C • H • A • P • T • E • R 2

Racing on the Ceiling, Swimming Through Syrup

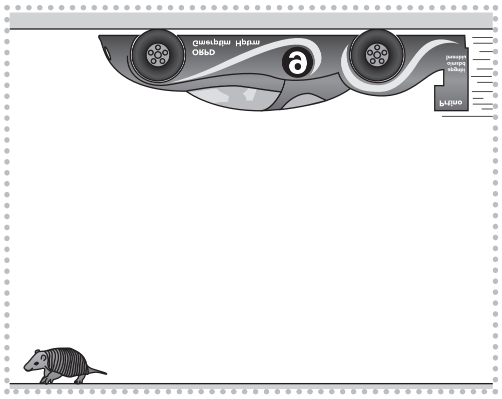

Figure 2-1 / *Item 2.1*

2.1 • Race cars on the ceiling

A car traveling through a flat turn in a Grand Prix race depends on friction to stay in the turn. However, if the car is going too fast, friction fails and the car slides out of the turn. In earlier times, a car had to take the flat turns rather slowly. But modern race cars are designed so that they are literally pushed down onto the track to give the tires good grip. In fact, that push down, called *negative lift*, is so strong that some drivers boast they could drive their cars upside down on a long ceiling. What causes negative lift, and can a race car actually be driven upside down as done fictionally by a sedan in the first *Men in Black* movie?

Negative lift is dependable when a car is the only one taking a turn as in, say, a time trial, but a skilled driver knows that negative lift can disappear during a race. What causes it to disappear?

Answer About 70% of negative lift on a car is due to one or more wings that deflect the passing air upward. The rest of the negative lift is called *ground effect* and has to do with the airflow beneath the car. The faster a car moves, the greater both aspects of negative lift are. At the high speeds typical in a Grand Prix, the negative lift is larger than the gravitational force on a car. Thus, if the car were to move from a normal track to a ceiling (without slowing), the now upward negative lift would more than offset the downward gravitational force. Thus, the car could indeed be driven upside down as in *Men in Black*.

Ground effect is due to the constricted flow of air below a car. As air is squeezed into a small passage beneath the car, its speed increases at the expense of its pressure. So, there is lower air pressure below the car than above it, and the pressure difference presses the car onto the track. In a race, a driver can reduce air drag on the car by closely following another car, a procedure known as *drafting*. However, the leading car disrupts the steady flow of air under the trailing car, eliminating the ground effect on it. If the trailing driver does not anticipate that elimination and slow accordingly, sliding into the track wall may be unavoidable.

The Chaparral 2J was an early race car using ground effect. It had two fans at the rear to suck air under the car from openings at the front. A road-hugging skirt along each side prevented air from the sides from entering the flow. The low pressure beneath the car held the car on the track in a fast turn, and the outflow from its fans diminished the normal vortex formation behind the car, reducing the air drag on the car. As a result, the car was reasonably fast on the straight-track sections and unbeatable on the turns. It was so good, in fact, that it was banned from races.

2.2 • Drafting

Race car drivers in many styles of racing take advantage of one another by *drafting*, in which a trailing car is positioned almost directly behind a leading car. This is obviously dangerous. What advantage does it offer?

Answer In spite of its aerodynamic design, a race car still meets a lot of drag. One source of drag is the pressure difference between the front and rear of the car. At the front, the air impact creates high pressure. At the rear, the airflow breaks up into vortexes, which have reduced air pressure. So, the pressure difference between front and rear acts to slow the car, requiring greater fuel consumption for the car to maintain its high speed.

If a trailing car pulls behind a lead car, both cars have an advantage. The trailing car disrupts the vortex formation at the rear of the leading car, and the leading car has a smaller front-to-rear pressure difference. The trailing car has less air impact on the front, and so it too has a smaller front-to-rear pressure difference.

The trailing driver can use a *slingshot pass* to go around the leading driver: The trailing driver pulls back somewhat from the leading car to allow vortex formation to be set up behind the leading car. The low-pressure vortexes act to slow the leading car and pull the trailing car forward. Timing this carefully, the trailing driver can accelerate into the vortex region and then snap around the side of the leading car.

Reportedly, Junior Johnson was the first to use these aerodynamic techniques in the 1960 Daytona 500 NASCAR race, which he won in spite of his car being rated as slower than other cars in the race.

Drafting is used in other sports, notably in bicycle racing. It is also practiced by animals, as when a mother duck leads