides a platform for students to showcase their technical knowledge, problem-solving abilities, and innovation in the field of autonomous vehicles. It encourages collaboration, teamwork, and the application of cutting-edge technologies to overcome challenges associated with autonomous navigation and task completion.

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1 Rules and Guidelines

1.1 Timeline

1. February 2024: Registration Starts and opening Webinar.
2. June 2024: Registration Closes and Submissions Deadline.
3. July 2024: Regional Finals.
4. September 2024: Global finals.

1.2 Registration

Registration will open from February 2024 to May 2024, on

Seniors Category is for postgraduate and undergraduate students.

Juniors Category is open for high school students.

The team members cannot be less than 3 and not more than 10 including mentors or advisors.

Discover Category: The school age groups are from 6 to 12 years. (No more than 5 team members can be registered)

All data should be written in English.

Email and phone number for each member must not be duplicated.

For more information, please visit our website.

2 Autonomous formula challenge

The small automatic car competition challenges engineering students to design and build autonomous vehicles using AI and technological knowledge to perform specified tasks, fostering innovation and problem-solving skills.

2.1 Senior category

This category is for undergraduate and postgraduate students with no age or age restrictions. Technical and non-technical levels. In this category, (small autonomous vehicle).

The vehicle must be built by team members for specific simulation tasks.

Specific scientific and engineering concepts.

In this category the car must be autonomous, and any non-autonomous car isn't accepted.

2.2 Junior Category

This class is intended for school students.

In this category, required (Self-Driving Mini Car)

To be built by team members for specific simulation tasks, with a complexity of less than senior teams, with specific science and engineering concepts.

To carry out tasks specified by the competition.

In this category the car might be non-autonomous but autonomous car will get the team bonus.

2.3 discover Category. (LEGO&SPIKE)

Abstract of LEGO

FIRST LEGO League (FLL): FLL is a global robotics competition for elementary and middle school students. Teams design, build, and program autonomous robots using LEGO Mindstorms kits to complete missions on a themed playing field. They also conduct research on a real-world problem related to the theme and present their solutions.

FIRST LEGO League Jr. (FLL Jr.): FLL Jr. is tailored for younger students (ages 6-10). Teams explore a real-world scientific problem, build a model using LEGO elements, and create a Show Me poster to present their findings.

FIRST LEGO League Challenge (formerly FLL World Festival): This is the culmination of the FLL season, where top teams from regional competitions gather to compete on a global stage. Participants showcase their robots' abilities, present their research projects, and engage in teamwork challenges.

LEGO Education Master Educator Program: Not a competition per se, but worth mentioning. This program recognizes educators who are passionate about using LEGO Education solutions in innovative ways to enhance learning. Master Educators share their expertise with other educators worldwide.

LEGO MINDSTORMS Challenges: LEGO occasionally hosts online challenges or contests where individuals or teams can showcase their programming and robotics skills using LEGO MINDSTORMS kits. These challenges often have specific themes or objectives.

SPIKE Prime is a robotics and coding platform designed by LEGO Education for students aged 11-14. SPIKE competitions provide a dynamic way for students to showcase their STEM skills in various challenges. These competitions often feature tasks that require problem-solving, creativity, and collaboration. Teams build and program robots using the SPIKE Prime set to complete specific missions within a designated time frame. Challenges can vary widely, ranging from navigating obstacles to completing tasks related to environmental sustainability or space exploration. Competitions foster teamwork, critical thinking, and technical proficiency while offering an engaging and fun learning experience for participants.

LEGO Education competitions provide students with hands-on learning experiences, fostering skills such as critical thinking, communication, and collaboration, all while having fun with LEGO bricks and robotics.

3 Challenges Phases

3.1 Submissions

All the submissions shall be sent before 20/6/2024.

3.1.1 Cost Analysis (20 points)

Each team should prepare cost analysis and send it before the competition.

3.1.2 Technical Report (70 points)

Each team should prepare a technical report document and send it before the competition.

Only the technical report required from the Discover category.

includes

Design pictures.

Sensors used.

The code used.

Date of sending the file 1/7/2024

3.1.3 Safety Document/Software Safety Check (20 points)

Each team will be asked to deliver a safety document prior the competition. All rules are mentioned in the Safety section.

3.2 Challenge Day

The challenge will be divided into three sections as following:

3.2.1 Safety Check (20 points)

Each team will perform the safety check according to the specifications described. In the Safety section, teams that cannot pass the check will be disqualified.

3.2.2 Mission (180 points)

- Each team will have three trials for the Mission using their robot. The total time of each trial is 10 minutes. 3 minutes for setup, 5 minutes for performing the tasks, and 2 minutes for leaving the station.
- **Discover category.**

Each team will have three trials for the Mission using their robot. The total time of each trial is 15 minutes. 4 minutes for setup, 8 minutes for performing the tasks, and 3 minutes for leaving the station.

3.2.3 Presentation (50 points)

Each team will be required to perform a 10-minute pitch presenting their work, the pitch will be followed by 10 minutes of Q&A for evaluation by the judging panel.

4 Playground Specifications

Each team separately places the car on the track shown in figure 1 and starts operating it from the specified start/end line until it reaches the acceleration line, and then the car reaches the starting line again without touching the track walls. **Cars can't depend on the walls instead of steering system which means cars can't be in physical touch with the walls for long time.**

The playground surface will be made of Plywood material.

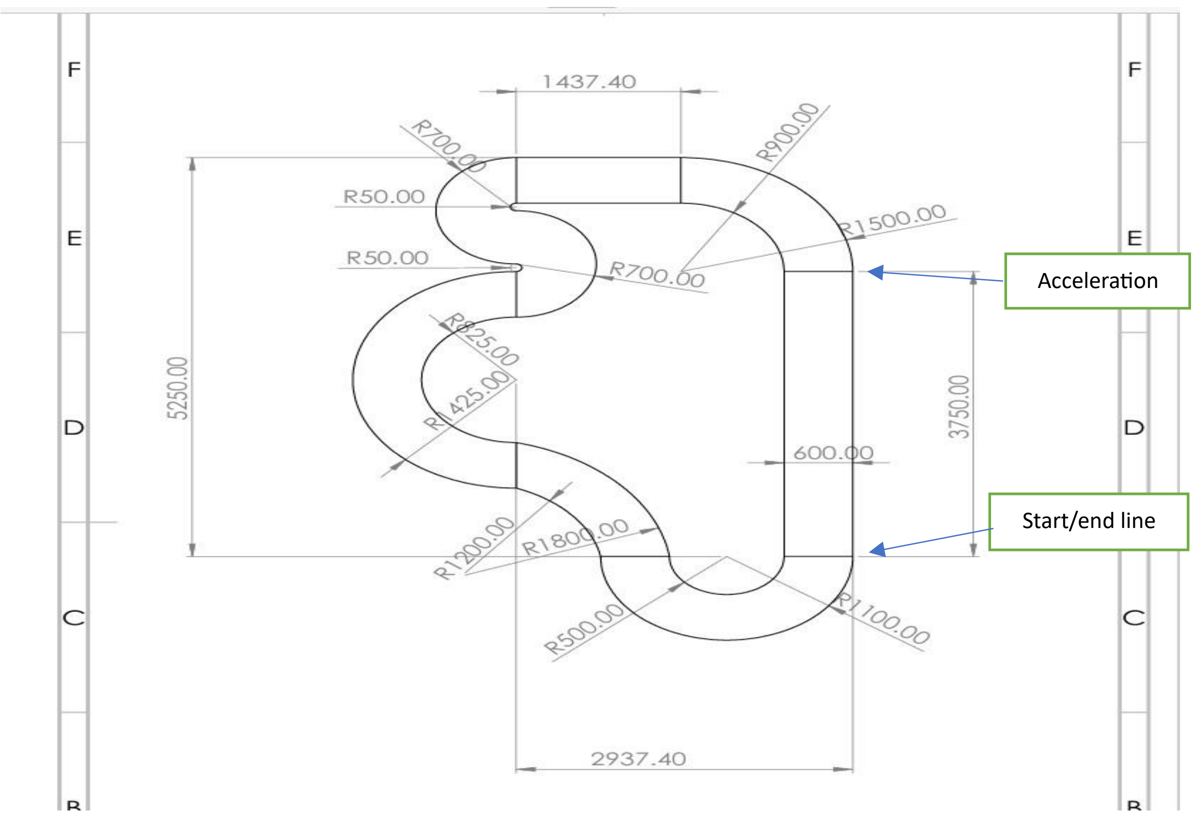

Figure 1: Playground.

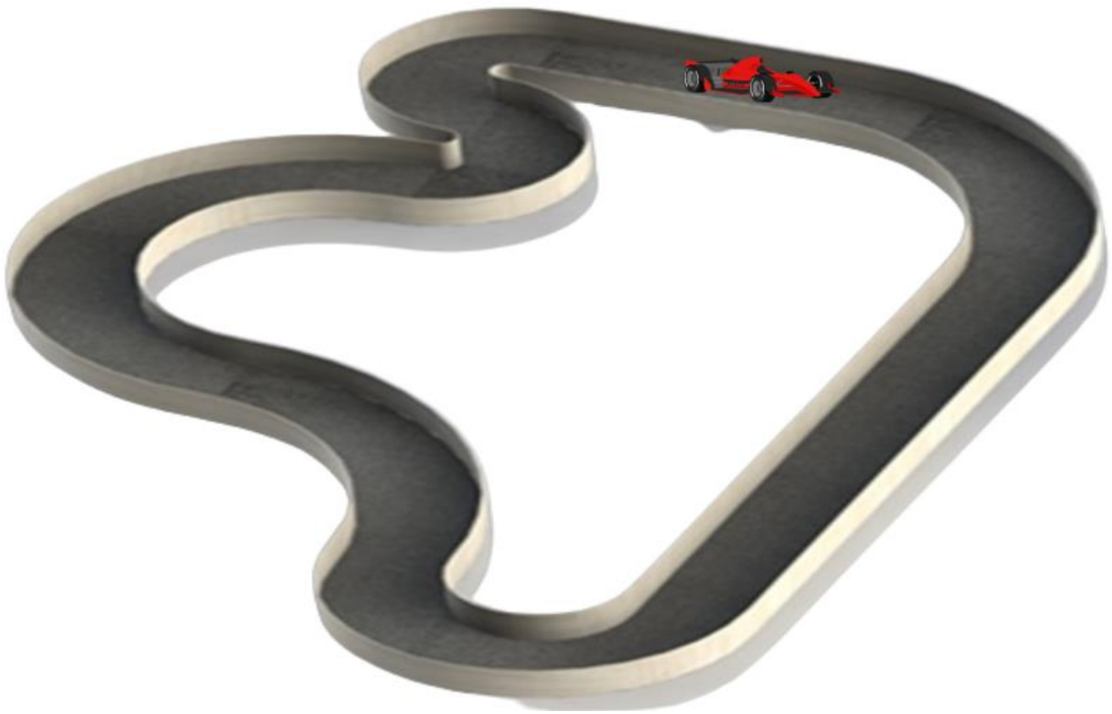

Figure 2: Playground

4.1 Tasks

Each team has only 3 trials, Time is recorded from crossing the start/end line at the beginning and again at the end.

Acceleration will be calculated from start to acceleration line in each trial and the best acceleration will get 5 points bonus.

The judge may use stopwatch if the start end line doesn't work or damaged.

Once the robot crossed the line and moved fully autonomous, the team will get 5 points bonus.

The lowest time from all the trial will be taken as the best time for the team as well as the lowest acceleration time and stability points.

The scoring will be as the following: If the robot finishes the trial in under 1 minute, it earns 300 points plus (60 - seconds) points.

- If the robot finishes the trial in under 2 minutes (or exactly 1 minute), it earns 240 points plus (60 - seconds) points.

- If the robot finishes the trial in under 3 minutes (or exactly 2 minutes), it earns 180 points plus (60 - seconds) points.

- If the robot finishes the trial in under 4 minutes (or exactly 3 minutes), it earns 120 points plus (60 - seconds) points.

- If the robot finishes the trial in under 5 minutes (or exactly 4 minutes), it earns 60 points plus (60 - seconds) points.

- If no team finishes within 5 minutes during the first trial, the judges will modify the scoring sheet based on the trial times.

- If more than 3 teams finish within 5 minutes or fewer, any team that couldn't complete the trial will not have additional trials.

Example:

- Team 1 finished in 44 seconds; Team 1 score will be calculated as 300 + (60-44) = 316
- Team 2 finished in 1:20 seconds, Team 2 score will be calculated as 240 + (60-20) = 280
- Team 3 finished in 2:30 seconds, Team 3 score will be calculated as 120 + (60-30) = 150
- Team 4 finished in 3:01 seconds, Team 4 score will be calculated as 60 + (60-1) = 119

Each trial score will include:

- 20 points safety check.
- 5 points bonus if the team had the best acceleration.
- 5 points if the car fully autonomous (for junior category).
- Each time the car touches the wall the team will lose one point.

Example:

Team 1 has finished in 44 second with score 316, with safety check 15/20 points and with fully autonomous robot but their car touches the wall two times.

Team 1 score = 316 + 15 + 5 - 2 = 334

Team 2 has finished in 1:20 seconds with score 280, with safety check 20/20 points, with fully autonomous car, not touching any of the wall and best acceleration.

Team 2 score = 280 + 20 + 5 + 5 = 310

NOTE: Each trial will has its numbers and teams cannot combine best numbers from 3 trials.

5 Vehicles and Additional Devices Specifications

For the seniors category, the length of the vehicles is limited to 40 cm in length and 30 in width, and the weight is 10 kg weight, vehicles exceeding these limits will not be allowed to compete in the track.

For the juniors category, the length of the vehicles is limited to 35 cm in length and 25 cm in width, and the weight is 7 kg weight, vehicles exceeding these limits will not be allowed to compete in the track.

No modifications are made to vehicles after size and weight measurements allowed.

Additional device is allowed to help the car perform the task as long as its works without human interference (for seniors category).

Additional device is allowed to help the car perform the task with human interference such as joysticks (for juniors category).

Each team will be required to submit design documents for the main vehicle, additional devices (if exist), and their SIDs.

Teams can’t use any wired connection between any device and their car within the trial time.

For the discover category, the length of the vehicles is limited to 25 cm in length and 25 in width, and the weight is 3 kg weight, vehicles exceeding these limits will not be allowed to compete in the track.

6 Mechanical design helper

Note that this is helper not rules.

6.1 Chassis Design:

6.1.1 Material Selection:

- Choose lightweight and high-strength materials for the chassis construction, such as aluminium alloys or carbon fiber composites. This helps improve the overall weight-to-strength ratio and enhances the vehicle's agility and energy efficiency.
- Consider the cost-effectiveness of the materials while ensuring they meet the competition's regulations and safety standards.

6.1.2 Structural Integrity:

- Ensure the chassis design provides sufficient structural rigidity and stiffness to withstand the forces experienced during acceleration, braking, and cornering.

- Utilize appropriate structural reinforcements, such as cross-bracing, gussets, or roll bars, to enhance the chassis' strength and rigidity.

6.1.3 Aerodynamics:

- Consider aerodynamic principles in the chassis design to minimize drag and improve vehicle efficiency.
- Incorporate streamlined features, such as smooth contours and optimized body shaping, to reduce air resistance and enhance overall performance.

6.1.4 Suspension Mounting Points:

- Position suspension mounting points appropriately to optimize vehicle handling and stability.
- Ensure proper alignment between the suspension components and the chassis to promote accurate wheel control and responsiveness.

6.1.5 Ground Clearance:

- Determine the required ground clearance based on the competition's terrain and tasks.
- Design the chassis with sufficient clearance to prevent scraping or damage to the vehicle's underbody during manoeuvres.

6.1.6 Weight Distribution:

- Aim for an optimal weight distribution across the chassis to improve balance and traction.
- Consider the placement and integration of heavy components, such as the powertrain and battery, to achieve the desired weight distribution and minimize the impact on vehicle dynamics.

6.1.7 Manufacturing Considerations:

- Consider manufacturability and ease of assembly during chassis design.
- Simplify the design by minimizing the number of complex components and incorporating standardized fastening methods.
- Document the manufacturing process to ensure repeatability and facilitate evaluation.

6.1.8 Safety Features:

- Incorporate safety features into the chassis design, such as impact-absorbing structures or a safety cage, to protect occupants in the event of a collision.
- Comply with relevant safety regulations and standards to ensure participant safety during the competition.

6.2 Suspension System:

The suspension system of a small car in the competition plays a vital role in ensuring stability, maneuverability, and comfort. A well-designed suspension system effectively absorbs shocks, maintains tire contact with the road, and allows for precise control. Consider the following guidelines when designing the suspension system:

6.2.1 Suspension Type Selection:

- Choose an appropriate suspension type based on the competition's requirements and the desired balance between performance and cost.
- Common suspension types include independent suspension (such as double-wishbone or MacPherson strut) or dependent suspension (such as solid axle or torsion beam). Evaluate the pros and cons of each type for the specific competition tasks.

6.2.2 Suspension Geometry:

- Optimize the suspension geometry to achieve desired handling characteristics and stability.
- Consider factors such as camber, caster, and toe-in or toe-out angles to ensure proper tire contact, minimize tire wear, and enhance cornering abilities.

6.2.3 Damping and Spring Rates:

- Select appropriate damping and spring rates to control the vehicle's response to bumps, impacts, and body roll.
- Balance the suspension stiffness to maintain stability while providing adequate comfort and traction.

6.2.4 Wheel Alignment:

- Ensure proper wheel alignment by adjusting camber, caster, and toe settings.
- Align the wheels to optimize tire contact patches, reduce rolling resistance, and enhance steering responsiveness.

6.2.5 Adjustability:

- Incorporate adjustability features into the suspension system to fine-tune performance based on competition requirements or changing track conditions.
- Consider adjustable shock absorbers, adjustable sway bars, or adjustable suspension arms to adapt to different situations.

6.2.6 Ground Clearance:

- Determine the required ground clearance based on the competition's terrain and tasks.

- Design the suspension system to provide sufficient travel and adjustability to handle various obstacles or uneven surfaces.

6.2.7 Bracing and Reinforcements:

- Reinforce suspension mounting points and critical components to withstand the forces exerted during acceleration, braking, and cornering.
- Consider using additional bracing or reinforcements to enhance structural integrity and minimize flexing or bending under load.

6.2.8 Testing and Tuning:

- Perform thorough testing and tuning of the suspension system to optimize performance.
- Utilize testing methods such as track testing, dynamic simulations, or suspension analysis tools to assess and fine-tune the system.

6.3 Steering System:

The steering system of a small car in the competition is responsible for controlling the direction and manoeuvrability of the vehicle. A well-designed steering system ensures precise and responsive handling, allowing the to navigate through tasks effectively. Consider the following guidelines when designing the steering system:

6.3.1 Steering Mechanism Selection:

- Choose an appropriate steering mechanism based on the competition's requirements, vehicle size, and desired steering feel.
- Common steering mechanisms include rack and pinion, recirculating ball, or electronically assisted systems. Evaluate the pros and cons of each type for the specific competition tasks.

6.3.2 Linkage Design:

- Design the steering linkage to provide accurate and predictable steering response.
- Optimize the linkage geometry, such as steering arm length and mounting points, to achieve desired steering angles and minimize play or slop in the system.

6.3.3 Turning Radius:

- Consider the competition's track layout and turning requirements when determining the turning radius.
- Design the steering system to provide an appropriate turning radius for manoeuvring in tight spaces or around obstacles.

6.3.4 Steering Wheel and Column:

- Choose a steering wheel design that provides comfortable grip and easy control.
- Ensure the steering column is properly aligned and adjustable for different driver sizes and preferences.

6.3.5 Power Assistance:

- Evaluate the need for power assistance based on the competition's requirements and the desired steering effort.
- Determine whether manual steering or power-assisted steering (such as hydraulic or electric power steering) is necessary.
- If incorporating power assistance, consider the integration of appropriate sensors, controllers, and power sources.

6.3.6 Alignment and Calibration:

- Ensure proper alignment of the steering system components, including the steering wheel, steering column, and tie rods.
- Perform accurate calibration to achieve precise steering response and minimize any potential steering drift or inconsistency.

6.3.7 Steering Feel and Feedback:

- Design the steering system to provide appropriate steering feel and feedback to the driver.
- Consider factors such as steering ratio, damping, and mechanical linkages to achieve the desired feedback and responsiveness.

6.3.8 Safety Considerations:

- Incorporate safety features into the steering system design, such as a collapsible steering column or redundant steering components, to enhance occupant protection in the event of a collision.

6.3.9 Testing and Tuning:

- Perform thorough testing and tuning of the steering system to optimize its performance and responsiveness.
- Utilize testing methods such as track testing, dynamic simulations, or steering analysis tools to assess and fine-tune the system.

6.4 Manufacturing and Assembly:

Efficient manufacturing and assembly processes are crucial for the successful construction of a small car in the competition. Well-planned manufacturing and assembly strategies contribute to the timely completion of the vehicle and ensure its reliability. Consider the following guidelines when addressing manufacturing and assembly:

6.4.1 Design for Manufacturability:

- Design the small car with manufacturability in mind, considering the capabilities of the manufacturing facilities and available resources.
- Simplify the design by minimizing the number of complex components and optimizing part geometry for ease of production.

6.4.2 Component Integration:

- Ensure proper integration and fitment of components within the small car's assembly.
- Consider the accessibility of components for maintenance, repair, and potential modifications.

6.4.3 Standardized Fastening Methods:

- Utilize standardized fastening methods, such as bolts, nuts, and screws, to simplify assembly processes and enhance ease of disassembly if needed.
- Document the recommended torque values for fasteners to ensure proper tightening.

6.4.4 Assembly Sequence Planning:

- Develop a well-defined assembly sequence and provide detailed assembly instructions or diagrams to assist in the construction process.
- Consider logical steps and dependencies between components to minimize errors and rework.

6.4.5 Prototyping and Testing:

- Conduct prototyping and testing stages during the manufacturing process to identify and address any design or assembly issues.
- Utilize rapid prototyping techniques, such as 3D printing, to quickly validate designs before final production.

6.4.6 Documentation:

- Document the manufacturing and assembly processes, including step-by-step instructions, diagrams, and photographs.
- This documentation serves as a reference for future improvements, repairs, or modifications and aids in evaluating the vehicle's compliance to competition rules.

6.4.7 Quality Control:

- Implement quality control measures during the manufacturing and assembly stages to ensure the small car meets the required standards and specifications.

- Inspect critical components, verify tolerances, and perform functional tests to identify and rectify any potential issues.

6.4.8 Team Collaboration:

- Encourage effective communication and collaboration within the team to streamline manufacturing and assembly processes.
- Assign clear roles and responsibilities to team members, ensuring everyone understands their tasks and deadlines.

6.4.9 Time Management:

- Develop a realistic timeline for manufacturing and assembly, considering the complexity of the design, available resources, and competition deadlines.
- Prioritize tasks based on critical path analysis to ensure efficient progress.

6.4.10 Iterative Improvement:

- Continuously seek opportunities for improvement during the manufacturing and assembly stages.
- Incorporate feedback from testing, inspections, and team members to refine the design and streamline production processes.

6.5 Torque calculation Helper

6.5.1 Rolling Resistance Torque:

- The rolling resistance torque is the force required to overcome the friction between the tires and the road. It can be calculated using the equation:
- Trr = Crr * N * r
- Where:
- Trr is the rolling resistance torque.
- Crr is the coefficient of rolling resistance (depends on tire type and road surface)
- N is the normal force on the tires
- r is the effective tire radius

6.5.2 Aerodynamic Drag Torque:

- The aerodynamic drag torque is the force required to overcome air resistance. It can be calculated using the equation:
- Tdrag = 0.5 * ρ * Cd * A * V^2
- Where:

- Tdrag is the aerodynamic drag torque.
- ρ is the air density
- Cd is the drag coefficient.
- A is the frontal area of the car.
- V is the velocity of the car

6.5.3 Acceleration Torque:

- The acceleration torque is the torque required to accelerate the vehicle. It can be calculated using the equation:
- Tacc = (m * a * r) / η
- Where:
- Tacc is the acceleration torque.
- m is the mass of the vehicle
- a is the desired acceleration.
- r is the effective tire radius
- η is the overall drivetrain efficiency (accounts for losses in the transmission, differential, etc.)

6.5.4 Total Torque:

- The total torque required from the motor is the sum of the rolling resistance torque, aerodynamic drag torque, and acceleration torque:
- Total Torque = Trr + Tdrag + Tacc

7 Electrical design helper

Note that this is helper not rules.

7.1 Connect batteries.

7.1.1 Batteries in Parallel:

When batteries are connected in parallel, their positive terminals are connected, and their negative terminals are connected. This creates a parallel circuit, where the batteries share the load.

- Effect: Connecting batteries in parallel increases the total capacity (measured in ampere-hours, Ah) of the battery system. In other words, the battery system can provide more current for a longer period.
- Mathematical Example: Let's say you have two batteries, each with a capacity of 50 Ah. When you connect them in parallel, the total capacity of the battery system becomes 100 Ah. So, if your car consumes 5 amps of current, the batteries connected in parallel can power the car for 20 hours (100 Ah / 5 A = 20 hours).

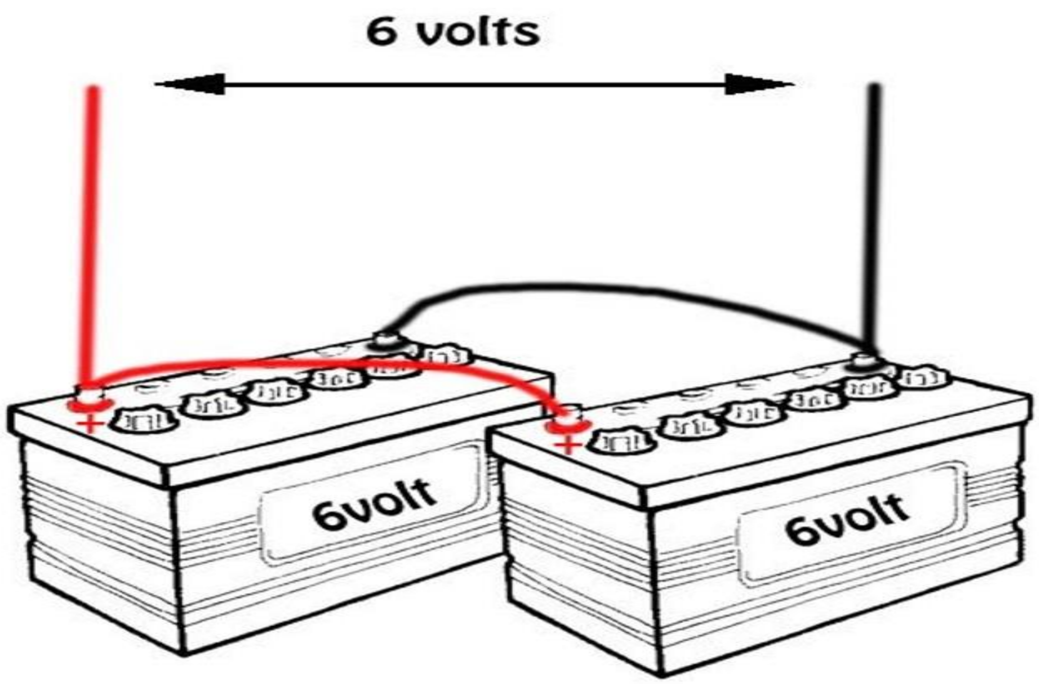

Figure 3: Batteries in Parallel

7.1.2 Batteries in Series:

When batteries are connected in series, the positive terminal of one battery is connected to the negative terminal of the next battery. This creates a series circuit, where the voltages of the batteries add up.

- Effect: Connecting batteries in series increases the total voltage (measured in volts, V) of the battery system. In simpler terms, it provides more power to run electrical components that require higher voltage.
- Mathematical Example: Consider two batteries, each with a voltage of 12 volts (V). When you connect them in series, the total voltage of the battery system becomes 24 V. This higher voltage can be useful for powering devices that require 24 V to operate.

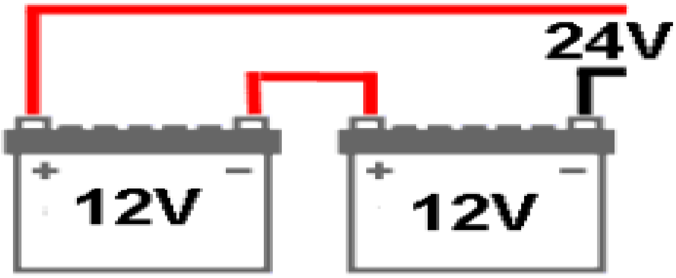

Figure 4: Batteries in Series

8 Penalties and Disqualifications

- Attempting to cheat in any way leads to disqualification.
- Failure to respect the referees or the organizers leads to disqualification.
- Failure to pass the safety check will result in your exclusion from the truck mission.
- The car that cannot pass the size and weight measurements will not enter the track, but the team can still participate in the other challenge stages such as presentation.
- Participation of mentors, coaches or any person not registered with the team in any activity (mission, safety, or swindling) this leads to disqualification.
- During the period of the mission, only four members are allowed to be in the track area, any of them Additional member interference will result in a 5-point penalty.
- Each trial have maximum 5 minutes trial with 3 setup minutes and two leaving minutes this totally gives 10 minutes for each team per trial. Any team exceeds these 9 minutes will have 5 points penalty.
- Discover category The number of sensors must not exceed 4

9 Safety

9.1 Electrical safety:

- Each team should submit one paper showing electrical SID and fuse calculations. The SID shows the connections of every electrical component, and the fuse calculations shows the maximum ampere used by the car and shows number of the used fuse.
- Teams can remove components from the car but can't add any components that's not included in the SID paper.
- A fuse with maximum 10 ampere should be installed after the battery positive terminal by at least 10 cm. the installed fuse must be the same fuse written in the submitted paper.
- It has to be not any exposed wires.
- No wires should be coming out from the car body.
- All the electrical components should be installed without any movement or vibrations.
- Teams must put a switch that cuts the electrical current across all the car electrical components.

9.1.1 Fuse calculations

Fuses are important safety devices used to protect electrical circuits from overcurrent situations. Proper fuse selection is crucial to prevent damage to the circuit and ensure safety. The fuse rating is determined based on the maximum current the circuit can handle without risking damage. Here's how to calculate the appropriate fuse rating:

Example:

Suppose you have a circuit with a maximum current rating of 7 amps. In this case, you would use a factor of safety 1.3 or 1.26

So your FOS ampere is 7*1.3 = 9.1 you may use 10 ampere fuse

Table 1: Fuse calculation Table

Number	Type	Amper	Total amper
4	Motors	1.5A	6A
1	Servo	0.5A	0.5A
2	Camera	0.2A	0.4A
1	MCU	0.1	0.1
Total		7A	

A_{FOS} = 7*1.3 = 9.1 A.

The used fuse is 10 A.

9.2 Mechanical safety:

- Car must have no sharp edges.
- If either hydraulic or pneumatic systems are used teams must put safety valve.
- Car bodies must not include any external appendages that might be dangerous to participants; this includes pointed parts of the Car body. Sharp points must have a radius of 50 mm or greater; or covered with foam or a deformable material.