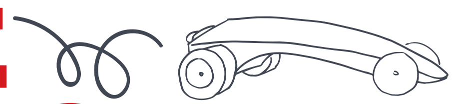
THE SCIENCE OF GOING FAST



LEARN MORE

This site is dedicated to the pursuit of designing and building CO_2-powered race cars and making them go fast. This is accomplished by employing an understanding of the physical forces at work.

CO_2 racing is enormously fun and motivates students to learn. During the last 40 or so years, tens of thousands of students have shared in the experience. Teachers can use this built-in motivation to get students interested in how friction, gas expansion, thrust, and other science concepts play into their success or downfall on the racetrack.

The following are some science concepts that are explored through CO_2 cars. If looking for a more structured curriculum to help you get the most out of dragsters, check out our updated Science of Speed 2 curriculum.

PITSCO EDUCATION

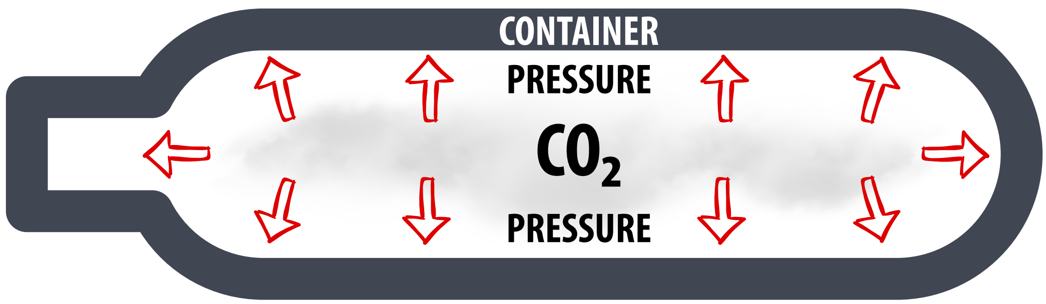
EXPANDING GAS: BOYLE'S LAW

How does a CO_2 cartridge propel a car down the track? What is its fuel? The answer has to do with Boyle's law.

Volume and Pressure

In a confined container, the volume of a gas is inversely proportional to the pressure that is applied when the temperature is constant. Stated another way, if you double the pressure, you reduce the volume by half.

This is exactly the case with CO_2 cartridges. At the factory, they are filled with pressurized carbon dioxide gas and then sealed. The CO_2 is confined to a small container; the volume of the gas would be much greater if it were released into the air. The large volume of CO_2 can fit inside the small cartridge because of the pressure that has been applied to it.



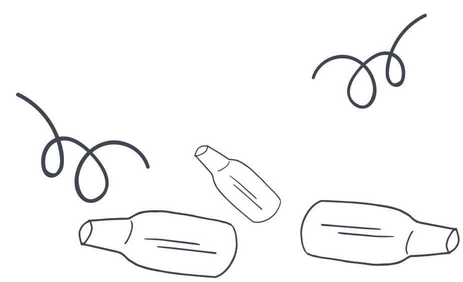
Atmospheric Pressure

The air around us is actually under pressure as well. Atmospheric pressure is 14.7 pounds per square inch at sea level. Imagine a one-inch cube of air. Now, imagine a stack of one-inch air cubes that reaches from the ground all the way to the edge of the Earth's atmosphere. That stack of air cubes actually weighs 14.7 pounds.

The pressure inside a CO_2 cartridge is far greater than atmospheric pressure. That's why the gas escapes so rapidly when the cartridge is punctured. The gas continues escaping until the pressure inside the cartridge equals the atmospheric pressure outside the cartridge.

ACCELERATION

Simply put, acceleration is the rate of change in velocity. When a CO_2 cartridge is punctured, the equal and opposite reaction (see Thrust on p. 3) of the gas leaving pushes the dragster away from the launch pod. This force keeps pushing the car forward until all the gas is out, so the car keeps accelerating even after the launch.



This is another reason why a lighter dragster will usually go faster – the force the cartridge provides makes a light dragster accelerate more than a heavy one.

INERTIA

Inertia is a property of matter by which it remains at rest or in steady motion in the same direction unless acted on by some other force.

What this means for a race car: the greater the mass of a stationary car, the more energy required to get it moving. If two cars use the same amount of propulsive energy, the car with the lower mass will accelerate faster – and win the race.

Surface friction and fluid friction also come into play as the inertia of the stationary car is overcome. If the masses of two cars are equal, the winner will likely be the car with the least friction (more on that below).

Because all CO_2 race cars use the same amount of propulsive energy (the escaping gas from a CO_2 cartridge), it is important to reduce all factors – mainly mass – that contribute to inertia.

THRUST: NEWTON'S THIRD LAW OF MOTION

Sir Isaac Newton's third law of motion states that for every action (or force) there is an equal reaction (or opposing force) in the opposite direction.

CO_2 cars are propelled by carbon dioxide rapidly escaping from the cartridge. The cartridge is positioned in the car so that the escaping gas moves rearward. The rearward force of the escaping gas is the initial action described by Newton.

The reaction part of Newton's law is fulfilled by the car's movement. Remember that the reaction occurs in the opposite direction: when gas escapes rearward, the car moves forward. As the car begins to move, its inertia is overcome.

FRICTION

Simply put, friction is the force that resists motion between two points of contact – such as where the wheel touches the ground or where the car's surface pushes against the air.

There are two types of friction that come into play with CO_2 race cars: surface friction and fluid friction. Both of these are inversely proportional to speed!

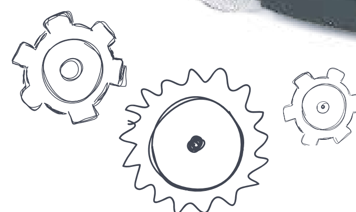
Surface Friction

Depending on a car's design, friction might occur between either the wheel and axle or the axle and body material. An often-overlooked fact: smaller-diameter wheels rotate more times as they travel a given distance than larger-diameter wheels do. Therefore, friction is more prevalent with smaller-diameter wheels.

FRICTION
FLUID
SURFACE

Friction also occurs between the wheel and the track surface. In a passenger car, friction between the tire and road surface gives you traction, which is a good thing. The wheels, however, do not propel a CO_2 car, so the less wheel-road surface friction, the better.

While friction can be reduced for better performance, it cannot be totally eliminated.



CHECK OUT:
FLO Visualization Tunnel

Fluid Friction

As the race car travels down the track, it moves through a fluid. Most people don't think of air as a fluid, but it is. While in motion, the car's surface contacts air molecules. Because there is relative motion between the car and air molecules (the car is in motion while the air is stationary), friction occurs.

Fluid friction contributes to aerodynamic drag, which is a resistance to the forward motion of a body through a fluid (the air).

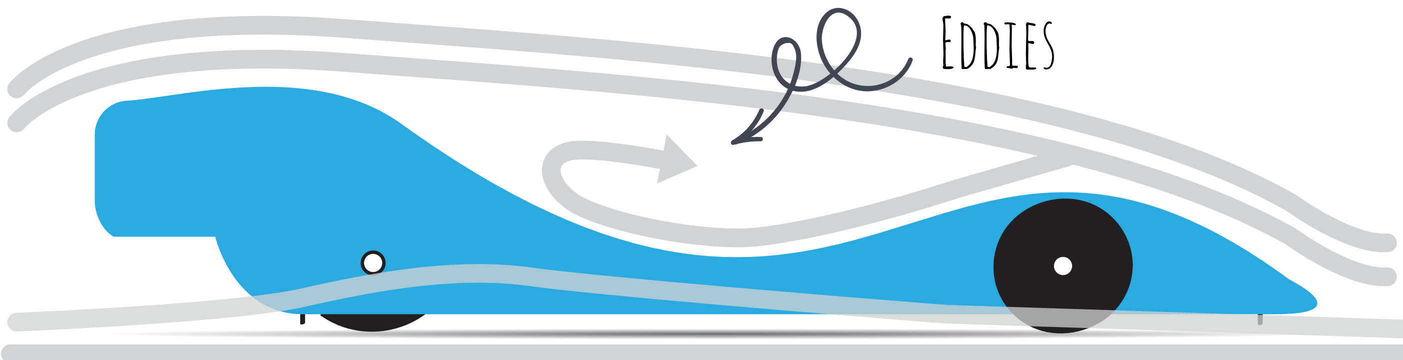
Though they use computer modeling, automotive engineers also test their designs in wind tunnels to see where drag might occur. A wind tunnel simulates road airflow conditions by moving a stream of air around a stationary car. Luckily, there are smaller wind tunnels than what the pros use, including some priced for the classroom, though they might not have all the same features. For example, wind tunnels used by automotive companies often have a rolling road created by a movable floor.

Well-designed wind tunnels produce a laminar airflow. Laminar flow is a straight, layered flow of air without turbulent air pockets known as eddies – this is usually visualized by using a fogger with the wind tunnel. It is desirable for a car in the tunnel to disturb the laminar flow of air as little as possible. On a regular car, features such as large side mirrors jut out into the airstream and cause turbulence.

The presence of turbulence increases the aerodynamic drag, which resists the car's forward motion. The amount of turbulence depends on the shape of the car, wheel placement (which is why some people create shell cars – to keep the wheels out of the airstream), and even the paint job.

Here are some factors that determine the amount of friction between two surfaces:

- What the two surfaces are made of. If the surfaces are made from materials that are naturally slick, they will not have as much friction as other materials. Lubricants can increase how slippery a surface is, which is handy if you cannot use a very slippery material.
- How rough the surface is. Rough surfaces have greater friction than smooth ones.
- How much force is pushing the two parts together, or frictional force. The more force, the more friction. In some friction points of a car, the overall mass of the car will affect the frictional force.



DRAG

It's a drag when your car doesn't perform well, so it behooves you to teach students to pay attention to drag, which is a part of the aerodynamics of a car. As a dragster moves through the air, it is met with air resistance as speed increases. This air resistance pushes against your CO_2 car and prevents it from going as fast as it could in a vacuum. This is drag. You'll never be rid of drag completely; however, you can reduce it by designing a more aerodynamic car, but sometimes that is easier said than done.

Testing in a wind tunnel helps identify where your car might be creating more drag than it should. If you design your car in a CAD program, you can also test your virtual dragster from the design stage right on your computer using computational fluid dynamics (CFD). When using a wind tunnel, you want a smooth flow of air free of swirling currents called eddies. If you have too many of those, you might want to use sandpaper to smooth out the design or go with a new one altogether.

For a detailed curriculum about building dragsters and learning related STEM concepts, check out Pitsco's The Science of Speed 2 curriculum units.