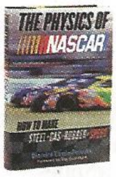
The Physics of NASCAR

A new book explains why Sir Isaac Newton will always be the champion of any track

BY DIANDRA LESLIE-PELECKY



THE MORNING I DROVE THE track at the Texas Motor Speedway was a dreary Friday in February. Heading west on Texas Highway 114, you get the feeling that you aren't going anywhere. The speedway—known to NASCAR fans simply as TMS—dwarfs the surrounding town, but you don't see it until you reach the top of a hill, and then there it is. TMS is a 1.5-mile track that holds 200,000 spectators. Today I'd be one of the few who get to experience things from the driver's side.

I would be driving today at up to 150 m.p.h., which means that in 1 sec., I'd travel almost three-quarters of a football field. I am a NASCAR fan and professor of physics at the University of Texas at Dallas, so I grasp that in my brain. But that's not the same as having a gut-level feel for it.

I arrived at the track and, after donning a fire suit and helmet, faced my first challenge: getting into the car. Standing on the driver's side facing forward, I swung my right leg into the window, got my other leg in and contorted into the seat. I'm 5 ft. 6 and very flexible. Two-time Daytona 500 winner 6-ft.-5 Michael Waltrip either is a very limber guy or has a high tolerance for pain.

I felt a bit claustrophobic in the car, more so after an employee slipped the steering wheel onto the column. The seat, which enveloped me, was low in the car. The biggest modification to the car I'd be driving was the addition of a second seat, which today was occupied by my instructor, Paul.

Driving a stock car is nothing like driving a street car really fast. The first part of Newton's law of inertia says a body at rest tends to remain at rest unless something makes it move. The tires move the

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Three forces are at play in a turn ...

A car moving at 180 m.p.h. in a straight line will keep moving 180 m.p.h. in a straight line. That's the law of inertia. But a NASCAR race is a long series of left turns, and that's where the race is won or lost. In a turn, drivers must counter the car's inertia or they'll go straight into the wall. A successful high-speed turn is a delicate balance of three powerful forces acting all at once and constantly changing. Too much or too little of any force could lead to disaster

GRAPHIC BY LON TWEETEN

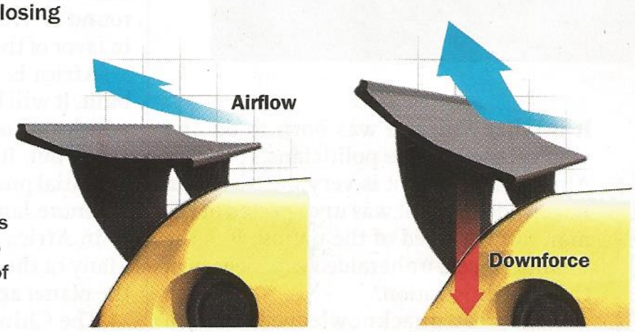
1 CENTRIPETAL FORCE
The "center-seeking" force pulling inward to make the car turn fights the car's inertia, which wants the car to go straight. This creates the feeling that the driver is being pushed outward

Direction of forces

... and three adjustments counter them

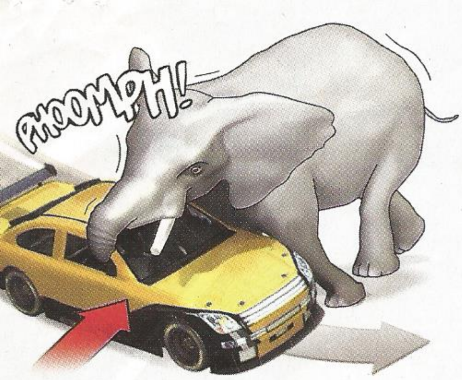
In previous years, NASCAR teams built different cars for different tracks. Today NASCAR has one vehicle style for all tracks, but that car can be customized in small yet critical ways to suit various racecourses and a driver's feel for the car's performance. Even minute changes can mean thousandths of a second—and the difference between winning and losing

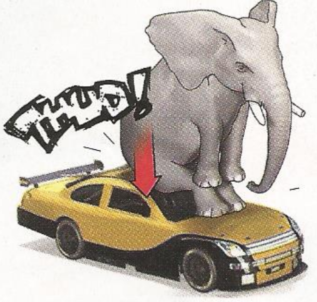
1 THE WING
The rear wing can be adjusted up to 16° from horizontal. Because each track is different, crews try to find the perfect mix of stability and drag for each race



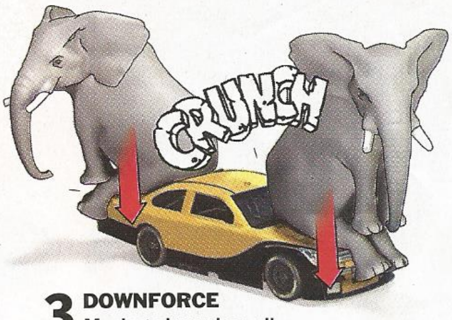
Air flows smoothly over the wing, with less drag on the car

More air strikes the wing, increasing rear-end stability

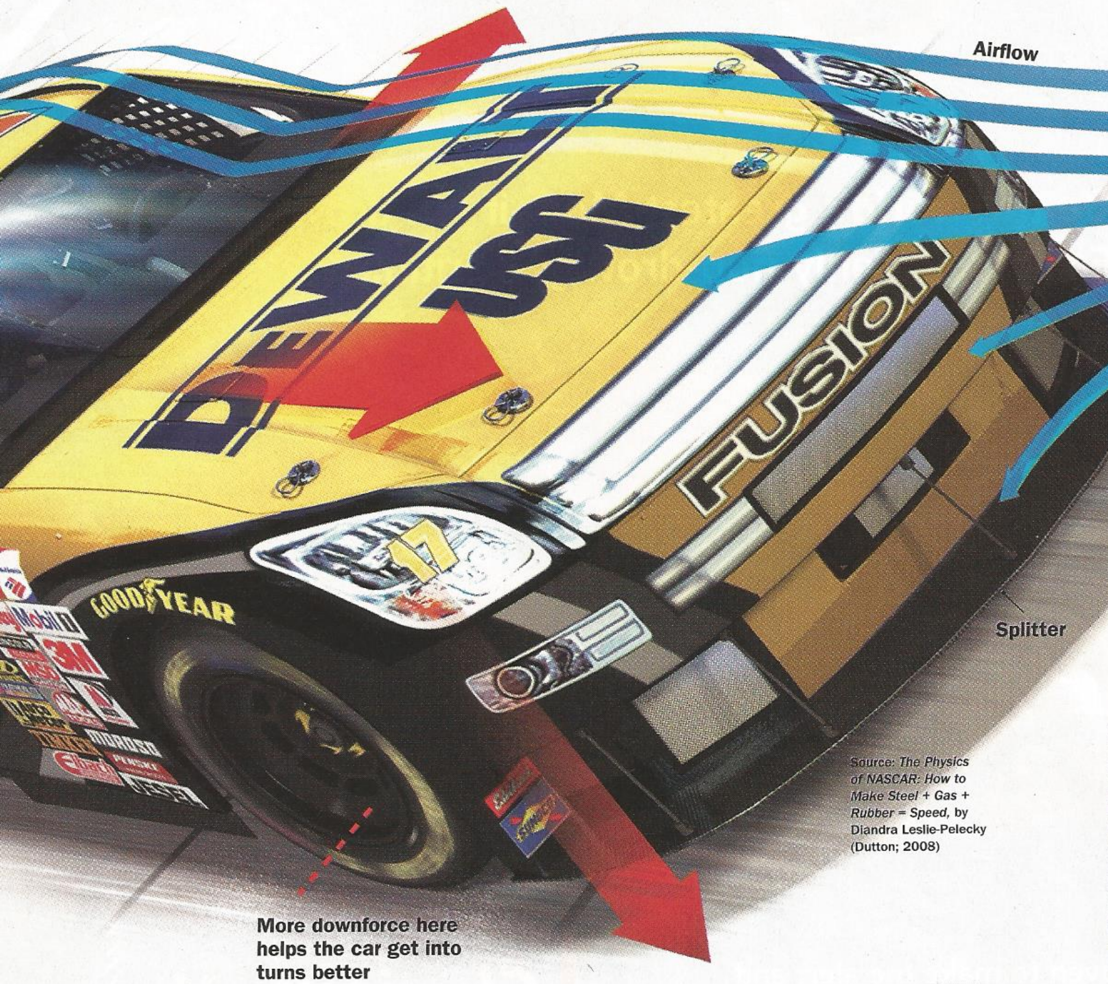




2 FRICTION The tires grip the track—a result of the car's weight pushing down. Without it, the car would skid

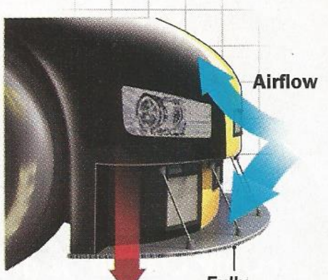


3 DOWNFORCE Moving air pushes all around the car. The air pushing down creates additional grip. Faster air means more downforce



Source: *The Physics of NASCAR: How to Make Steel + Gas + Rubber = Speed*, by Diandra Leslie-Pelecky (Dutton; 2008)

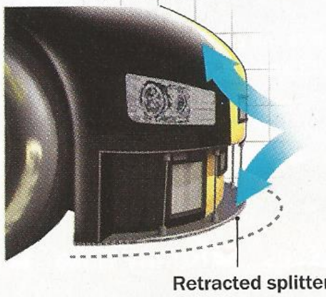
More Speed For an enhanced interactive NASCAR graphic, visit time.com



2 THE TIRES Each is inflated differently. Most teams use nitrogen to avoid pressure changes caused when water molecules inside a tire heat up during a race

Lower pressure increases the tire's "footprint"—its grip on the track

The right-side tires bear more weight during turns, so they get inflated more



3 THE SPLITTER The small shelf along the nose of the car can be pushed forward to increase downforce by directing more air onto the front end chassis, the chassis moves the seat, and the seat moves the driver. The second part of Newton's law dictates that a car moving at 150 m.p.h. keeps moving at 150 m.p.h. in the same direction unless something causes it to change its speed or direction. When you brake, your body keeps moving forward until the seat belts exert a force that stops you.

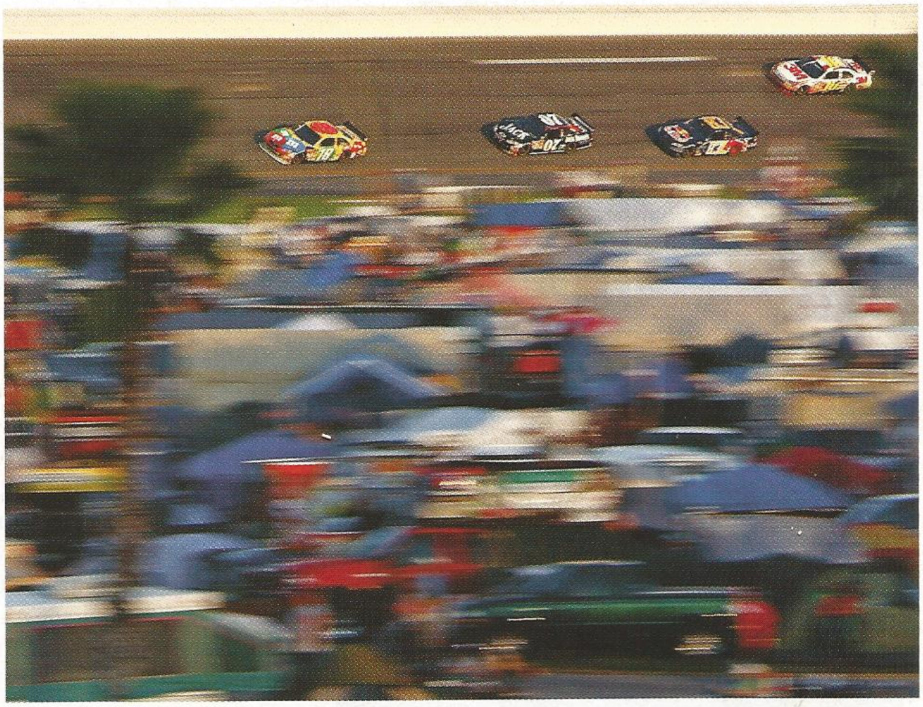
Just as you feel pushed backward when you accelerate and forward when you brake, when you turn, you feel pushed toward the outside of the circle. This is often described as centrifugal force, but there isn't really a force pushing you outward. There is, however, an inward-pointing force called "centripetal" (or "center-seeking"). Centripetal force is the reason cars turn; the force you think you feel pushing your body outward is actually your body trying to obey Newton and go straight.

When you accelerate, you feel a "g" force. The *g* stands for *gravity*, which is misleading because it's really a measure of acceleration in any direction. A dropped object accelerates by 32 ft. per sec. (22 m.p.h.) every second, the standard measure of 1 G. Going from 0 to 70 in 5 sec., you experience acceleration of 0.6 G. If you weigh 160 lbs., that means you feel a force of 96 additional lbs.—or 0.6 of body weight. A space-shuttle liftoff creates an acceleration of 3 Gs, which feels like three people your weight sitting on top of you. During a race, a NASCAR car can accelerate from 0 to 200 m.p.h. in 12 sec., which is almost 0.8 G.

Another force is exerted by air. People say Dale Earnhardt Sr. could "see" the air because he was so good at using aerodynamics, but most of us don't have that ability. A wind tunnel helps. The fans in a tunnel produce a flow that acts like sheets of air on top of each other. Pressure gauges measure how hard the air hits the car. The car itself sits on a scale sensitive enough to detect the change in weight when a half-dollar is placed on the bumper.

A car's weight doesn't actually change when air moves over it; instead some of that air pushes down. The faster you go, the more downforce you get. Although most of the air travels over the car, some gets beneath it. If the force of the air flowing underneath is greater than the force of the air flowing above, you get lift, which is not what you want. One of the reasons the back end of a stock car is higher than the front is to help air escape.

Grip on the track is maintained by the flat area on each tire where it touches the ground, called the "contact patch." The contact patch for a tire on my pickup truck is about 4 in. long by 7 in. wide, or 28 sq. in. The contact patch for a Goodyear racing tire is roughly 36 sq. in., which is about the size of a man's size-11 shoe. A typical tire pressure for a consumer vehicle is 30 lbs. per sq. in. (psi). On NASCAR cars, a tire may be inflated to only 10 psi. But pressures don't stay low very long.



High speed, hard science *For a while, Kyle Busch set the pace in his No. 18 car at this month's 50th running of the Daytona 500. In the end, though, Busch finished fourth to winner Ryan Newman*

When the air in a tire heats up—which it does quickly as the tire rotates on the track—the molecules move faster, exerting more force. On passenger cars, tire pressure may change 1 psi for every 10°F temperature change. Your tires reach about 160°F on the expressway, but the tires of a race car can reach 300°F. After a long run, pressures in left-side wheels can increase 10 psi, and right side 20 psi.

None of this was on my mind when I took my turn at TMS. We trundled down pit road, and when Paul motioned, I pressed the clutch, shifted into third, then released the clutch and stepped on the gas. Actually, I stepped on the gas *and* brake because they are so close together. Paul and I shouted, "Whoa!" I recovered, shifted cleanly into fourth and moved onto the track.

Driving a stock car is nothing like driving a street car really fast. I asked how fast we went, figuring we hit 120 m.p.h. In fact, we were going 148 to 150

A NASCAR engine is optimized for speed, so when you're puttering along at 100 m.p.h., it chugs uncomfortably. The solution is to go faster. Paul gave me the thumbs-up, letting me increase my speed. As we completed laps, I started to appreciate what spotters mean when they tell drivers, "Get back in your rhythm." The repetition of slow-constant-fast sequence around the corners is comforting. I learned to brace myself against the seat as we were thrown to the right around corners.

As I passed the start-finish line on what I thought was a particularly good lap (Paul had given me a level-off hand signal on the backstretch), I realized that the flagman had waved the white flag, signaling that this was the last lap. I had been warned to resist the urge to think, "This is the last lap—now I need to go really fast," but before I finished that thought, the checkered flag was waving and we coasted into the pit.

It didn't matter that the cars don't have speedometers, because I didn't take my eyes off the track once. I asked Paul how fast we went, figuring we hit 120 m.p.h. In fact, when he gave me the level-off sign, we were going 148 to 150 m.p.h. When I climbed out of the car, I realized my legs were wobbly and my heart was racing. As I exited TMS later in my own car and headed back down Highway 114, I counted no fewer than five cars pulled over by the police. I made a mental note to watch the speedometer. ■