YUVRAJ RUPAREL'S

THE YOUNG TURBOCHARGERS

Learning the depth of AERODYNAMICS

2

TEAM PREFACE

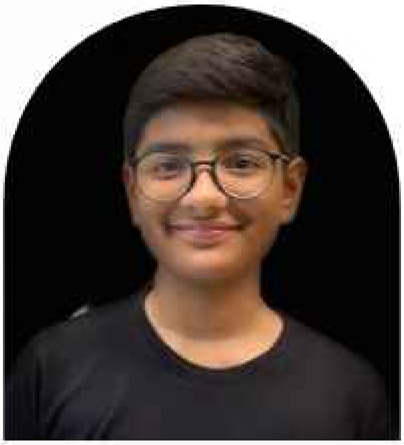
The Young Turbochargers, a group of six curious teenagers, participated in the **F1 In Schools World Finals Competition.** We started our journey on the 24th of March 2022. Each of us reside in Mumbai, India and were from different schools. The Young Turbochargers represented India at the 2023 World Finals and aspired to wave the colors of blue and tangerine on the top of the podium.

Our team consisted of young teenagers who were thirsty for knowledge and were extremely interested in **STEM (Science, Technology, Engineering Mathematics)** as well as **Formula 1**. Hence, this competition was a complete must-do for us. Our members were:

The Team: Lakshya Hirawat (Team Manager, Graphic Designer), Aryaman Kejriwal (Team Manager, Design Engineer), Nathan Doshi (Sponsorship Manager, Manufacturing Engineer), Raghav Sharma (Sponsorship Manager, Graphic Designer), Yuvraj Ruparel (Design Engineer, Manufacturing Engineer) and Rajvir Sehgal (Resource Manager, Graphic Designer).

While being very different and unique from each other, we all shared one common goal; being crowned as the **2023 WORLD CHAMPIONS**.

MEET OUR TEAM

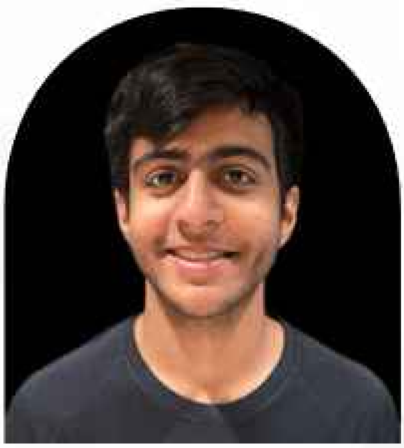


Lakshya Hirawat
Team Manager
Graphic Designer

Aryaman Kejriwal
Team Manager
Design Engineer

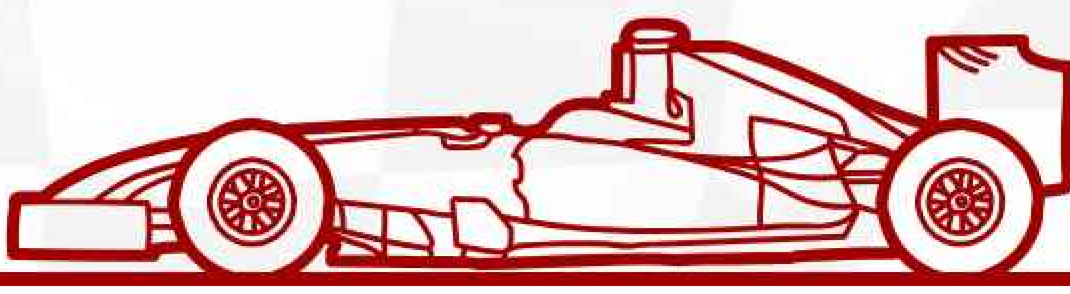
Nathan Doshi
Sponsorship Manager
Manufacturing Engineer

Raghav Sharma
Graphic Designer
Sponsorship Manager



Yuvraj Ruparel
Design Engineer
Manufacturing Engineer

Rajvir Sehgal
Graphic Designer
Resource Manager



F1 IN SCHOOLS

"F1 In Schools is a worldwide STEM competition where teams from various countries vie for the title of 'World Champions' at the World Finals. Each team, comprising 3-6 members, mimics the structure of an actual F1 team with assigned roles. Using CAM or CAD software, teams design cars based on the official F1 model block, showcasing their STEM skills.

In addition to car design, teams must create two portfolios detailing their journey and car design: The Project Management & Enterprise Portfolio and The Design & Engineering Portfolio. Teams must also adhere to a set of regulations to ensure their car is race legal.

The competition encompasses both Technical and Competition Regulations, fostering the enhancement of design skills and teamwork abilities within each member."

THE ACHIEVEMENTS

Our team's accomplishments in our F1 In Schools journey fill us with immense pride. The Young Turbochargers encountered substantial obstacles during both the India Regional Qualifiers and the India National Finals. Facing off against 55 competing teams in the Regionals presented a formidable challenge, yet The Young Turbochargers triumphed, clinching two esteemed accolades: The Best Newcomer Award and The Best Project Management & Enterprise Portfolio Award, ultimately securing the title of CHAMPIONS of the India Regional Qualifiers.

The journey continued into the India National Finals 2022, where despite initially feeling confident following our prior victory, apprehension gripped us. With only the top 3 teams out of 50 advancing to the World Finals 2023, the pressure mounted. Nevertheless, our apprehensions failed to deter us as the National Finals drew near.

During the National Finals, The Young Turbochargers not only claimed three awards but also garnered nominations for seven others. We were bestowed with the People's Choice Award, The Best National Collaboration Award, and The Best Scrutineering Award. Despite aspiring to rank among the top 3, our team attained 3rd place (2nd Runner's Up) at the Nationals, solidifying our position in the World Finals 2023.

We eagerly anticipate the forthcoming challenges and prospects awaiting us at the World Finals. Our objective is to proudly exhibit the saffron, white, and green hues of our nation atop the podium.

We invite you to extend your best wishes and lend your support as we embark on our most audacious undertaking yet: The Formula 1 In Schools World Finals 2025.

THE ACHIEVEMENTS

Explore the impressive array of prestigious awards earned during our F1 In Schools endeavor.

India Regional Qualifiers 2022:

National Finals India 2022:

DRAG FORCE

Drag force is defined as the force which is faced by the object as it moves through the air. Its size is proportional to the speed differential between the air and the solid object. Aerodynamic drag force for a vehicle depends mainly on the front area of the vehicle, side mirrors, ducts, and many other factors.

There are three types of drag force experienced by F1 in School cars:

- Friction Drag
- Form Drag
- Interference Drag

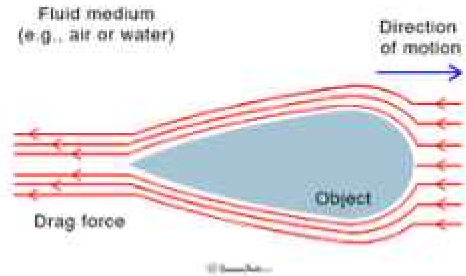


Image of airflow on teardrop shape
[Effective for reducing drag]

Friction Drag: It is the result of the friction between the solid molecules and the air molecules in their vicinity. Friction and its drag depend on both the fluid as well as the solid properties. A smooth surface of the solid for example produces less skin friction in comparison of a rough one.

Form Drag: It is a type of aerodynamic resistance that occurs when a solid object moves through the air. It is directly related to the shape of the object, such as a wing. As air flows around the object, the changes in local velocity and pressure create a resisting force.

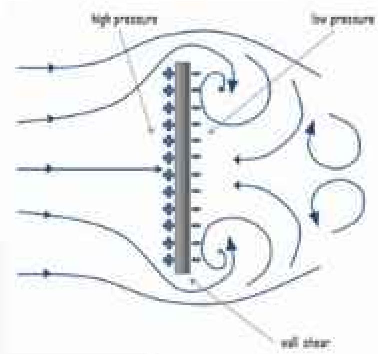


Image of air moving around a body

Interference Drag: It is the result of vortices that are generated behind the solid object. A vortex is created where the airflow meets unchanged, straight flow, when the direction of the air around the wing changes. The size of the vortex & thereby its drag strength increases with an increasing angle of attack of the aero foil.
In race cars, wave drag and ram drag are usually negligible. Drag is measured by the drag coefficient, which represents the ratio of drag force to the force from dynamic pressure times the area.

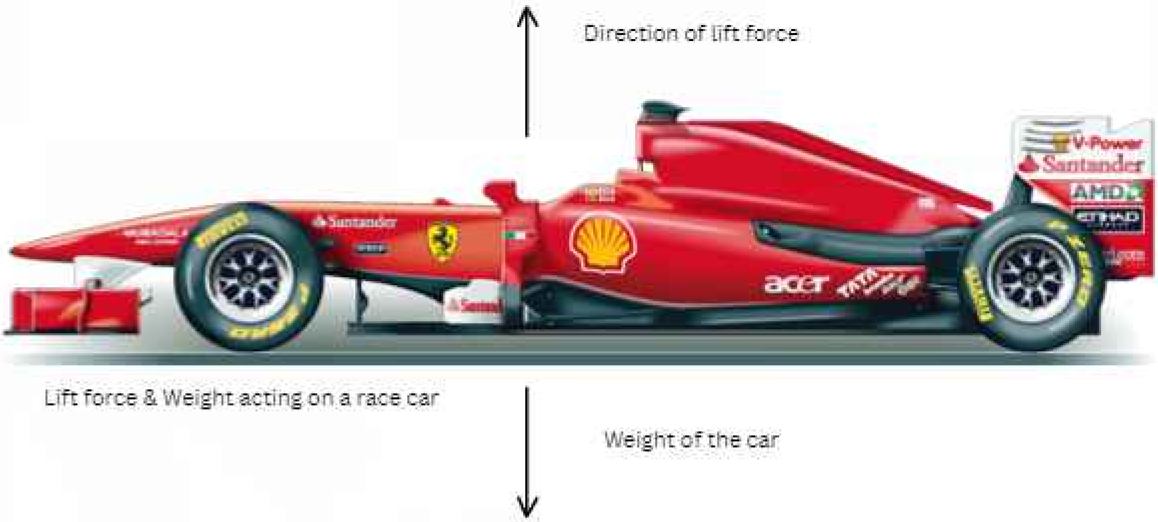
The formula to calculate the drag coefficient is:

$$F_D = \frac{1}{2}\rho v^2 C_D A$$

where Fd is drag force, p is the density of the fluid, v is the flow velocity relative to the object, Cd is the drag coefficient, and A is the reference area.

LIFT AND DOWNFORCE

Lift force directly opposes the weight of a race car, pushing it up. It is created by every part of the car and increases when there is greater air resistance on the vehicle. Here is a diagram to show how the lift force acts on the car.



Lift force & Weight acting on a race car

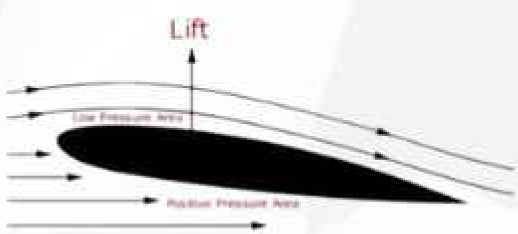
Lift occurs when a moving flow of air is deflected by a solid object, generating lift in the opposite direction according to Newton's Third Law. When more lift is produced, it pushes the wheels down, reducing their grip on the track. This decreases the wheels' rotational speed and the forward force, significantly slowing down the vehicle.

When greater lift is produced, the wheels are pushed down, reducing their grip on the track. This decreases the wheels' rotational speed and forward force, significantly slowing down the vehicle. The amount of lift generated by an object in airflow is measured by the lift coefficient.

It is calculated using the Lift Equation:

$$L = C_l \left(\frac{1}{2}\rho v^2\right) A = C_l q A$$

Where $q = \frac{1}{2}\rho v^2$



Where L is the lift force, Cl is the lift coefficient, p is the density of the fluid, v is the flow velocity relative to the object, A is the wing area, and q is the dynamic pressure.

LIFT AND DOWNFORCE

Downforce, or negative lift, pushes the car on to the track. Down force has to be balanced between front and rear, left and right.

We can easily achieve the balance between left and right by simple symmetry. Front and rear is a different thing. Flow in the front greatly affects flow in the back of the car, and vice versa.

Many people confuse downforce with weight, when they are not the same thing, because weight force of an object due to gravity, acting on the center of mass, while downforce is produced by the whole car.

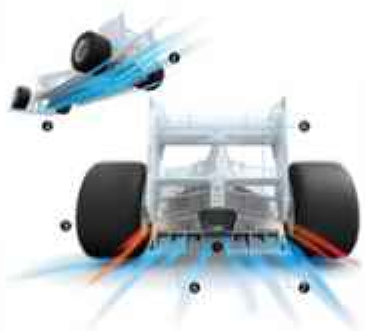
Downforce keeps the car firmly on the track, enhancing wheel grip, which boosts rotation speed and forward force, accelerating the car.

While this explanation of lift and downforce is basic, the actual process is complex and requires powerful computers to study. For gases, we must conserve mass, momentum, and energy simultaneously. Therefore, a change in gas velocity in one direction causes a change in velocity in a perpendicular direction.

The conservation of mass, momentum, and energy in a fluid (ignoring air viscosity) is described by the Euler Equations, named after Leonard Euler. Many computer algorithms use these equations to approximate real-world situations.

LIFT AND DOWNFORCE

There are many parts in F1 cars that are used to create downforce on the car, such as vortex generators, diffusers, spoilers & more. Spoilers are used to reduce the gap between the ground & the vehicle so that, there is less air that goes under, reducing the lift.



Too much downforce is not beneficial for optimum speed, as more downforce may create more friction, reducing the speed of the car on the track.

Due to the complexity, today's Formula One cars are designed using CFD (computational fluid dynamics) and CAD (computer-aided design). These tools let engineers design a car and immediately simulate airflow around it, considering environmental factors like traction, wind speed, and direction.

THRUST FORCE

Thrust is a reaction force that operates according to Newton's third law of motion. Newton's law states that for every action, there is an equal and opposite reaction. In the context of thrust, when a system expels mass in one direction, the acceleration of that mass generates a force of the same magnitude but in the opposite direction. This force that pushes back against the expelled mass is known as thrust.

In Formula 1, the concept of thrust force is crucial for the acceleration of the car. The car's engine burns fuel to expel masses of air from the rear, creating a force in the opposite direction. This reaction force, known as thrust, propels the car forward.

Similarly, in the F1 in Schools competition, the cars use a CO_2 cartridge as their fuel source. The CO_2 gas is released from the cartridge, producing thrust that propels the car. However, it's important for teams to manage this energy efficiently, as most of the gas is expelled at the beginning of the race, leading to significant energy waste.

To optimize performance, teams need to focus on conserving and utilizing the energy from the CO_2 cartridge more effectively throughout the race. Strategies might include improving the aerodynamics of the car, reducing friction, and finding ways to control the release of CO_2 gas for a more sustained thrust. By doing so, they can ensure that their car maintains higher speeds for a longer duration, improving their chances of success in the competition.

THRUST FORCE

The optimization of CO2 chamber energy utilization calls for the implementation of a sophisticated mechanism within the vehicle framework. This mechanism, denoted as a Longitudinal Energy Release System (LERS), effectively captures and dispenses CO2 cartridge energy in periodic bursts. Such integration enhances the vehicular energy matrix, rendering it more streamlined and efficient.

Another way of increasing the thrust force of the car, is by incorporating another of Newton's laws which states:

$$F = ma$$

where in; F - Force, m - mass and a - acceleration

In our context, "force" pertains to the thrust force. This force tends to remain consistent across cars unless teams have integrated an LERS (Kinetic Energy Recovery System) into their car designs. Thus, enhancing acceleration necessitates reducing the other variable: the car's mass.

Teams have various methods to decrease their car's mass, with two notably effective approaches:
1. Crafting the car's body hollow.
2. Utilizing lighter 3D printing materials for manufacturing.

Opting for the first method is best because lightweight 3D printing materials aren't very strong. When hollowing out the car's body, avoid making any part too thin to prevent breakage. You can use the shell tool or cut out sections to make it hollow.

These changes will greatly boost the car's performance by reducing its weight, crucial for acceleration. To win, keep the car's weight under 52 grams. Avoid adding too many paint layers during manufacturing to keep it light.

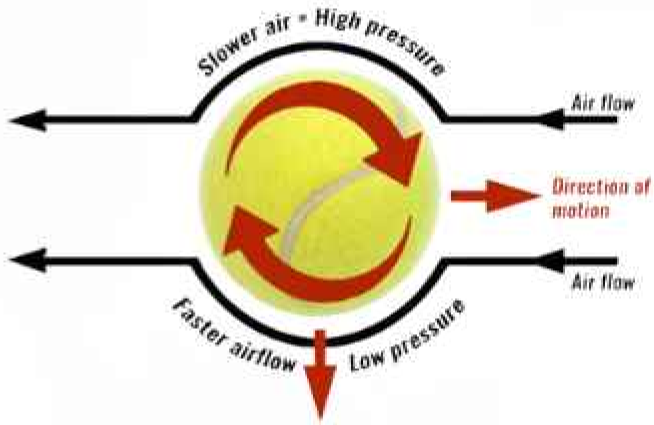
ACTIVITY- RESEARCH TIME

Explore various methods to reduce your car's weight. We recommend drawing diagrams and adding pictures to gain a clearer understanding of how you can achieve this. Your team can also investigate other ways to improve acceleration.

MAGNUS EFFECT & COANDA EFFECT

The Magnus effect is a scientific phenomenon, observed when a spinning object is moves through a fluid. This occurs when there is a relative motion between the spinning body and the fluid. It is responsible for the 'curve' of a served tennis ball or driven golf ball and affects the trajectory of a spinning artillery shell.

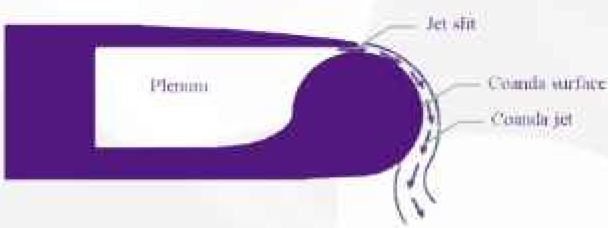
A spinning object moves along a straight path due to the pressure differences that develop in a fluid, which are caused by velocity changes induced by the object's rotation.



The Magnus effect can be interpreted as a manifestation of Bernoulli's Theorem, fluid pressure decreases at points where the fluid speed is increased.

The Coanda effect, in simple terms, is the tendency of a fluid to stay in contact with a curved surface. This concept has significant impacts on the aerodynamics of vehicles. Airplanes stay in the air because the air clings to their wings and body due to the Coanda effect.

To understand this better, consider an example: when water flows off a sloping roof, it sticks to the surface of a gently sloping gutter. Similarly, in cars, the Coanda effect can be used to redirect airflow around the car so that it does not come in contact with other parts of the car.



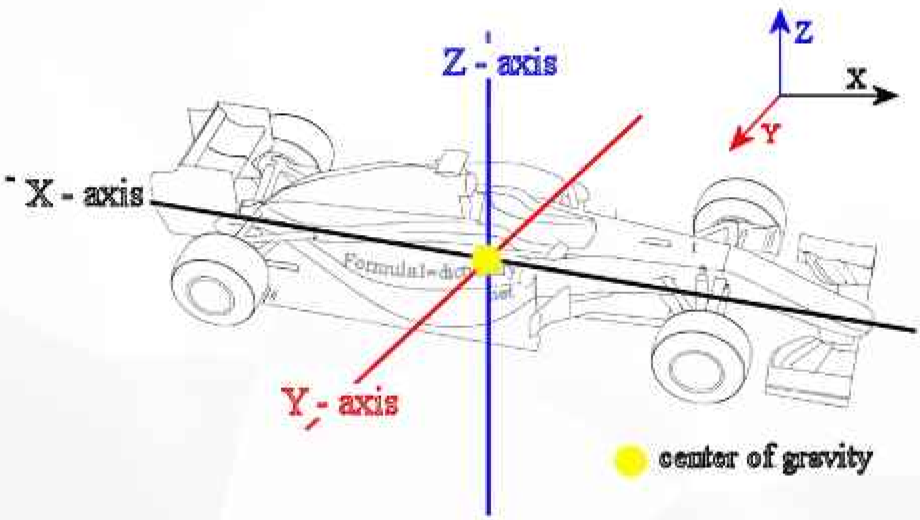
The Coanda effect creates lift, necessitating increased downforce for F1 cars to maintain stability and grip on the track.

In the F1 in Schools competition, the Coanda effect is crucial for designing the car's wings and sidepods. Properly directing airflow can prevent wheel interference and reduce air resistance, maximizing the car's performance.

CENTER OF MASS & STABILITY

The center of mass, also known as the center of gravity or center of weight, is a point within a body where all its mass is considered to be concentrated. Typically, the center of mass is located at the geometric center of the body.

The center of gravity (CoG) is crucial in racing car design, as it affects weight distribution and handling. It needs to be low to the ground because all forces, like acceleration, braking, and cornering, act through it. Having the CoG positioned between the front and rear wheels and close to the ground minimizes the car's tendency to rotate. Tuning the static weight distribution to move the CoG closer to the rear improves traction by placing more weight on the rear wheels.



The location of the center of mass in a car greatly impacts its stability, affecting the likelihood of toppling over. There are two key impacts:

1. Height of the center of mass:
F1 cars are designed with bodies close to the ground for increased stability. A lower center of mass enhances stability, keeping the car in contact with the ground and reducing the risk of wheels lifting off, thus improving efficiency.

2. Lateral position of the center of mass:
It's crucial that the center of mass remains between the right and left wheels to prevent instability and potential toppling if a wheel leaves the surface. While less significant in F1 in Schools due to tether line guides preventing toppling, it's still an important consideration in car design. However, the first point remains critical in F1 in Schools.

MOMENT OF MASS & INERTIA

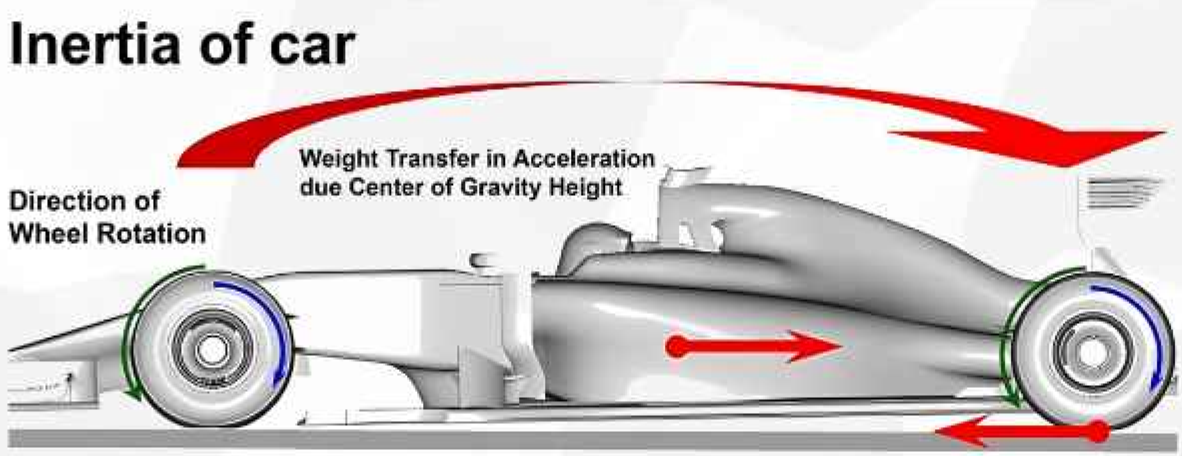
The moment of inertia, a physical property of an object, characterizes its resistance to rotational motion about a specific axis. It reflects how the object's mass is spread out relative to that axis of rotation. Put simply, it quantifies the object's ability to resist changes in its rotational motion.

When we apply this idea to cars, it becomes even more important. Here's why:

a. Acceleration: A car with a larger moment of inertia will be slower to respond to changes in its rotational motion. So, if you're driving a car with a hefty moment of inertia, you'll notice it takes more time to speed up, slow down, or change direction. This slower response can affect things like turning or spinning maneuvers, making them feel more sluggish.

b. Stability: Picture a car making a sharp turn at high speed. The moment of inertia comes into play here, too. A car with a higher moment of inertia will tend to resist changes in its rotation more strongly. This can actually be a good thing for stability – it helps the car stay more planted during turns, reducing the risk of skidding or losing control, especially in tricky driving situations.

So, in essence, the moment of inertia isn't just some abstract concept from physics class – it's a real factor that affects how cars handle and behave on the road.



Acceleration "resisted" by the need to rotate significant masses such as the wheels

NEWTON'S LAWS OF MOTION

Newton's first law of motion, or the law of inertia, asserts that objects will maintain their state of motion unless acted upon by an external force. This principle plays a significant role in F1 in Schools competitions, where various forces impact the performance of the cars.

During the race, the car experiences a series of external forces. At the start, the CO2 chamber provides an initial push, initiating motion. However, as the race progresses, other forces like air resistance and rolling friction come into play, affecting the car's velocity.

Consequently, the car's speed fluctuates throughout the race as it responds to these external influences. Whether it's accelerating, decelerating, or maintaining a constant speed, the car's motion is continuously adjusted in response to the forces acting upon it.

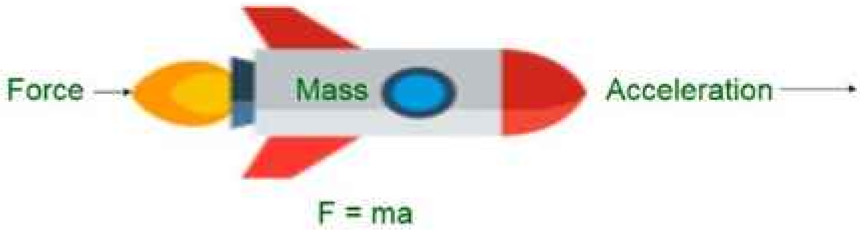
- In essence, Newton's first law shapes every aspect of the F1 car's performance, influencing its straight-line speed, braking, cornering, and response to external factors. Mastering this fundamental law of physics is essential for optimizing the design and performance of F1 cars on the track.

NEWTON'S LAWS OF MOTION

Newton's second law of motion, or the law of acceleration, states that force is equal to the rate of change of momentum. This relates the net force acting on an object to its mass and acceleration. It can be stated mathematically as follows:

$$F = m * a$$

Where: F represents the net force acting on the object, m represents the mass of the object, and a represents the acceleration produced by the net force.



In simpler terms, this law explains how things move when you push or pull them. It says that if you push something harder, it will speed up more, as long as it's not too heavy. But if you make something heavier, even if you push it the same way, it won't speed up as much. Understanding this equation is really important because it helps you design things like F1 in Schools cars.

In the context of F1 cars, Newton's second law has several implications:

1.Accelleration
2.Force Balance

To get a better understanding of the impact of this law in F1 in school's cars. Let us consider an example of the image above:

The man is applying some force F on the car. In our competition this force F is provided by the CO2 chamber canister, is same for all the teams. So, the lefthand side of the equation is the same for all teams. On the righthand side of the equation, we have the mass and acceleration of the car. Now, In order to maximize the car's acceleration, will have to decrease the mass of the car since, the mass of the car is something we can control. We have to keep the mass of the car between 50-51 grams, to maximize the acceleration. Keep in mind, the mass that will be added during any manufacturing defector painting and decals.

NEWTON'S LAWS OF MOTION

Newton's third law of motion, often called the law of action and reaction, states that when one object pushes or pulls on another object, the second object pushes or pulls back with an equal force in the opposite direction.

In simpler terms, this law shows us that when something pushes on something else, that second thing pushes back just as hard in the opposite direction. This helps us understand how things interact with each other and reminds us that forces come in pairs, always acting on different objects at the same time.

In the world of Formula 1 (F1) cars, Newton's third law is hugely important. It tells us that for every action, there's an equal and opposite reaction, and this directly affects how F1 cars perform.

For instance, when an F1 car speeds up, the engine generates a force that pushes the car forward. According to Newton's third law, as the engine pushes the car forward, the car pushes back on the engine with an equal force in the opposite direction. This reaction force pushes down on the ground, giving the car the grip it needs to move forward effectively.

FRICTION

Friction is a force that pushes back when two surfaces rub against each other. It makes it harder for things to slide or move smoothly. Friction happens because surfaces aren't perfectly smooth – they have bumps and rough spots that snag on each other.

There are a few types of friction:

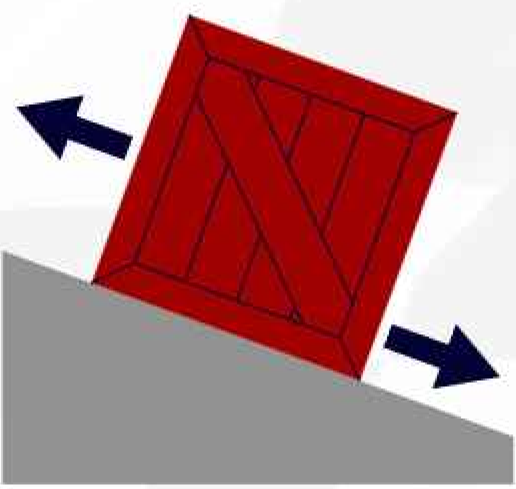
1. Static Friction: This is the force that keeps things still, like when you try to push a heavy box and it won't budge. It's like a barrier that needs to be overcome to get things moving.

2. Kinetic Friction: This type of friction kicks in when things are already moving against each other. It slows them down, making them stop eventually.

3. Rolling Friction: When something rolls over another surface, like a ball on the ground or a wheel on a road, rolling friction comes into play. It's usually not as strong as kinetic friction, so things can roll more smoothly.

4. Fluid Friction: This happens when things move through stuff like air or water. It works against the motion and depends on things like the shape of the object and how fast it's going.

In F1 in Schools, rolling friction and fluid friction really matter for how fast your car goes. Knowing how to reduce these types of friction can make a big difference in your car's speed.

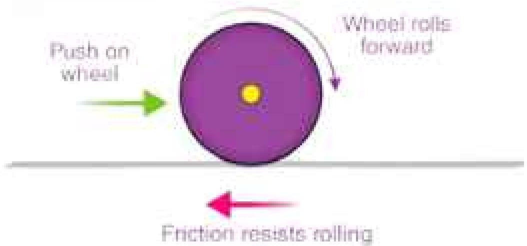


ROLLING FRICTION

Rolling friction, also known as rolling resistance, is a type of friction that occurs when an object rolls over a surface. It's the resistance experienced by a moving object in contact with a surface while rolling instead of sliding.

This rolling friction is primarily encountered in two places: between the outer surface of the wheel and the track, and between the axle and the wheel.

To minimize the impact of this friction, it's important to reduce its effect in both these areas.



The factors that affect the rolling friction include:

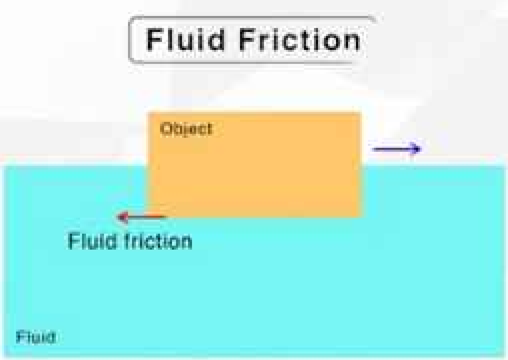
1. Nature of the surfaces: The materials and surface characteristics of both the rolling object and the surface it rolls on can affect rolling friction. Rough surfaces typically result in higher rolling friction compared to smooth surfaces.

2. Load or weight: The amount of weight or load pressing the object against the surface can influence rolling friction. Heavier objects generally experience higher rolling resistance.

The most effective ways to reduce the rolling friction are:

- Optimal bearing usage.
- Regular maintenance of bearings.
- Weight reduction in design aspect.
- Material selection low coefficients of friction for wheel construction.

Fluid friction, also known as viscous drag or simply drag, is the friction which a body faces, when its set in motion through a fluid like air or water. In our case, the fluid is air and the friction is drag. The ways to minimize the drag faced by the car have been spoken about earlier.



ACTIVITY- KEY TAKEAWAYS

After studying the various scientific concepts, jot down the most important points you've learnt for easy reference when designing your car. Writing them down will also help you remember them better.