ground effects innovations
in Automobile Racing

Questions for Analysis

What are ground effects? How do they use physics principles? How are they important for race cars?

Key Concepts

Airfoil
A winglike device on a race car that creates downforce as the air flows over it.

Bernoulli's principle
Air moving faster over the longer path on a wing causes a decrease in pressure, resulting in a force in the direction of the decrease in pressure.

Downforce
The force on a car that pushes it downward, resulting in better traction.

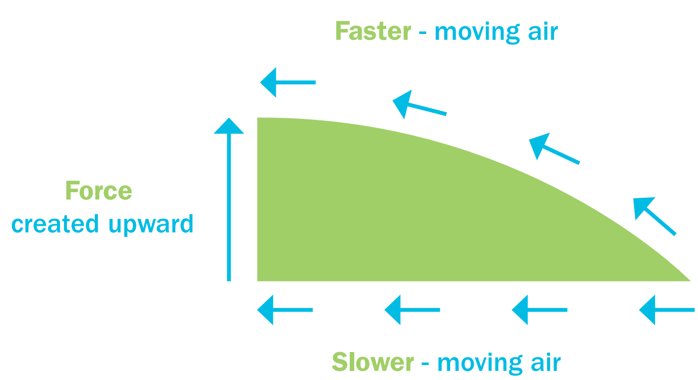
Ground effects
The effects from aerodynamic designs on the underside of a race car, which create a vacuum.

Pressure
Force divided by area.

Motion of Air and Its Effects on Racing

Race car designs can manipulate the motion of air around the cars through aerodynamics. A ground effect results from an aerodynamic design on the underside of a race car, which creates a vacuum.

One of the most interesting aspects of automobile racing involves Bernoulli's principle. Fast-moving air produces a drop in air pressure and a force in the direction of the drop in pressure. If you look at a wing of an airplane, you will see that the top of the wing has a longer surface than the bottom of the wing. The air has to travel faster over the longer, upper surface. The faster-moving air produces a drop in pressure above the wing, giving the bottom of the wing comparatively higher pressure. There will be a force created from the pressure difference, and that force will push, or lift, the wing upward. In the drawing below, note that the air is coming in from the right.



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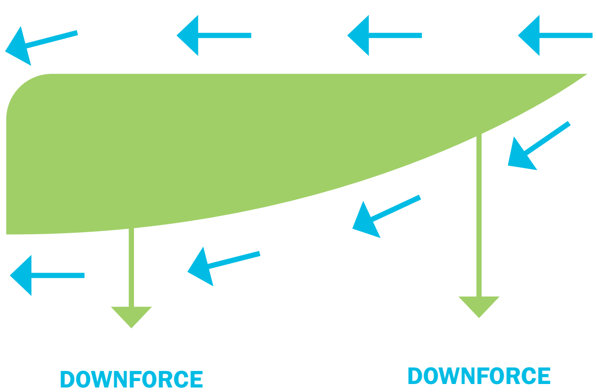
Downforce and Bernoulli's Principle

Race car engineers have used this concept to make small winglike objects called airfoils. They are actually wings turned upside down, so the longer surface is on the bottom. The wing is attached to either the front or the back of the car to push down on the car, thus gaining better traction. Look at the airfoil on the Texaco Star race car [March 84C Race Car, 1984 (aerial view ID# THF69371)].

The airfoils are attached to the top of the car above either the hood or rear area. As the air passes over the airfoil, the faster-moving air below causes a drop in pressure under the wing and a comparatively higher pressure above the wing. A force is created from high pressure to lower pressure. This effect causes a downforce to force the car down.



The faster-moving air goes under the airfoil wing. The faster-moving air causes a drop in pressure. The drop in pressure causes a downward force.

There is a second way to gain downforce. The fronts of race cars (and passenger cars) are slanted downward, not to take advantage of Bernoulli's principle, but simply to allow air to pass over the car without pushing against the front of the car.

Wind Resistance

A large force in racing is wind resistance, or drag. At high rates of speed, the air pushes against the front of the car. This causes a great force against the race car.

Innovators are constantly redesigning cars to cut down on wind resistance by shaping the front of the car. Look at Willys Gasser, 1958 (front view ID# THF69394). This car certainly would cause a great amount of air resistance, requiring the car to push the air. The force of the air would have slowed the acceleration and speed of the car. To decrease the air resistance from its large, flat front, the top of the Gasser was chopped off and lowered. When the Gasser's owner, George Montgomery, finally retired the Willys, he replaced it with a modified Mustang that was much lower and had better aerodynamics.

Notice the difference between the shape of the Gasser and the shape of the Ford Thunderbird [Ford Thunderbird, NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69264)]. The front of the Thunderbird is slanted forward. This allows two advantages. First, the air rides over the top of the car without pushing straight back against the car so there is less force opposing the car's motion. Second, when the air hits the front of a race car with a low front and continues over the top, the air actually pushes down on the front of the car to give it better traction. There is a downward force on the front of the race car that gives the tires better grip and allows for faster cornering. Notice that the low-sloped front causes the oncoming air to push down on the front of the car.

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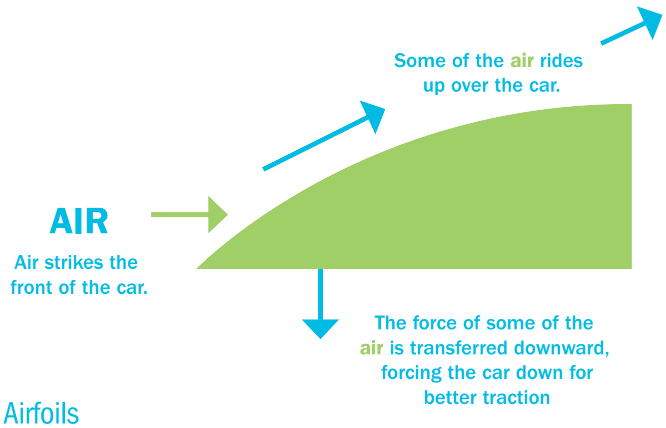


Airfoils

Sometimes the airfoil itself is tilted so that the airfoil transfers force directly downward to the car. When the air strikes the tilted airfoil, there are two forces produced. Not only is Bernoulli's principle in effect, but the tilt of the airfoil causes a transfer of the force downward. The angle of the airfoil can be adjusted for different racing conditions. If the track has more straight sections, the foil is kept level with the track. If there is a lot of cornering, the foil is tilted to produce more downforce. Notice the airfoils on the Texaco One Car [March 84C Race Car, 1984 (side view ID# THF69368)].

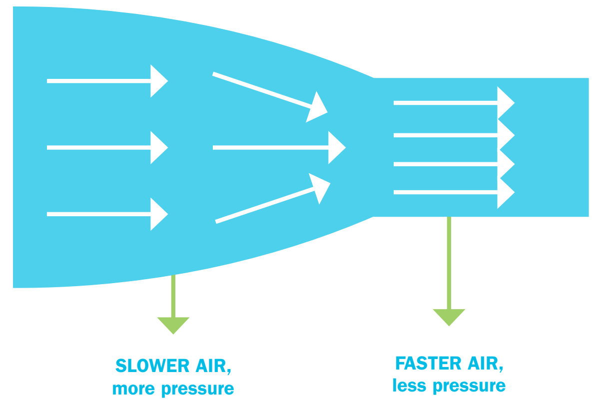
Notice how the air moves in from the left. The air strikes the front of the airfoil, which is slanted downward on this side. The angle of the air against the foil causes a push, or downward force. The airfoil is attached to the hood and therefore forces the car downward onto the track, allowing greater traction for cornering.

The drawback to using the airfoil angled downward is that it increases the force against the front of the car, slowing it down. This represents a trade-off: The car gains cornering ability but loses overall straightaway speed. An airfoil angled downward would only be useful on tracks with short straightaways and a higher percentage of curves.

Venturi Effect

Another method of achieving downforce is through the Venturi effect. When air, a fluid, travels through a space that changes from a large cross-section to a smaller cross-section, the same amount of fluid (air) must pass through the constriction, so the air gains speed there. Faster-moving air causes a decrease in pressure, so there is a force, or pressure, created toward the faster-moving air.

If the Venturi section is placed beneath the race car, the car will be forced down for greater traction.



Jim Hall, Aerodynamics Innovator

Automobile racing has not always taken advantage of aerodynamics in the ways described here. Jim Hall, an engineer and former race car driver from California, pioneered a new way of thinking about and using aerodynamics in the 1960s and '70s. Rather than trying to prevent aerodynamics from hurting the car's performance, Hall began searching for methods of using aerodynamic force to help the car. He especially worked on increasing the downforce on his cars, which would help them hold the road better, particularly on turns. He did this with wings and the shapes of car bodies. His cars won a number of races, both in the United States and in Europe, and profoundly influenced race car design. Hall's next innovation was to suck air from underneath the car instead of using air to press down on the car from above. He did that with a fan driven by a separate motor from the car's motor. It worked so well that his competitors got the innovation banned. Racing rule makers often outlaw new innovations, just to give other race teams a chance. Wings were also banned after competitors did a poor job of imitating Hall's wings, resulting in racing accidents. Even though his original solutions were banned, Hall inspired others to keep looking for a positive way to use aerodynamic forces, leading to the development of ground effects.