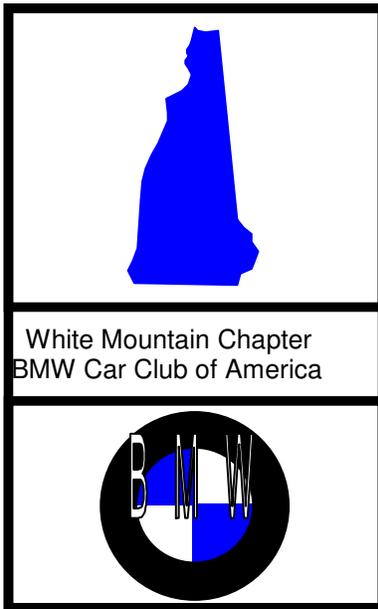


# BMW CCA

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WHITE MOUNTAIN CHAPTER DRIVER'S SCHOOLS

## CURRICULUM



## INTRODUCTION

Welcome to the White Mountain Chapter and our driver education programs. Over the years we've assembled an impressive offering, conducted by an exceptional group of volunteers and instructors. Whether you've joined us intending to challenge your driving precision on an autocross course, hone your skills at the limit and beyond on the skid pad, or experience the thrill of driving at speed on the track, the WMC has a program to accommodate you. For those who feel they've reached a plateau in our advanced driving groups we offer an intensive instructor training program designed to insure that our instructors are among the best the BMW CCA, or any club, has to offer.

The following curriculum has been written to help those getting started to better understand the principals and terminology associated with performance driving. The first half focuses on our Advanced Skills School, a requirement for novice drivers; the second half focuses on our track Driver's Schools. This curriculum is by no means exhaustive, but it will help you to assimilate those important fundamentals held in common by every truly skilled driver. We're confident that you will find your experience with the WMC both enjoyable and rewarding, and on behalf of our dedicated and enthusiastic membership... Welcome.

# ADVANCED SKILLS SCHOOL

"At some stage in your development, you may have to overstep your known capabilities. I strongly urge that you pick that spot carefully."

Jim Clark, 1966

In Jim Clark's day the spot that a driver chose to overstep his or her capabilities was all too often on a racetrack with little protection provided either inside or outside the car. Driver's schools were in their infancy and the idea of using a skid pad, once called a skid *pan*, to train novice drivers was embryonic at best. Today, thanks to years of refinement by professional driving schools such as those founded by Skip Barber and Jim Russell, the idea of creating a controlled environment in which to exceed one's limits has reached maturity. The experience of such an environment should be, in our opinion, the very first step in the development of a skilled driver.

It's probably no surprise that the majority of people consider themselves to be good or excellent drivers. Among enthusiasts - those who read car magazines and have car club decals on their windows - the positive response would likely be closer to universal. In truth, most of these people are justified in their confident self-evaluations. Good driving is the successful coordination of judgement and skill. Most of us use good judgement and manage to stay out of trouble, especially the kind requiring significant driving skill, hence we're right to call ourselves good drivers. If, however, our good judgement is backed by strong skills we become better still, and this can be particularly important in an environment where we are not alone in determining our immediate circumstances. Poor judgement on the part of those around us, and of course many forces of nature, can put us in situations where our only chance for a safe outcome depends upon our driving ability. If asked to rank their driving skill, it's likely that the same people would again rank themselves as either good or excellent. In this case, however, most would be overly confident.

It's difficult to separate driving skill from judgement; each informs and interacts with the other in very important ways. As we enter a familiar corner, at our usual speed, we discover that recent road work has left gravel strewn across the pavement at the apex. Our judgement, tutored by experience, tells us that the car is going to lose traction when it hits the gravel, and it instructs us to use our braking skills to slow the car as much as possible before we get there. Further, our judgement readies us to use our skill to correct for the slide that occurs in the gravel, and recover from the slide as the tires abruptly regain traction once beyond it. In this scenario our judgement and skill work hand-in-hand to get us out of trouble.

Unfortunately, however, we do not always have the luxury of time with which to make judgements. Instead of visible gravel, the apex of the same corner can be covered with invisible black ice. Perhaps our judgement should have been aware of this possibility and reduced our speed accordingly upon first leaving the driveway. Nevertheless, we suddenly find ourselves sideways in the middle of the corner and we must drive reactively. Our recovery in this case depends upon skill and skill alone; it depends upon our proficiency at driving by the seat of our pants. The latter term, most often used pejoratively, nevertheless refers to the most important tools of the highly skilled driver - the senses. It is our senses, especially the visual, tactile and kinesthetic senses that tell us not only what is happening with the car, but also the rate at which it's happening... or ceasing to happen. As we approach the limits of a car's performance capabilities both the sensory cues to, and the required inputs from, the driver become subtler. In order to develop and hone these inputs - in order to become skilled drivers - we must first understand what it means for a car to be at its limit.

## VEHICLE DYNAMICS

## THE LIMIT

The interrelationship of many physical factors determines the limit of a vehicle's ability to grip the road, and these relationships can be maddening in their complexity. From the perspective of the pavement, however, a car is very simply four **contact patches**. A contact patch is that portion of the tire that is, at any given moment, in contact with the pavement, and it's not much bigger than the sole of a shoe.

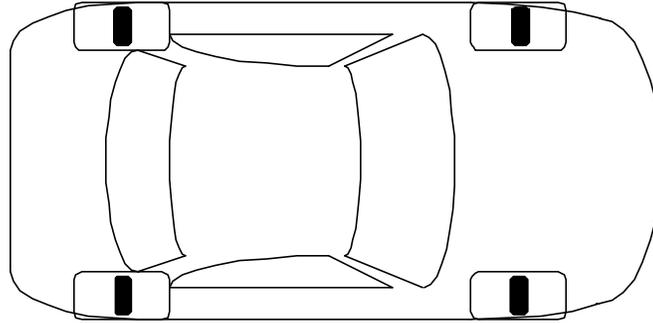


FIGURE 1

The black rectangles in Fig. 1 illustrate the basic size and shape of the four contact patches while the car is at rest. The "at rest" distinction is crucial because as we start driving (accelerating) the contact patches change not only their size and shape, but also their relative ability to influence the motion of the car. As a mechanism a car is designed to accelerate, decelerate and/or corner. When we do any of these three things we induce what is known as **weight transfer**. If you've ever hit the brakes and watched your briefcase or your dog fly into the passenger footwell, then you've witnessed weight transfer. Perhaps a more useful way to consider weight transfer is to imagine a tennis ball attached by a string to the headliner of the car. As we accelerate, the tennis ball will swing back toward the rear seat. If we brake, the tennis ball will swing forward toward the windshield. When we corner, it swings laterally to one side or the other. Just as the force of acceleration, whether longitudinal or lateral, keeps the tennis ball moving relative to its mounting point, so will the entire mass of the vehicle move, or try to, relative to the contact patches.

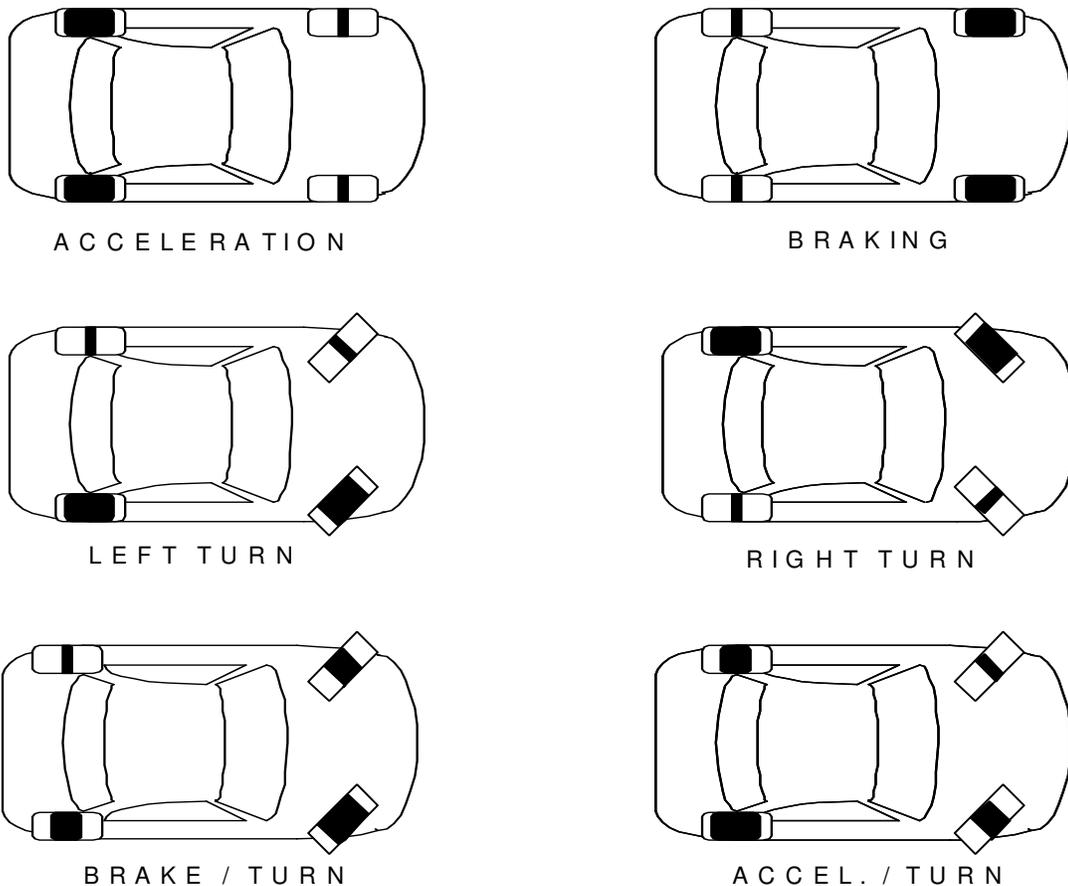


FIGURE 2

In Figure 2 the exaggerated contact patches illustrate how weight transfer effects the size and relative grip of the four tires under different types of acceleration. As commonly used in reference to cornering, the term "the limit" describes that point at which a tire is on the verge of losing grip and sliding, and most people envision this as a sudden and dramatic event. In reality, however, a tire doesn't even reach its limit until after it has already begun to slide or, more accurately, deflect.

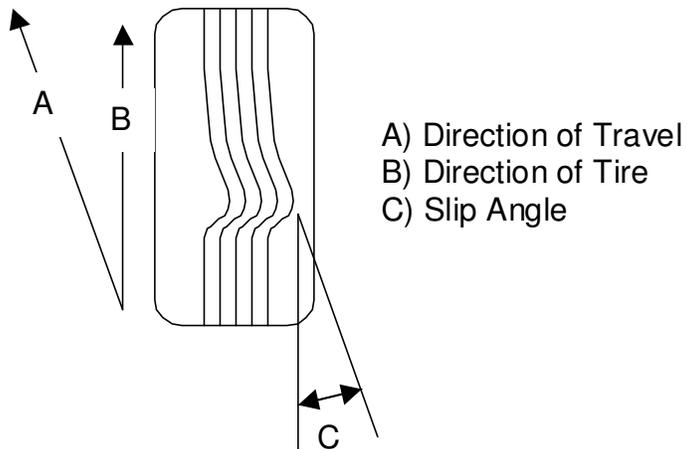


FIGURE 3

Figure 3 illustrates the shape of the tire tread under heavy cornering forces in the dry. Most of the "slide" that occurs at the limit is actually due to the deflection of the tread rubber, which gradually deflects as it approaches contact with the road and then abruptly snaps back to place as it breaks contact. The severity of the slide is referred to as a **slip angle**.

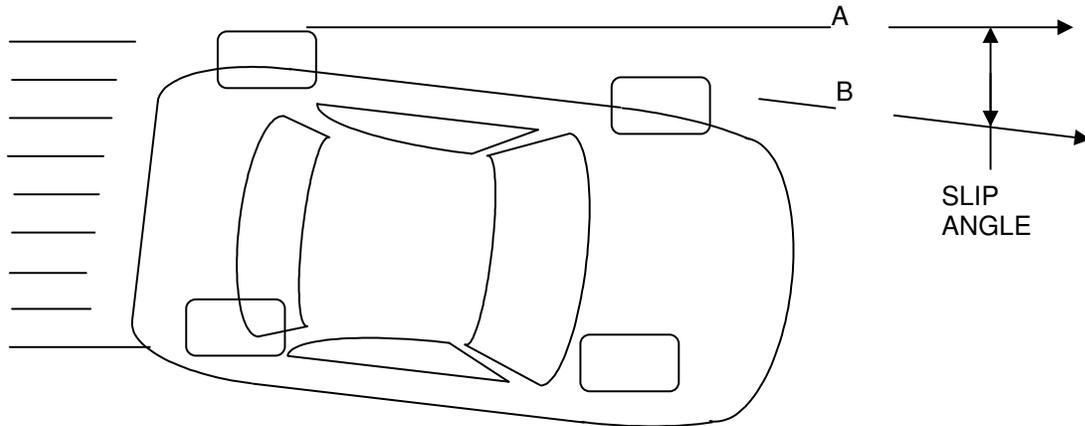


FIGURE 4

The classic image of a racing car travelling through a corner in a subtle and balanced four-wheel-drift illustrates a car cornering at the limit (Figure 4). Keep in mind that the front tires can simultaneously generate slip angles different than those of the rear tires, which we'll discuss later. The slip angle where a tire produces the greatest grip varies according to tire type, size, compound, temperature, etc. As a rule, however, the limit falls between 6 and 12 degrees.

Just as a tire has a limit in cornering it also has a limit in both accelerating and decelerating, and as with cornering the tire produces its greatest grip after it has begun to slide, or in this case slip. In braking, the tire is at its limit when rotating just slightly slower than it would be with no brakes applied. Under acceleration the limit is found when the tire is rotating just slightly faster than it would be if the car were at that given speed without acceleration. This difference in the rate of rotation is referred to as the **slip ratio**, or percentage slip, and the tire produces its greatest grip at between 10 and 15%. A car within this range under deceleration is considered to be **threshold braking**; the point just before the tires lock up... or would without an Antilock Braking System (ABS).

The limit of a tire isn't really that hard to find... the hard part is consistently keeping the car on the limit once we've found it. This is especially difficult when cornering in combination with acceleration or braking. The easiest way to consider the limit in this situation is to remember that the tire has only 100% potential. If we are using all of this potential to do any one thing, such as braking, there is no potential left for it to do anything else. Before the advent of ABS this realization came to many drivers in the form of locked and sliding tires that were pointed distinctly away from the object they eventually slammed into. If we are threshold braking - if we are using 100% of the tire's potential to slow the car - and we then ask the tire to turn the car as well it will simply lock up. The advent of ABS has made this situation far more tenable, though the potential ability of the tire hasn't significantly changed since that time. ABS simply makes better use of that potential. Nevertheless, the skilled driver, by balancing the combination of braking and turning, can be a match for ABS. This skill of balancing braking and steering inputs, where breaking pressure is gradually decreased while steering is gradually added, is called **trail braking**.

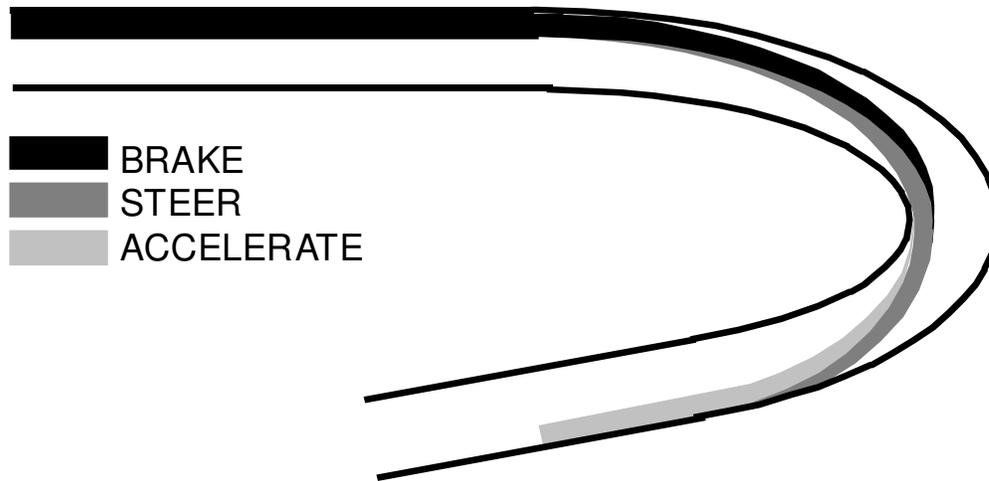


FIGURE 5

Figure 5 shows a common progression through a corner requiring trail braking. As the car reaches the point on the track where the driver must turn into the corner, steering is gradually added while braking pressure is proportionally reduced. Eventually braking tapers, or "trails off," to nothing and 100% of the tires potential is dedicated to turning. Very quickly, however, some of that potential is given up by the drive wheels for acceleration. As with trail braking, acceleration is added gradually as the steering wheel is unwound. A terrific visualization tool is to imagine a string with one end tied to the bottom of the steering wheel and the other end tied to the big toe of the right foot. As one enters the corner under braking and begins to turn the steering wheel, the string will pull the right foot off of brake pedal in proportion to the amount of steering added. Likewise, as the right foot is pushed down on the accelerator exiting the corner, the string will pull the steering wheel straight. Notice in Figure 4 that steering is both added and taken away gradually. While this technique isn't used in every corner, trail braking is an important tool and one fundamental to becoming a smooth and quick driver.

## BEYOND THE LIMIT

In their effort to find the limit many novice drivers manage to thoroughly exceed it. In doing so some exceed not only the limits of their cars, but also the limits of the paved track surface, the grass run-off and, on occasion, the barriers lining them. The skills we teach in the Advanced Skills School will help to prevent such a costly process of discovery. The following are common ways of exceeding the limit.

### UNDERSTEER:

"The mutt won't hunt!" is NASCAR for a condition where the front tires have relatively less grip than the rear tires. The front tires aren't turning the car as much as the steering wheel is asking them to.

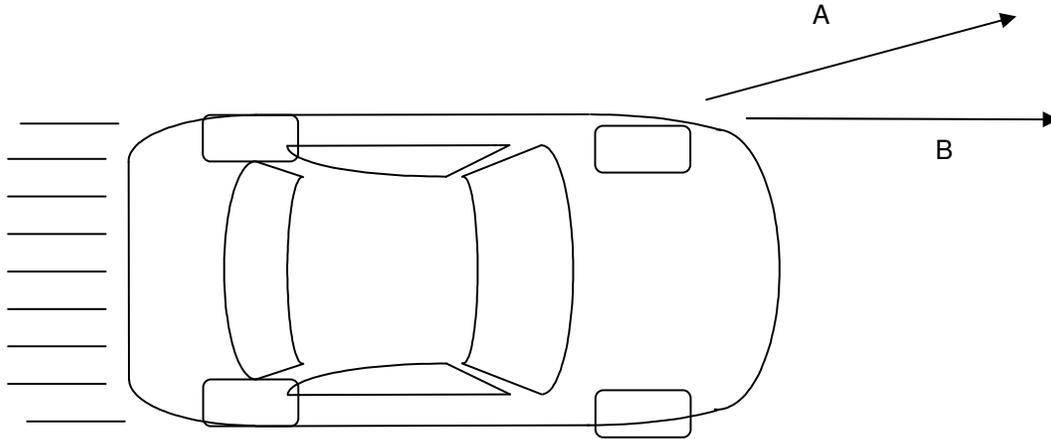


FIGURE 6

Figure 6 illustrates **understeer**. Line A is the direction the front tires are pointed and line B is the direction the car as actually travelling. While there is more than one way to induce understeer, the cause most often seen involves an impatient right foot. As a driver begins to accelerate weight is transferred away from the front tires, which are subsequently less effective at turning the car. The novice driver will often add more steering, worsening the problem. The experienced driver will leave the steering wheel where it is, or perhaps even lessen the amount steering, and reduce the level of acceleration. The latter returns to the front tires some of the weight transferred away under acceleration and allows them to regain grip. In fact, production street cars are designed to understeer. The average person's natural panic reaction (to pretty much everything startling) is to lift off the gas and go for the brakes. In this case the first half of their first impulse happens also to be the proper response to most understeer situations: get off the gas. The advent ABS has added a footnote to understeer. Before ABS a driver who tried to enter a corner too quickly, and asked too much of the tires under trail-braking, was rewarded with locked and sliding tires. ABS has altered this to become what is essentially an understeer condition. There is nothing the driver can do in this case, however, other than wait for the car to scrub speed and arrive at a radius large enough for the tires to regain grip. While preferable to locked and sliding tires, the wait can be unpleasant - especially with barriers looming.

**OVERSTEER:**

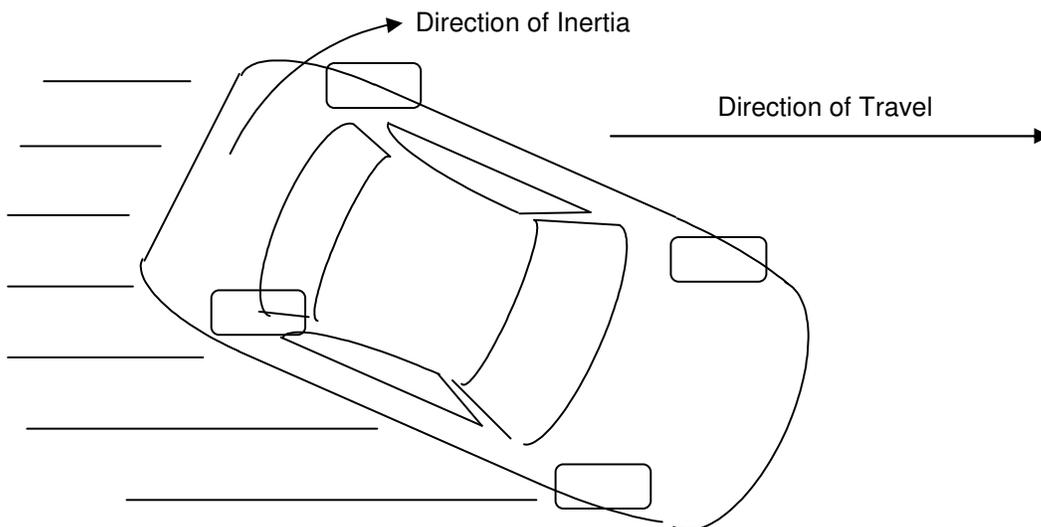


FIGURE 7

Just as the front end of the car can come unglued independently so, too, can the rear end; this is called **oversteer** (Figure 7). While presence of mind is really all it takes to deal with understeer, oversteer requires legitimate skill to prevent the rear end of the car from successfully passing the front end, which is what happens when a slide becomes a spin. Before discussing what to do with oversteer, let's first look at the causes.

**Trailing Throttle Oversteer (TTO):** TTO is usually seen in the exit of a corner immediately after a driver realizes he or she turned too early into it, and it probably exacts a higher toll from novice drivers than any other mistake. When a car is at its limit in cornering the burden is divided roughly equally between the front and rear tires. When a driver lifts off the throttle weight transfers to the front tires, which grip and turn even better, and away from the rear tires, which grip less. At the limit a very small lift can be enough for the rear tires to break traction and begin to slide.

**Power Oversteer:** Just as the name suggests, too much power to the rear tires will cause them to break traction and begin to slide. Front-drive cars will **Power Understeer**.

**Secondary Reaction Oversteer:** When a car is cornering at its limit there is an enormous amount of potential energy stored in the various components resisting the lateral forces. The first and obvious components are the springs. Less obviously, however, are the tire sidewalls, wheels, sway bars and the chassis itself. If a driver quickly changes directions in this condition, that stored potential energy can surge to the opposite side of the car so abruptly that the rear tires break loose before any significant downforce can increase the contact patch's ability to grip the road. Like a branch pushed out of the trail and abruptly released, the rear of the car snaps beyond center and the car oversteers.

**Trailing Brake Oversteer (TBO):** This term isn't well established in the vernacular, and there are two variations of the phenomenon that the term presumes to describe. Many, however, believe in the legitimacy of TBO so we'll include it here. The first and simpler version suggests that a driver who aggressively trail brakes into a corner will so thoroughly load the front tires, and so thoroughly unload the rear tires, that the latter will break loose and oversteer will result. The second version is more complicated. Recall the trail-braking diagram at the point after turn-in where the tire's potential is divided roughly 80% for turning and 20% for braking. The second TBO theory suggests that if the driver abruptly lifts off the brake at or near that point, the front tires will immediately take advantage of the potential abandoned by braking and will begin to turn the car even harder. Since braking has already unloaded the rear tires, which are already at their limit, they break loose fairly easily with the increased lateral loading. Regardless of which, if either, TBO definition properly explains the phenomenon, doing things just right while trail-braking *will* produce very real oversteer. In fact, most quick drivers use this technique to get the car pointed into certain types of corners. When done on purpose, it's called inducing **rotation**.

Whatever the cause, oversteer is exciting and, if one knows what to do about it, fun. As soon as the rear tires break traction they begin to accelerate laterally... in other words the car begins a spin. This accelerating mass develops corresponding inertia (a body in motion tends to stay in motion) that will have to be dissipated before the rear tires can regain traction. To allow time for this to happen we must accelerate the front of the car in the same direction as the rear, which is facilitated by turning the front wheels in the direction of the slide. Eventually, depending on the severity of the slide, the rear wheels regain traction and place the car very suddenly in the secondary reaction situation mentioned previously.

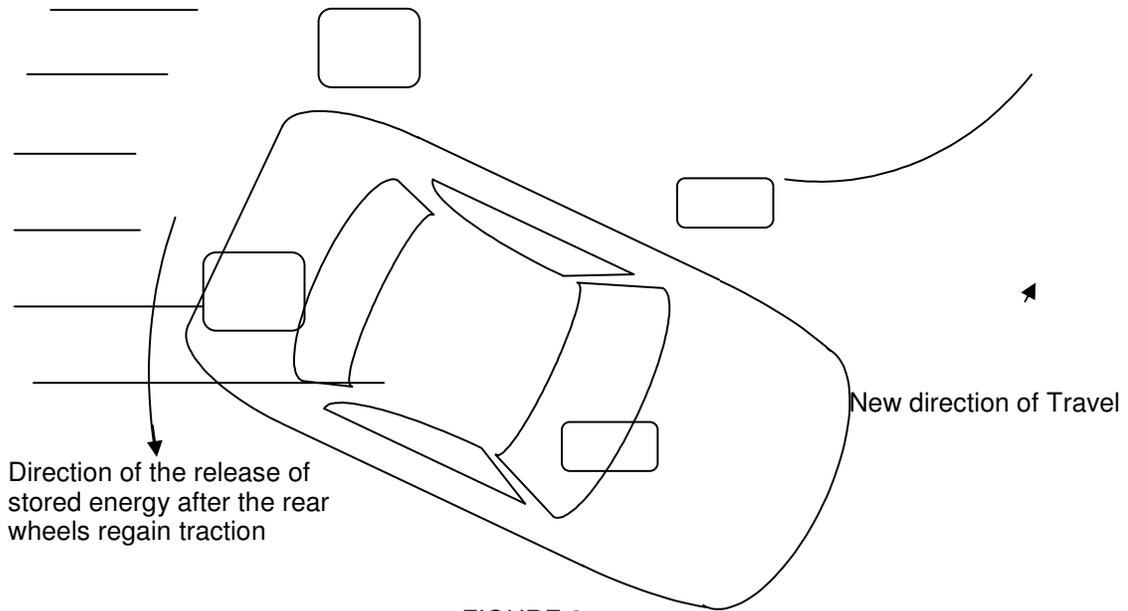


FIGURE 8

Figure 8 shows the same combination of sliding and steering depicted in Figure 7. In this case, however, the rear wheels have just regained traction. The stored energy will release rather violently in the opposite direction of the initial slide *and*, if nothing is done with the steering wheel, in the opposite direction that the front wheels are still pointing. The resulting 3,000 pound pinwheel is thrilling to watch... though less thrilling to ride in. To prevent this from happening the steering wheel must be turned back toward center, away from the direction of the slide and toward the direction the car is actually pointing, as soon as the rear wheels regain traction. Skilled drivers will actually anticipate this and begin centering the steering wheel preemptively, thus generating smooth, seamless slide recoveries such as those demonstrated by BMW CCA instructors.

The discussion of understeer and oversteer thus far has used dramatic examples of a type and degree rarely exhibited unintentionally by skilled drivers. Nevertheless, the skilled driver is constantly balancing understeer and oversteer to keep a car at its limit. As mentioned previously, the front and rear tires can have different slip angles, resulting in either oversteer or understeer. If the front and rear tires have slip angles of 5° and 10° respectively, the car will oversteer. In this case the driver will balance the car by turning slightly in the direction of the slide, which cancels the front tire's slip angle and replaces it with actual steering to match the slide of the rear tires. If the front tires are generating larger slip angles, the driver must reduce the level of acceleration and provide slightly more weight to the front tires, which reduces their slip angles to match those of the rear tires. In either case it would be difficult for a spectator to actually see what's happening, even from the passenger seat. Nevertheless, a driver who is at the limit through a corner is constantly sensing and adjusting.

Note: Given the choice between slight oversteer and slight understeer, most drivers opt for the former on road courses and the latter, or neutral, on speedways. While an oversteering car is more difficult to driver, it nevertheless allows the driver to accelerate harder through corners. The speeds sustained on tracks such as Indianapolis, however, make an oversteering car tiresome and risky, hence the theoretically slower neutral or slightly understeering set-up is preferred by most drivers.

## ADVANCED SKILLS EXERCISES

In place of highway off ramps and barrier-lined race tracks we use a big parking lot, little orange cones and a couple of thousand gallons of water to help drivers find the limit. The exercises are as follows:

## BRAKING

Braking as a skill is fast becoming a lost art, at least at the marquee club level. ABS is a truly worthy invention that has saved countless lives, and it has become so refined that all any driver needs to do is simply stomp on the brake pedal and the car will slow or stop without any loss of control. While ABS certainly makes life safer on the streets, and easier on the track, it is nevertheless still too early to consider braking skill vestigial. As we'll see in a later exercise, the ability to modulate the brake pedal with subtlety can pay enormous dividends when it comes to controlling the car and lowering lap times. Further, most true race cars, which some of you may eventually drive, don't bother with ABS simply because a skilled driver can approximate its performance without the added weight. For these reasons we've decided that braking skill is worth spending a little time on.

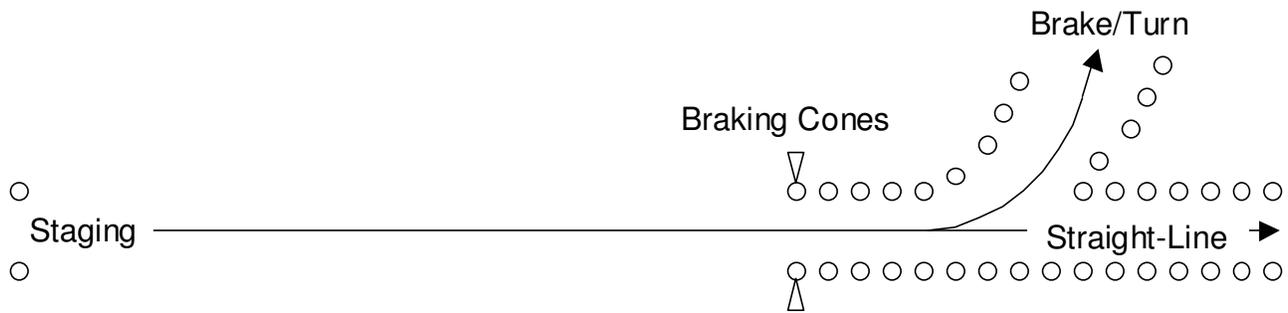


FIGURE 9

Figure 9 shows the layout of cones used in the braking exercise. Students will line up in the staging area and wait for an instructor to signal their turn with a wave. The first couple of runs will get the student used to entering the exercise at a constant speed and hitting the brake pedal precisely at the braking cones. Next the student will establish what we call the "benchmark," the distance they'll try to beat throughout the rest of the straight-line portion of the exercise. Students driving cars with ABS will be asked to accelerate to a specific speed, say 30 mph, and at the braking cones simply stomp on the brake pedal and hold it down until the car has come to a complete stop. In subsequent runs the students will try to match or beat the ABS stop, but without engaging the ABS. The pulsing of the system can be both felt and heard in most cars, and use of the system will be akin to locking the brakes. As with lock-up in a non-ABS car, students will be instructed to relax braking pressure until the ABS goes away. Students without ABS will simply build braking pressure, braking from the same speed, until the instructor deems they've reached threshold braking throughout the entirety of the braking distance. Once most students have mastered straight-line braking, the exercise will change to braking/turning. In this portion students will use the same process to learn and refine the skill of **trail-braking**.

## LANE CHANGE

The Lane Change exercise is designed to induce, and subsequently teach the student how to deal with, secondary reaction weight transfer. As discussed in the Oversteer portion of this curriculum, weight transfer alone can cause the tires to exceed their limits. The controversy surrounding SUV rollovers might quiet somewhat if everybody had the opportunity to master a lane change exercise.

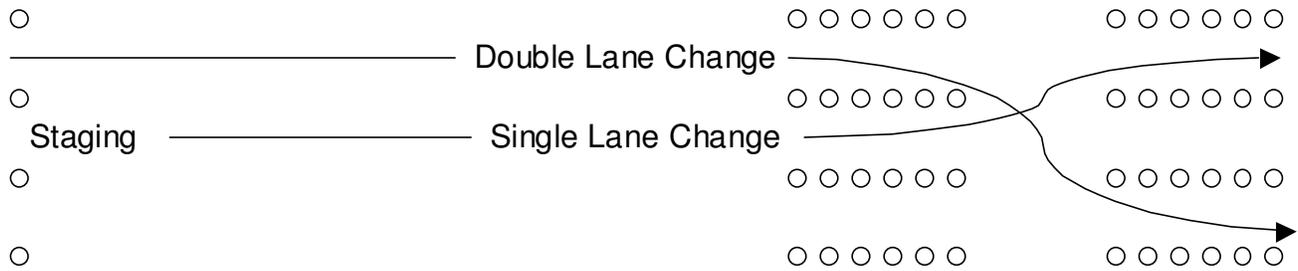


FIGURE 10

As with the braking exercise students will assemble in the staging area and await a signal from the instructor, who will be at the far end of the exercise. During the single lane change the student will drive through the center lane of the first set of cones, at a set speed, and will then be directed by the instructor into either the first or third lane of the second set of cones. Depending on the driver and the car, the instructors will increase the student's speed and/or delay the lane change signal. For the double lane change students will alternate their starts between the first and third lanes, swerving to the far side in the second set of cones. As with the single lane change the instructors will raise the speed, and perhaps add a lift or braking at the initial turn-in, as the student becomes more proficient.

### SKID PAD

The skid pad and the Figure 8 are without question the best tools to help a novice driver first discover and then develop a feel for the limit of a car's potential. The skid pad is simply a perpetual corner in which the student drives faster and faster until the car reaches and then exceeds its limit, whereupon the student learns to deal with the consequences. A skilled driver can first induce extreme understeer and then dramatic, power-sliding oversteer without ever deviating from the same constant radius around the skid pad. Or, without ever moving the steering wheel, a driver can change radii back and forth to the very extremes of the skid pad surface.

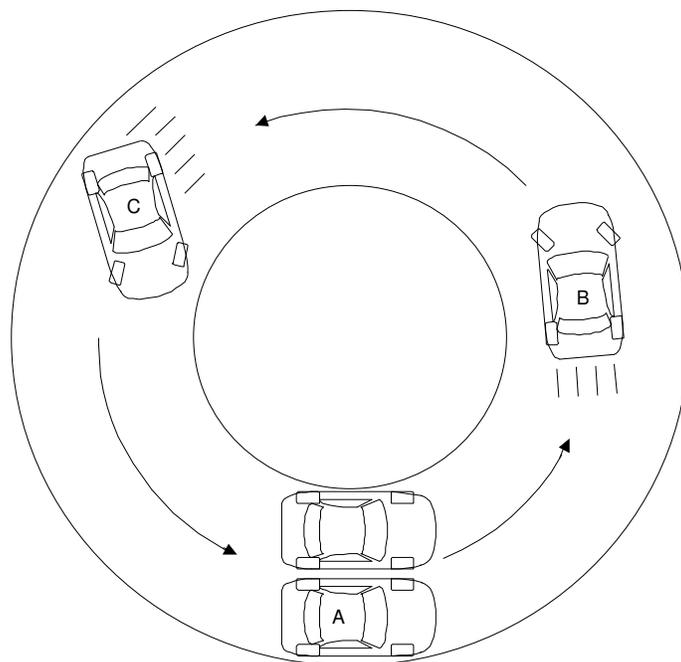


FIGURE 11

Figure 11 illustrates the three basic exercises that we do on a wet skid pad.

#### A) Steady State at the Limit

The initial goal of the skid pad exercise is to find the limit of the car's cornering ability. To do this the driver puts the car on a constant radius somewhere near the center of the skid pad surface, freezes the steering wheel and very gradually accelerates until the limit is reached. While this sounds easy it's in fact challenging for most students, who make constant adjustments with the steering wheel and throttle without realizing it. Every movement of the steering wheel and every change in the throttle setting, no matter how small, initiates weight transfer and alters the relative limit of every tire. For students to truly learn to feel the limit, a constant radius and steady throttle are absolutely crucial, and they are the basis from which subsequent skid pad exercises are begun. In fact, any driver unable to thoroughly grasp the importance, and subsequently master the subtlety of this most basic exercise will likely never learn to drive a car consistently at the limit. Once at this steady state at the limit the student will again gradually add power, and as the car exceeds its limit the radius, without any movement of the steering wheel, will begin to get larger. With hands frozen on the wheel, the student will then gently modulate the throttle and change the radius at will (A).

#### B) Understeer

Once students have the first exercise under control they will then be asked to again find a constant radius, get the car at its limit and then add a lot of steering and a little power simultaneously. In most cars this will induce understeer (B), which the student can then modulate or eliminate entirely using only the throttle. In fact, once understeer has been created the steering wheel can be turned fully to its stop toward the center of the skid pad, called gross understeer, and be left there while, again using the throttle, the student changes the radius back and forth (A & B combined). Alternatively, the degree of understeer can be altered throughout its entire range without changing the radius the car is travelling on.

#### C) Oversteer

Lastly, students will be asked, again with the car at its limit on a constant radius circle, to abruptly lift off the gas. In most cases, because most students are driving street cars with inherent understeer, this will do nothing but reduce the radius the car is travelling on. In some cases, however, **Trailing Throttle Oversteer**(TTO) will be induced. If not, students with rear drive cars will be asked to abruptly lift off the gas and immediately give the throttle a quick "kick." Lifting unweights the rear tires and the quick kick of the throttle hopefully gives them enough power to break the rear tires free. The result is oversteer (C). If a front-wheel-drive car doesn't have ABS, oversteer can sometimes be induced on the skid pad by **left foot braking**. Leaving the throttle at perhaps 30% the student "kicks," for a little longer, the brake pedal instead of the gas pedal. The power from the engine partially overcomes the pressure applied to the front brakes, artificially altering the brake bias to the rear tires; they lock up and oversteer results. The last resort for uncooperative cars is to use the emergency brake, though we usually recommend that the student simply wait for the Figure 8. Once oversteer is created students will learn to correct the slide with steering, feel for the rear tires to regain grip, and recover from the slide once they do. Initially, oversteer will be dealt with using only the hands. Once students have demonstrated an ability to do this, they will then add a small amount of power during the slide, which transfers weight to rear tires and helps them regain grip. Lastly, students with rear drive cars may add a little more power and keep the car sliding around the skid pad. This is called a **powerslide**, and is the most challenging of the skid pad exercises.

### FIGURE 8

With the completion of the exercises discussed thus far students have hopefully improved their braking and car control skills. The next step is to integrate these skills by approximating how they are used on the race track. Just as the skid pad is a perpetual corner, the figure 8 is a perpetual series of corners.

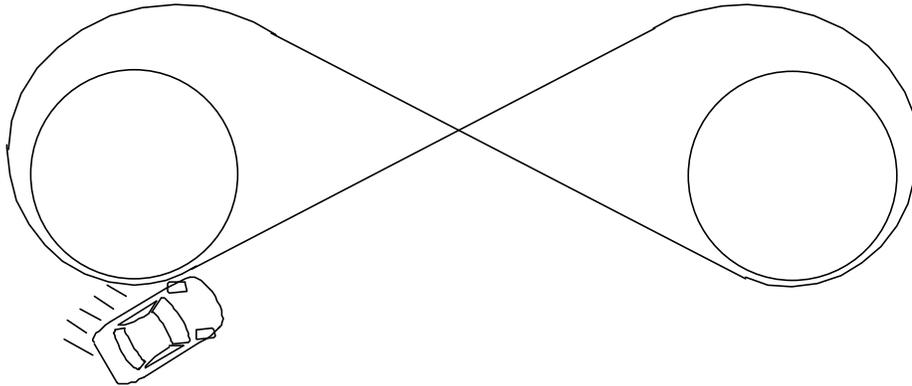


FIGURE 12

Figure 12 shows how the two skid pads are combined to form a figure 8. In this exercise students brake into the first skid pad, turn through it and accelerate away to the second skid pad, repeating ad infinitum. You'll notice in Figure 12 that the line showing the path that the cars follow is asymmetrical relative to the skid pads. In racing the term **The Line** refers to a very specific path that the driver follows around the race track, the reasons for which we'll discuss in depth in the Driver's School portion of the curriculum. In the figure 8 the student drives on a line that is wide of the skid pad entering the corner and tight to the skid pad exiting it. This provides a larger radius and longer turning time entering the corner and better positions the car for the next skid pad upon exiting. Students will start by finding the proper line around the figure 8, using visual reference points located both within and without the exercise. The initial goal is to create a smooth integration of braking, turning and accelerating. The student will be encouraged to look further ahead than they're likely used to, and will be reminded of the string and toe analogy discussed earlier. Done properly, the imaginary tennis ball hanging from the headliner will move directly to the front, gradually and on a smooth radius move to the side, and then likewise to the rear. Once this has been mastered the student will be asked to pick up the pace until the car begins to exceed its limits. Most students will first find understeer, and then, in rear drive cars, power oversteer. Ultimately, students will use the brakes to rotate the car into the corner by inducing TBO, creating a slide which they will catch with power and hold through the remainder of the corner. Those able to master this exercise will be justified in calling themselves truly skilled drivers.

## AUTOCROSS

The modern autocross has its roots early in automotive history, when gas, steam and electric powered vehicles participated in public challenges designed to demonstrate the automobile's versatility and maneuverability. These evolved into gymkahnas, which tested the diverse abilities of the driver more than the car. The modern autocross tests the ultimate performance of both, against the clock, in an intense and demanding series of gates and turns. In such an event the difference between first and second place is very often measured in hundredths, and sometimes thousandths of a second. The autocross is also an exceptionally useful teaching tool that can be designed to present very specific challenges to the student, and encourage and emphasize common mistakes for the benefit of the instructors. The autocross used in our Advanced Skills School, which makes use of the braking, lane change and skid pad exercises, will put students in some of the circumstances they may find themselves in on the track, encouraging understeer, oversteer, TTO and secondary weight transfer slides. Further, because the course is lined with cones it will require accuracy facilitated by the use of **reference points**, such as the braking cones used in the braking exercise and the other landmarks used in the Figure 8.

This concludes the review of the Advanced Skills School. In the scheme of things related to performance driving the several pages you've just read barely scratch the surface. Nevertheless, this information will help you to gain more from the Advanced Skills School you attend, which in turn will improve your experience and your performance on the track.

## DRIVER'S SCHOOL

### INTRODUCTION

Welcome to the Driver's School portion of the curriculum. Whether a novice having just completed an Advanced Skills School, or an already advanced driver joining us for the first time on the track, this curriculum will help insure that you and your instructors are speaking the same language. As with the Advanced Skills portion of the curriculum, the points discussed in the following pages are really only a summary of available information. There have been dozens of books written on racing and performance driving, each offering information beneficial to a developing driver. We encourage you to take advantage of these resources and read well beyond our modest curriculum.

## SOME BASICS

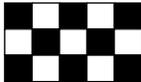
FLAGS - Flags exist to allow those controlling the event to communicate with individual drivers as they circuit the track. They will be displayed at flag stations, the locations of which the driver should learn immediately on the first session out.



GREEN: This flag indicates that the track is open. It is also waved to indicate the start of a race.



CAUTION: The caution flag means that there is a problem ahead... SLOW DOWN AND DO NOT PASS. If the yellow is stationary, the problem isn't severe. The harder it's waved, the worse the problem.



CHECKER: This flag means that the session is over or somebody won. Take a cool-down lap and enter the pits.



RED: The red flag means there has been a serious incident. Depending on prior instructions, drivers will either pull to the side and stop immediately, or drive SLOWLY to pits.



WHITE: Often seen with a red or yellow, this flag means that there is a slow moving vehicle on the track. It could be another car, a wrecker or an ambulance. Watch in front and behind.



DEBRIS: This flag indicates that the track surface ahead is slippery. Whether from oil, dirt or car parts, proceed cautiously.



BLACK: Directed at you, this flag means you're doing something somebody doesn't like. Given to all cars, it means there's a general problem. In either case, REPORT TO THE PITS IMMEDIATELY.



MECHANICAL: Also known to as the "Meatball," this flag means that there is a problem with your car. Check your gauges, look for smoke in your mirrors and REPORT TO THE PITS IMMEDIATELY.



PASSING FLAG: Not universally used in club events, this flag indicates that there is a faster car closing on you. Be prepared to get passed.

## DRIVER POSITION

Comfort and ease of movement are crucial when trying to control a vehicle at its limits. Particular attention should be paid to the following:

Hands: It is widely accepted that the hands are best kept at 3 o'clock and 9 o'clock on the steering wheel. This balances the inputs of each hand and allows a consistent reference when centering the steering wheel. There are two schools of thought, however, with regard to large movements of the steering wheel. The first suggests that at least one hand should always remain at either 3 o'clock or 9 o'clock while turning, thus always providing a reference for center lock. The other school of thought suggests that "shuffle steering," passing the wheel from hand to hand in quick movements, is more effective. We suggest that each student try both to determine subjectively which is more effective.

Seat Back: To gauge distance from the steering wheel, the driver should extend one arm over the top of the steering wheel and, without pulling the shoulder away from the seat, be able to bend the wrist on or just past the top of the steering wheel. This position will prevent the hands from being pulled off of the wheel when turning, while allowing the upper arms adequate freedom of movement away from the torso.

Pedals: The operation of the pedals also requires freedom of movement. If we are too close to the pedals the movement of our knees may be impeded by either the bottom of the dash or by the steering column. Also, if the knees are bent too much we begin to lose sensitivity as we flex our ankles to work the pedals, and eventually our legs will tire from holding our feet off the pedals. If we are too far away we'll be stretching with our legs and often

we'll find that contact between the seat and the bottoms of our thighs will inhibit our leg movement. When the clutch pedal is depressed, there should still be some bend in the knee.

## MIRRORS

Our mirrors are crucial when driving at high speeds with other, often faster cars around us. The rear-view mirror should be adjusted to center the rear window in our view. The side-view mirrors, contrary to common practice, are best adjusted to a point beyond where the side of the car can be seen. With adequate mirrors and proper adjustment a driver can often have a 360° view, eliminating completely the "blind spot." The image of a car moving from behind to the side will pass from the rear-view mirror to the side-view mirror. As the image leaves the side-view mirror the front of the car will begin to appear in our peripheral vision.

## PIT OUT

When we leave the pits we must be sure to stay out of the way of faster cars until we can enter traffic at roughly the same speed. Keep the car to the same side of the track as the pit exit, and under no circumstances cross the path of on-coming cars.

## PASSING

Through controlled practices the BMW CCA has virtually eliminated incidents caused by passing during driving schools. This requires, however, a great deal of awareness and cooperation among drivers. At each track that we visit **Passing Zones** will be determined. It is within these zones that a pass must be both initiated and completed. To accommodate this, the driver being over-taken should visibly point to the side on which he or she will be passed. This called a **Point-By**. Generally, we will ask that the car being passed maintain its position on the line, while slowing slightly if necessary to facilitate the pass. The car over-taking must wait to be pointed by before maneuvering around the slower car, and must also determine before pulling along side whether there is adequate space to complete the pass within the passing zone. A point-by does not necessarily mean that a pass is advisable. Mirrors are crucial; each driver should know well prior to reaching a passing zone that there is a faster car behind. Anticipating a pass will allow the slower car to point early and temper acceleration, giving the-taking car more time to pass safely. We are not racing for position during our track sessions. A faster car behind will serve only to break one's concentration, while a faster car in front may provide, if briefly, visible clues as to exactly why that car is faster.

Note: If a faster car is at the back of a line of slower cars, it is often advisable to make a slow run through the pits. This will give the faster driver the opportunity to return to the track with perhaps less traffic, and allow the slower cars time to sort out.

## SLIDES AND SPINS

Prior to the advent of the Advanced Skills School novice drivers at times found slides and spins to be mutually inclusive... a discouraging reality for one headed backwards off a race track. Depending upon the track, slides are most often caused by **Trailing Throttle Oversteer**, **Power Oversteer**, or when a driver drops two wheels off of the pavement, panics, and overcompensates with steering so that when the tires do find grip they propel the car violently to the opposite of the track. The correct response to any slide should be to position the feet for **BOTH FEET IN**. This means that as soon as the driver realizes the slide is going to become a spin, both brake and clutch pedals should go immediately to the floorboards. A spinning car without brakes will move erratically across the track as the four wheels alternately gain and lose traction. Cars following will find it very difficult to avoid. If the brakes are locked the car will still spin, but its trajectory will be straight and predictable (and roughly 70% of braking efficiency will be retained). Cars with ABS (Anti-Lock Braking Systems) will most often react erratically anyway, but the brake peddle should still be put to the floor. The clutch is pushed to the floor to keep the engine running and to reduce strain on the drive-train (and perhaps prevent yet another spin) if the brakes are released while the car is still moving. Also, with the engine running the driver will be able to more quickly move the car if needed. The rule is simple: In a spin, **BRAKE AND CLUTCH TO THE FLOOR**.



Figure 13

Figure 13 shows a basic 90° right-hand corner and the largest possible radius through it. There are three basic components to each corner:

- A) **Turn-In:** The point where the steering wheel is turned heading into a corner.
- B) **Apex:** The point where the driver "clips" the inside of the track.
- C) **Track-Out:** The point where the steering wheel is again centered exiting the corner.

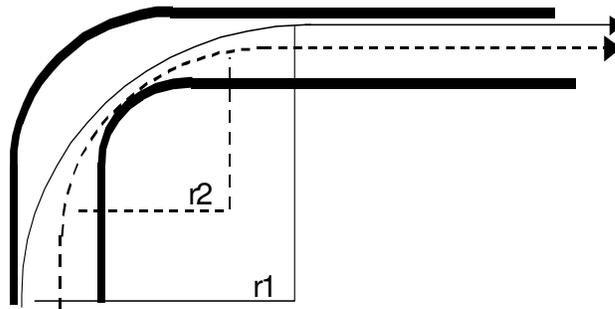


Figure 14

The two lines illustrated in Figure 14 show the difference in radius when a less than optimum line is used. In this case the driver entered the corner from the middle of the track, apexed correctly, and then tracked-out to the middle of the track. A logical observation would suggest that while the car on r1 is going faster, it is also traveling farther. This is true, and the car on r1 may conceivably take more time to get through the corner than the car on r2. What's more important for lower lap times, however, is **exit speed**. Any advantage gained in exit speed is carried over the entire distance of the following straight, and we generally spend more time driving the car in a straight line than we do cornering. If a car traveling on r1 enters the straight 1 mph faster than an equally powered car traveling on r2, the car on r1 will gain 1.5 feet of distance for every 1 second spent accelerating. This is roughly one car length for every 10 seconds spent traveling down a straight, and 1 mph may be the difference between tracking out to the edge of the track and tracking out 1 foot away from it. Exit speed is crucial.

## HOW WE FIND THE LINE

Knowing the theory of the line is something quite different than repeatedly placing the car on it at speed. To help us accomplish this we use three tools.

## REFERENCE POINTS

The primary means for establishing the line is the use of **reference points**. At some driver's schools there will be orange traffic cones marking the turn-in, apex and track-out points. These simplify our efforts because they show us rather graphically where the car should be placed. Without these cones, however, we must find other ways to help us consistently place the car on the line. A reference point is simply anything that tells us when to turn-in, where to clip the apex and where to track-out. Whether our reference points are cracks in the road, stripes on the curbing or chips in the pavement (and whether we turn in at them or four feet beyond them) reference points must

be determined by each individual driver and often with some creativity. Even a mountaintop on the horizon can be useful.

Note: Avoid less permanent reference points such as shadows or clumps of grass that may not survive getting run over.

## EYES

The idea that we use our eyes to find the line seems, of course, rather obvious. We will find, however, that the way we've grown accustomed to using them while driving around town is often less than adequate for the track. Most novice drivers will focus their vision relatively near the front of the car. As the car approaches the turn-in point the driver will be looking at that reference point until the car is nearly abreast of it. As the steering wheel is turned, the driver then begins looking for the apex. The basic rule to apply here is a simple one: **Our eyes tell our hands what to do.** If we turn toward the apex before we find it with our eyes, the movement of our hands will be both inaccurate and inconsistent. When done properly, our eyes will be focused on the apex before we actually turn in. The turn-in point is seen only in our peripheral vision, and we've learned from experience how to turn in at the proper point without looking directly at it. As we pass the apex, our eyes should have already found the track-out point. Using our eyes in this manner also allows us to create a sight-picture of the corner, where instead of seeing the small area surrounding a single cone we instead have the majority of the corner, often including all three cones, as our sight-picture. Events seem to happen much more slowly when the eyes are looking farther up the track. Lap times will fall along with the frequency of mistakes.

## HANDS

The third common practice used to help us both arrive at and stay on the proper line is simply to pay attention to what our hands are doing. If we've taken a corner improperly our hands will let us know. Our input to the steering wheel should be a gentle turning at the turn-in point, steady steering lock through the apex and a gradual unwinding of the steering wheel as we exit the corner. If our hands are doing otherwise, it's usually due to one of the following mistakes.

## COMMON MISTAKES

### EARLY TURN-IN

This is the most common mistake made by novice drivers trying to find the line. As we approach a corner and watch the road begin to disappear out the side of the windshield, a subtle sort of panic tells us to hurry and turn in. Figure 13 illustrates our line in this scenario.

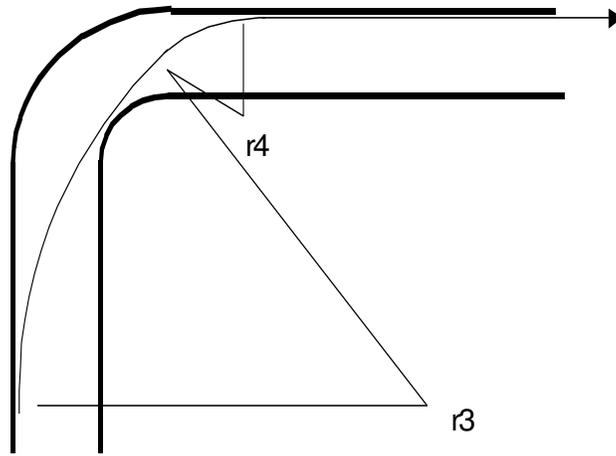


Figure 15

In Figure 15 the driver has turned in early using a large and initially comfortable radius ( $r_3$ ). Inevitably, the driver will take advantage of this large radius and maintain a proportionally high speed. The feelings of confidence and security last until just beyond the apex, where they turn into fear and dismay. The driver must now slow the car from the speed appropriate to  $r_3$  to the usually *much* lower speed appropriate to  $r_4$ . In less extreme examples the driver will have to stay out of the accelerator and turn the steering wheel more, "pinching" the car at the exit to avoid leaving the track... this greatly reduces exit speed. In more extreme circumstances the driver gets TTO, requiring those skills learned on the skid pad, which further reduces exit speed. In the most extreme circumstances the driver simply disappears from the track in a cloud of dust, eliminating exit speed altogether.

### LATE TURN-IN

Although technically improper, the late turn-in actually provides a safe method for finding the proper turn-in point.

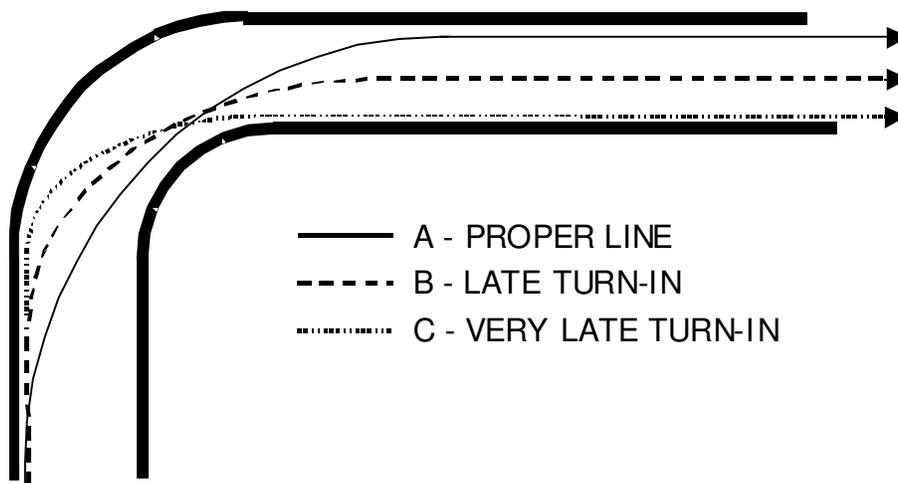


FIGURE 16

If we're approaching a corner for the first time it's advisable to turn-in at a point that is obviously late, such as line C in Figure 16. As we guide the car past the apex and unwind the steering wheel there will be a great deal of room left at track-out. Our hands have done the right thing, but in the wrong place. If we'd in fact driven the car out to the proper track-out point we'd find that our hands had turned in, straightened past the apex to get to the outside of the track, and then turned again at the track-out point. On our next lap we'll turn-in somewhat earlier (B), and discover that we reduced the amount of extra room at track-out, but still haven't eliminated it. Thus we continue, progressively, to turn in less and less late until we arrive at the best possible line.

## MISSED TURN-IN, APEX AND TRACK-OUT

Any inaccuracy anywhere in the corner, no matter how small, will reduce our exit speed. Whether the result is a smaller than optimum radius, a delay to power or a steering correction, which scrubs speed, if our line is bad our driving will be erratic and our speeds will be slow. There was a racer associated with a well-known racing school who measured his performance at track-out by looking in his mirror and evaluating the puff of dust raised at the edge of the track... too little, and not enough of the tire was hung off the edge. He didn't, of course, have to look in his mirror to know when he'd hung too much tire off. He was, and probably still is, an exceptionally precise driver. Some of the difference between a World Champion and his lesser competition can be measured trackside with a small pocket ruler.

As we've already discussed we use our hands and eyes to determine whether we're using all of the track. Our hands should smoothly turn in, hold lock through the apex and gradually unwind as we exit the corner. If we're making adjustments with our hands to get close to our reference points, or if our hands are smooth but our proximity to our reference points is poor, then our line is poor. Using this combination of tools a student may in fact discover that traffic cones or paint marks placed on the track for the purpose of reference points have been placed inaccurately. Wherever the turn-in, apex and track-out, a driver must be accurate when placing the car near them.

## OPTIMIZING EXIT SPEED

By this time we've begun to envision ourselves driving smooth, constant radius lines through the corner. If our tires are generating perfect slip angles from turn-in through track-out, and we're accelerating away with crisp, smooth shifts, how can it be that another driver in an identical car just passed us on the straight? Recall that radius and speed are directly related, and recall the emphasis placed on exit speed. If we can exit a corner on a radius larger than would be allowed by a constant radius then we can improve our exit speed, and consequently reduce the time it takes for us to get to the next corner.

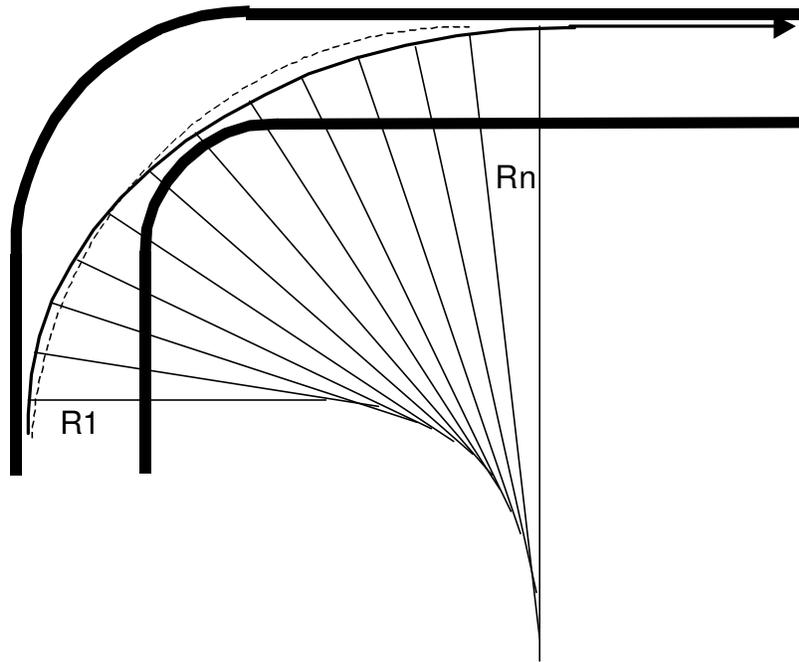


FIGURE 17

Figure 17 illustrates an increasing radius line. As we begin to accelerate away from the apex our increased speed will push the car onto a larger radius... the increasing radius is created not so much by steering, but instead by acceleration. The dashed line shows a constant radius through the same corner. Note that in order for the radius to be maximized at the exit ( $R_n$ ) the driver must turn-in slightly later, entering the corner on an initially tighter radius ( $R_1$ ), and use a slightly later apex. While easily illustrated, this technique is subtle and usually isn't mastered until a driver is well out of the novice ranks.

## ATYPICAL CORNERS

Our illustrations thus far have depicted flat, symmetrical  $90^\circ$  corners. In reality, however, there aren't very many of them out there. Even the corners at opposite ends of the same oval track have idiosyncrasies that distinguish one from the other. In short, there's no such thing as a typical corner. Nevertheless, there are general types of corners that effect our line in a significant way.

### INCREASING RADIUS CORNER

This type of corner is seen frequently in the form of highway on-ramps. The people designing our roads encourage the typical driver, by designing a turn that opens out, to accelerate from secondary road speeds to highway speeds.

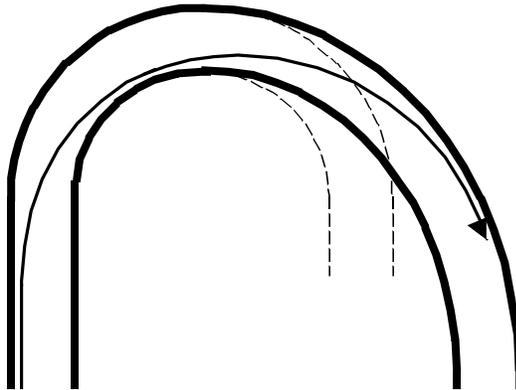


FIGURE 18

The dotted line in Figure 18 depicts a constant radius corner with the same radius as the initial portion of the increasing radius corner. The proper line here begins with an earlier-than-normal turn-in, made possible by the extra room at the exit of the corner. As we can see, this line would send us right off the track if we were in the constant radius corner shown by the dotted line.

### DECREASING RADIUS CORNER

Just as engineers often design on-ramps to allow drivers to accelerate, they often design off-ramps to slow people down, which they do with a decreasing radius corner.

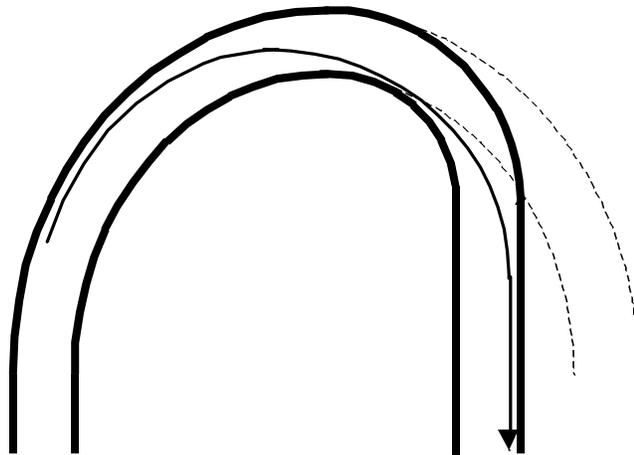


FIGURE 19

Figure 19 illustrates a decreasing radius corner with dotted lines showing a symmetrical corner following the initial radius. Unlike the increasing radius corner, where a turn-in appropriate to the initial radius will result simply in slow speeds, a turn-in appropriate to the initial radius of a decreasing radius corner will result in the same problems caused by early turn-in. We run out of track and are forced to slow and turn quickly, possibly spinning the in the process. The keys to decreasing radius corners are very late turn-ins, often after the corner has already begun, and great patience.

## COMPROMISE CORNERS

Having an infinite variety of corners complicates things reasonably well. Putting them in succession complicates them further.

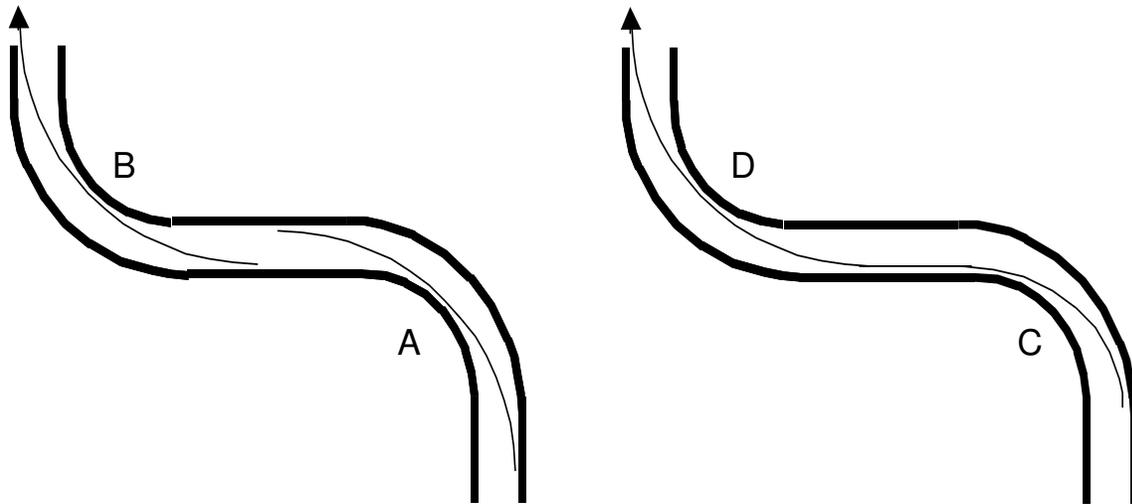


FIGURE 20

The corners shown above illustrate the most basic type of compromise corner. A and B depict lines that would be optimal if the corners were driven independently, yet their combination creates a problem when the driver tries to get the car from the track-out of turn A to the turn-in of turn B. Obviously, the lines through both corners can't be optimized. Since the second corner leads on to a straight, we compromise the first corner. Line C is a slow way through the first corner, yet it sets us up for Line D, which will maximize our exit speed out of the second turn.

## CAMBER CHANGES

Camber is best described as the tilt of the road. Drivers in the Winston Cup series race on tracks with as much as 36° of banking in the corners. The effect of these bankings, where the road surface tilts to the center of the corner, is to transfer some of the lateral force on tires into down force. The car gets better grip and can travel much faster than it could through a flat corner of the same radius. The opposite applies as well. If the road surface tilts away, toward the outside of the corner, the effect is to reduce down force on the tires and therefore reduce grip. These corners are called "off camber." The three types of camber are illustrated below.

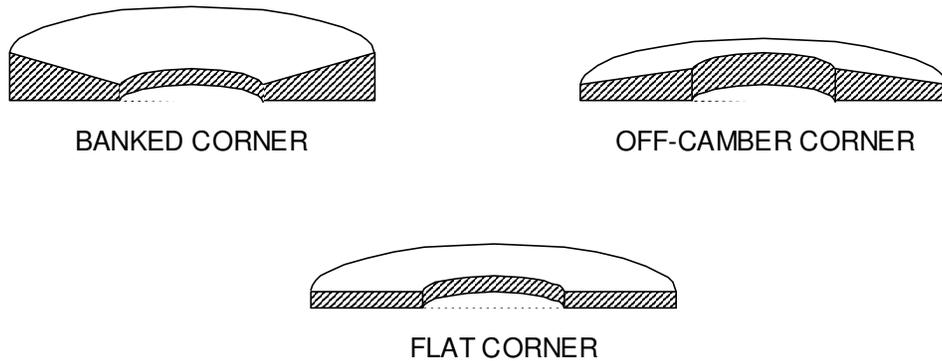


FIGURE 21

Camber often varies throughout a corner, yet our cornering speed is not necessarily dictated by the lesser amount of camber. If the camber is greater at the exit of a corner we can carry more speed into the corner and allow the greater camber, which provides improved grip, to help turn the car as we exit. In fact, even if the greater camber is only at the apex, we can still carry more speed through the corner.

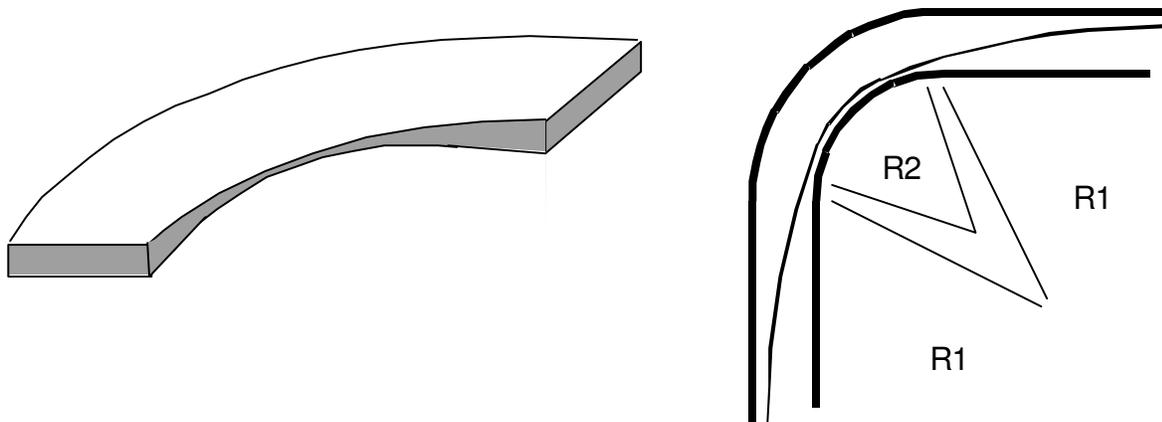


FIGURE 22

Figure 22 shows increased camber in the center of the corner. The driver can turn-in earlier and travel faster, on larger radii (R1), than would be possible in a flat corner. The increased camber improves grip and allows a tighter

radius at the apex (R2) without a significant loss in speed. This gets the car turned and pointed through the corner, allowing the driver to exit on a larger radius.

## ELEVATION CHANGES

The corners we've illustrated so far have been flat, but a great many race tracks have elevation changes as part of their character. If the track surface is rising under a fast-moving car (if the car is beginning to climb a hill), inertia will press the car into the track and increase both grip and potential cornering speed. Alternately, when the track surface drops away under the car, grip and potential cornering speeds are reduced.

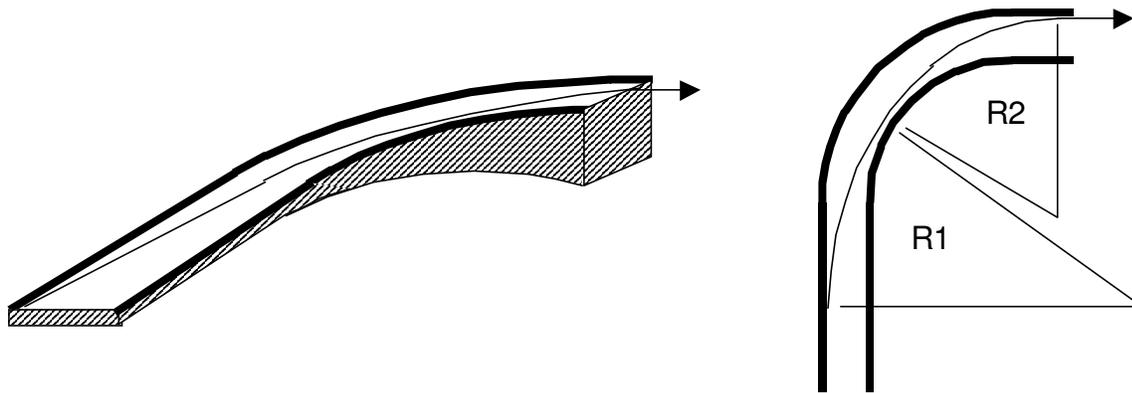


FIGURE 23

Figure 23 shows a corner that begins rising near the apex. A driver may enter the corner faster than normal, driving on a larger radius (R1). The increased grip provided by the elevation change will help to turn the car and allow it to exit the corner on a tighter radius (R2) but without a significant loss of speed. In a flat corner the illustration on the right would be depicting classic early turn-in.

## SURFACE CHANGES

Over time the material used to construct a race course will deteriorate, regardless of the aggregate and whether bonded with tar or cement. This deterioration is accelerated by racing cars, which, with their 700bhp, push and pull the sun-heated surface like taffy. The result is a loosening and dislodging of the aggregate. The modern racing tire, at racing temperatures, is literally sticky, and will pull aggregate out of the surface like a lint brush pulling lint. Lastly, there's downforce. Provided with enough room and a reasonable means of getting there, the modern race car could literally drive on the ceiling. What we know as downforce, which would make the former possible, the track surface experiences as pressure adjacent to suction... akin to a prying force. In fact, when the more sophisticated formula and sports cars race on public roads manhole covers have to be welded in place to prevent them from flipping into the air like tiddly-winks. This downforce, in addition to sucking the track apart, allows a 1,500 lb. race car to impact the surface with the weight of large truck. As a result the surface will develop, especially in the braking zones, washboards like those ubiquitous on dirt roads. In the corners the surface tends simply to fall apart and disappear. A driver returning to a track after, say, CART has been there may find that the track surface, and therefore grip, has suffered greatly. Eventually this damage gets bad enough that it must be repaired. More and more, these repairs are being done with more durable concrete, which provides different,

usually better, grip. Whether a patch is done with concrete or more pavement, drivers must be cautious the first time through at speed.

## **BRAKING**

In our effort to lower lap times around the track, braking is the last thing we work to optimize. Even when still working on our line, however, we must establish **braking points** for reference. Until our line is refined and consistent, our braking should begin early and at less than threshold level. When we're ready to begin working on our braking we first, using the same early braking point, build our braking pressure to the threshold level. As we do so we'll find that we've over-slowed for the corner. On successive laps, with calculated and minor changes, we begin to move our braking point deeper and deeper into the corner. Eventually, we find that we've carried too much speed past our turn-in. If we've approached this point gradually, our excess speed causes us simply to get off line while we scrub off some of that speed in order to get through the corner. We've blown our line and our exit speed is poor, but that's the extent of the consequences. The next time through we brake a bit earlier again and we've established our braking point for that corner. Our braking points may be complicated, however, by two factors.

## **NOVICE DRIVERS**

Novice drivers who try work to optimize both the line and braking simultaneously are presented with a particular challenge. While working their braking point deeper into the corner by improving braking skills, they've also increased their speed into that corner by virtue of the improved exit speed carried out of the previous corner. New drivers will travel progressively faster, requiring progressively earlier braking points. If you find that your braking points are bringing you into corners at irregular and unpredictable speeds, then move them farther out of the corner and brake consistently at below threshold level until you line is well established.

## **BRAKE FADE**

Whether driving a passenger car built for economy or a racing car built for performance, the driver must always be concerned with brake fade. Most production street cars have brakes that are perfectly adequate for highways, but are woefully inadequate for the track. Use the brakes during the first full session on the track, and pay particular attention to changes in braking. These changes can be a sense that the car just isn't slowing as well as it was previously, a "softening" of the brake pedal (boiling fluid), or a "hardening" of the brake pedal usually accompanied by the distinct odor of cooking brake pads. Some tracks have the unfortunate combination of hard braking zones in areas with poor run off. In such cases plan your strategy should your brakes fail. Given the choice between deep rows of tires and a cement barrier, most would opt for the former. Without planning ahead, however, the driver will not have the presence of mind to get the car there.

## **EVALUATING OUR PROGRESS**

Stirling Moss, one of the all-time great racing drivers, is quoted as saying that he never drove a perfect lap. No doubt he, like the rest of us, kept trying. Since measuring a perfect lap would take a stopwatch reading in nanoseconds, and since the BMW CCA doesn't allow stopwatches, we'll have to content ourselves with a less precise approach. The importance of exit speed has been established, so we'll do our best to quantify that for the purpose of measuring improvement. At the exit of each corner find a reference point a little past the track-out point. Using the track-out point itself can cause us to miss a reading if we're busy keeping the car on the track at that particular moment. As we pass the new reference point, look at the tachometer and remember the reading. It will take a few repetitions, but eventually the reference rpm's for every corner will be committed to memory. If the reading the first time through was, for instance, 5,300 rpm, try something a little different and see what reading results. A novice will see variations in the hundreds, while more experienced drivers will judge their performance by partial needle widths. An improvement in rpm's is an improvement in exit speed, which in turn will yield an improvement in lap times.

This brings us to another, closely related issue. It's important to recognize when our efforts are resulting in digression. Almost without exception, the driver trying really hard to go fast will ultimately go slow. Pushing the car too hard results in over-heated tires and brakes, lessening their performance. Further, driving a car in this way requires considerably more effort; the driver tires quickly and mistakes increase in frequency and magnitude. A prerequisite to going quickly is to remain smooth and patient in the cockpit. The car may be sliding and rotating,

even launching off of curbs, but the driver remains relaxed within. If you find yourself working hard, pull into the pits, take a deep breath, and then return to the track with the goal of progressing gradually to your limits.

## CONCLUSION

The pages you've just read do a reasonably good job of dissecting the art of performance driving. It's your job, now, to put all the pieces back together again. This is best done by ignoring the facts and figures and, instead, concentrating on two basic driving strategies: drive smoothly and drive consistently. While not necessary at slower speeds, smooth driving is absolutely crucial as you begin to go faster. The keys to smooth driving are a) eyes up and looking as far ahead as possible and b) hands and feet working in tandem. Consistency requires that you begin to know your surroundings in detail. When first driving through a corner you will be looking at the big picture. With each subsequent pass through that corner, however, the object of your focus will become more refined. Instead of tracking out in the general vicinity of a cone, you'll be concentrating on tracking-out to within a few inches of a small chip in the pavement 4 feet past the cone. Getting your eyes up and ahead will allow you more time to use more detailed reference points. Further, it will give you a better "sight picture," which is an understanding of your position not relative to specific reference points but to the scene in front of you taken as a whole.

To better envision what it means to drive smoothly and consistently, consider a friction circle. Simply put, this plots the driver's actual performance against a backdrop representing the car's ultimate potential performance. While few of us starting out are apt to drive cars with the accelerometers and computers necessary to produce our own friction circles, they are, considered generically, helpful in understanding how the dissected parts come together.

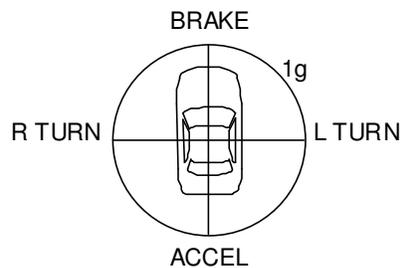
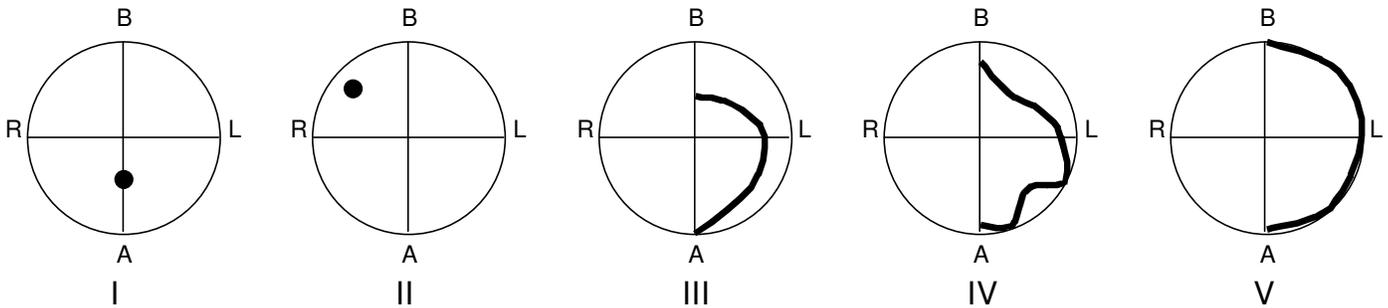


FIGURE 24

Figure 24 shows a basic friction circle. The circle itself represents the maximum potential of the vehicle on two axes, which are further broken into four components. For the sake of simplicity we've set this maximum potential at 1g. In reality, however, the friction circle for any given car would not be a perfect circle. The best way to imagine the friction circle is to envision a large version printed on the roof of your car, which has been replaced with a sheet of Plexiglas. The top of the circle, where it's labeled "BRAKE," would be next to the top edge of the windshield. The portion labeled "R TURN" would be next to the top of the driver's door. In the center, where the straight lines cross, imagine a string suspending a tennis ball inside your car. If the car is parked on level ground, the tennis ball is hanging straight down. When considering a friction circle, imagine that you're suspended over the roof, looking down at the tennis ball. If we start accelerating in a straight line the tennis ball moves straight back toward the rear window. If we hold a constant speed and start turning left, the tennis ball will move to the right of the circle, labeled "L TURN." If we're at the limit of the car's ability to accelerate, turn or decelerate, the tennis ball will locate itself squarely on the edge of the circle. The movement relative to the circle, and space left between the tennis ball and the circle itself, tells us not only how much of the car's potential we're using, but also how smoothly we're driving.



FIGURES 25 (I - V)

Figures 25 (A-E) show us various feedback we might see when using friction circles.

I) shows a car accelerating at roughly .5g (50% potential) in a straight line. This point could represent a static snapshot of a car - a single point in time - or a dynamic mapping of a car constantly accelerating in a straight line.

II) shows a car combining braking and turning right at roughly .75g (75% potential).

III) shows the progression of a car through a left hand corner. It first brakes at roughly 50% potential, then transitions to a left hand corner using roughly 75% of the car's potential, then transitions to accelerating at 100% of the car's potential.

IV) shows a car braking at 75%, after which the driver gets off the brakes and turns left. Notice that the driver using trail-braking (III) has a convex curve, which is closer to the shape of the friction circle. The driver in IV isn't using trail-braking and creates a concave curve, leaving a greater area between what was driven versus what was possible. As the driver begins exiting the corner he, perhaps, goes to power too quickly... the rear tires break traction and the car oversteers, causing the dip in the curve. The driver regains control and accelerates out of the corner at roughly 90%.

V) shows a smooth driver transitioning from braking, to corning, to accelerating using roughly 100% of the car's potential. While in all three of the latter examples drivers managed to drive their car at the limit, only in example V did the driver do so consistently. When driving around the race track, image the path of the tennis ball swinging around inside your car. A good driver would have that ball moving in large, smooth arcs. The poor driver would have the ball bouncing off windows and helmets.

While the twenty-odd pages you've just read are only a summary, there is enough information herein to befuddle even the most adroit student. It becomes especially befuddling if one attempts to apply this information while traveling quickly through an unfamiliar corner with an instructor chatting away in the passenger seat. When you get on the track for the first time, put all the facts and figures in the back of your mind and remember simply to take it easy, progress gradually and follow your instructor's instructions. First find the flag stations, then the reference points for the line, then braking points.... and so on. We strongly suggest that you have your instructor drive you around the track on the first session. Three or four laps spent watching your instructor drive the proper line is probably worth three or four whole sessions of hunting and pecking on your own.

We hope you've found this curriculum informative and useful. If some of what we've presented doesn't make sense just now, it will once you've spent some time in the seat. Remember, too, that your instructors are always willing to answer any questions you might have. Further, they are generally willing to take students for rides during the instructor run group. Watching somebody else do it right can be invaluable.

Have fun and be safe.

## GLOSSARY OF TERMS

APEX	A point describing where a vehicle drives near the inside edge of roughly the center of the corner
CAMBER	The lateral grade, or tilt of a surface
CONTACT PATCH	The portion of a tire coming in contact with the road
COOL-DOWN LAP	The final lap before entering the pits at the end of the driving session.
FRICTION CIRCLE	A graph on which the cornering, braking and acceleration forces of a vehicle are plotted.
g	A symbol used to denote the acceleration of gravity.
HEAL & TOE	A term used to describe a method of simultaneously shifting and braking.
MPH	Miles Per Hour
OVERSTEER	A condition where the rear tires are sliding more than the front tires.
PASSING ZONE	A portion of the track designated for over-taking (passing).
PIT-IN SIGNAL	A hand signal given by the driver of a vehicle warning that he or she

is travelling slowly, whether about to enter the pits or not.

POINT-BY	A hand signal given by the driver to indicate on which side another car should pass.
r	A symbol used to denote radius.
REFERENCE POINT	A landmark used by the driver to help judge distance.
REVS	RPM's - Revolutions Per Minute
ROTATION	The turning of a vehicle by using brakes and/or throttle.
SKID PAD	A circular surface that provides a driver with a perpetual corner.
SLIDE	A condition where the tires have lost grip and are sliding.
SLIP ANGLE	The degree to which a tire in forward motion is also sliding laterally.
SLIP RATIO	The degree to which a spinning tire is also slipping on a surface rotationally.
SPIN	A condition where the tires have lost traction and the vehicle is spinning around its vertical axis.
STEERING LOCK	The amount of steering input provided by the driver.
THE LINE	The term used to describe the specific path on which a vehicle is travelling.
THRESHOLD BRAKING	The point at which a vehicle is braking with as much force as possible.
TRACK-OUT	A point where the vehicle passes close to the outside edge of a track while exiting a corner.
TRAILING-BRAKE OVERSTEER	An oversteer condition caused by releasing the brake pedal as the vehicle is turning.
TRAILING-THROTTLE OVERSTEER	An oversteer condition caused by the transfer of weight from the rear to the front tires as throttle is abruptly reduced.
TURN-IN	A point at the outside edge of the track where a vehicle turns into a corner.
UNDERSTEER	A condition where the front tires are sliding more than the rear tires.
VEHICLE DYNAMICS	The study of the physical forces involved in driving a vehicle.
WEIGHT TRANSFER	The altering of the vehicle weight supported by each tire as a result of lateral and/or longitudinal acceleration.