Lesson 4 Ground Effects Innovations in Automobile Racing

Questions for Analysis

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

Key Concepts

- Airfoil
- Bernoulli's principle
- Downforce
- Ground effects
- Pressure

Digitized Artifacts
from the Collections of **The Henry Ford**

Lesson 4
Ground Effects Innovations in Automobile Racing

- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird, NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69264)
- March 84C Race Car, 1984 (aerial view ID# THF69371) (side view ID# THF69368)

Materials

- Computers with access to the Internet; digital projector and screen (preferred) OR printed handouts of Background Information Sheet, Student Activity Sheets and digitized artifacts' images and descriptions
- Background Information Sheet for Students 4A: Ground Effects Innovations in Automobile Racing
- Student Activity Sheet 4B: Ground Effects Innovations
- Answer Key 4B: Ground Effects Innovations

Duration 1-2 class periods (45-60 minutes each)

Instructional Sequence

1. Introduce the concepts of aerodynamics, air movement and forces.
2. Distribute copies of Background Information Sheet for Students 4A: Ground Effects Innovations in Automobile Racing. If possible, access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.
3. Use the Background Information Sheet to review, read and discuss with students the questions for analysis, key concepts, and information about aerodynamics, air movement and forces as they apply to automobile racing.
4. Encourage students to make their own observations, ask questions and offer other examples that illustrate these concepts in everyday life.
5. Follow up with discussions of Bernoulli's principle.
6. Ask students to draw their own illustrations of Bernoulli's principle or free-body diagrams on the board.

Assessment

Have the students complete Student Activity Sheet 4B: Ground Effects Innovations to assess their learning and understanding.

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.

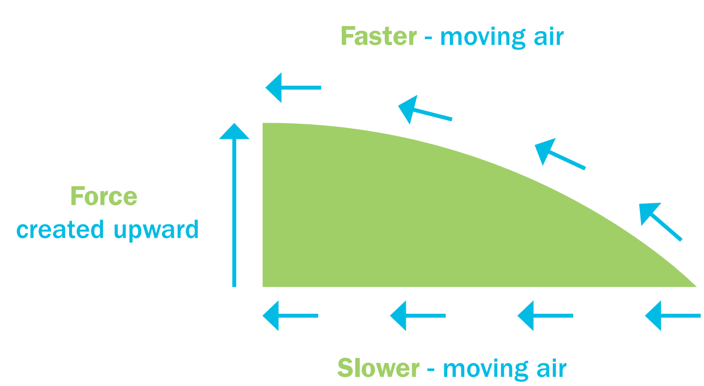
Pressure

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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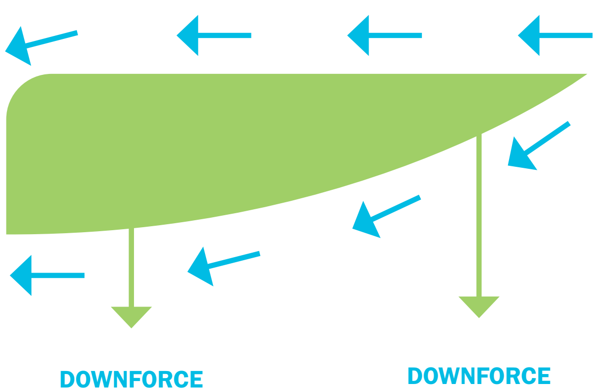
Downforce and Bernoulli's Principle

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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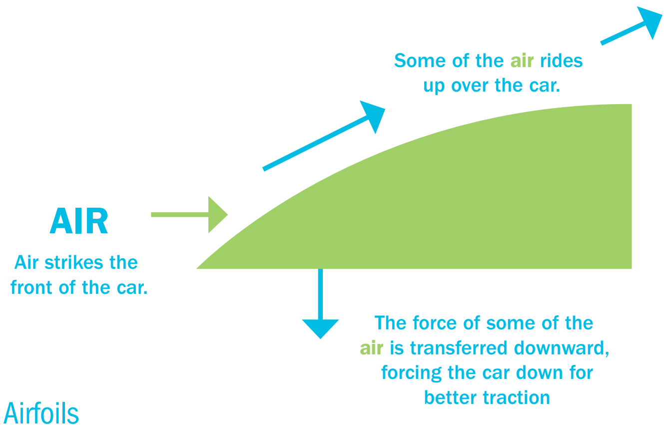


Airfoils

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)].

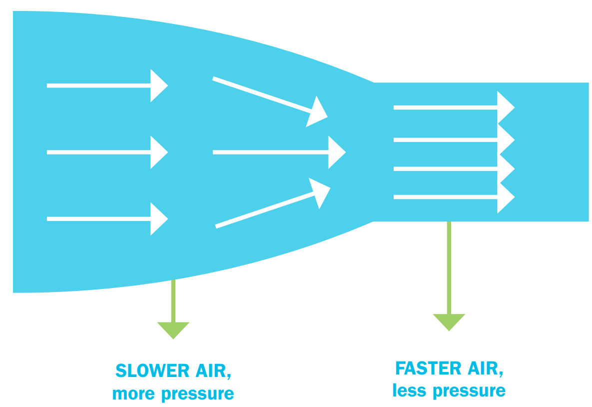
Notice how the air moves in from the left. The air strikes the front of the airfoil, which is slanted downward on this side. The angle of the air against the foil causes a push, or downward force. The airfoil is attached to the hood and therefore forces the car downward onto the track, allowing greater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

Name ______________________________

ground effects Innovations

1. Why do race car drivers race so closely together, often in a long row?

2. Using your own words and diagrams, describe how air creates downforce as air passes over an airfoil.

3. Compare the air flow around the Willys Gasser, 1958 (front view ID# THF69394) with the air flow around the Ford Thunderbird, NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69264).

4. Describe the forces from the air around the Indianapolis-style car March 84C Race Car, 1984 (aerial view ID# THF69371).

5. Why do you think that all NASCAR race cars in the same race must weigh 3,400 pounds, be no closer to the ground than 1 inch and be exactly the same height?

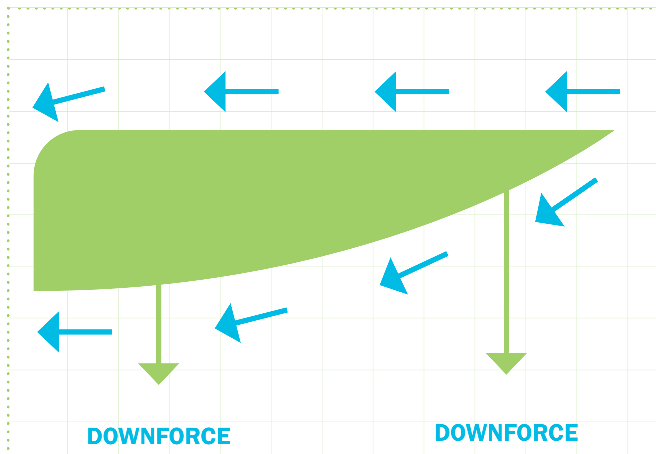
ground effects Innovations

1. Why do race car drivers race so closely together, often in a long row?

The air rises over the first car and then continues over the second car without causing a force on the front of the second car. The air flows over each succeeding car in the same manner so that they need not fight the wind. The front car also benefits, because a vacuum forms behind the first car, actually giving it push.

2. Using your own words and diagrams, describe how air creates downforce as air passes over an airfoil.

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 goes from high pressure to lower pressure, causing a downforce on the car.



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.

3. Compare the air flow around the Willys Gasser, 1958 (front view ID# THF69394) with the air flow around the Ford Thunderbird, NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69264).

The front end of the Willys Gasser is fairly flat, which means the "Gasser" has to push more against the air. The opposing force of the air decreases the possible speed of the "Gasser." The red Thunderbird is aerodynamically engineered with a sloping front to allow the air to pass over with less back force, so the red Thunderbird can travel faster and get better fuel mileage.

4. Describe the forces from the air around the Indianapolis-style car March 84C Race Car, 1984 (aerial view ID# THF69371).

- *Car is slender, so it has less air resistance.*
- *Car nose is knife-like, so it causes less air resistance.*
- *Airfoils can be adjusted for greater downforce to corner better.*
- *There are no extra grilles or other objects to catch the wind.*

5. Why do you think that all NASCAR race cars in the same race must weigh 3,400 pounds, be no closer to the ground than 1 inch and be exactly the same height?

NASCAR does not want the cars to travel too fast because the chances for accidents increase with too much speed. Having the same weight controls acceleration. (More weight or mass means less acceleration.) The distance under the cars must be a distinct height so everyone experiences the same downforces. The height affects the air resistance. By controlling the height, the speeds are controlled for safety.