DRIVING SCIENCE

OVERSTEER / UNDERSTEER

The Short Explanation

Oversteer is when the *rear* wheels lose traction in a turn and head towards the outside of the bend forcing the front of the car to point towards the inside of the bend. Understeer is when the *front* wheels lose traction and head towards the outside of the bend. In other words, Oversteer is when the car turns more than the bend would normally dictate, Understeer is when it turns less than the bend would normally dictate.

Oversteer

Oversteer is when, at some point during the bend, for what ever reason, the rear wheels lose traction. This in turn usually sends far more relative traction to the front wheels. Because you are turning at the time, the front wheels grip and carry on trying to go round the bend, and the rear wheels slide causing the back of the car to swing around the front. The general course of action is to steer into the skid. But this isn't really descriptive enough.

Lets take a right hand bend: During the turn the rear wheels lose grip causing the car to skid round to the right. The throttle techniques used to correct the skid are different if you are in a rear, front or all wheel drive car, but the steering is the same in the majority of cases. The general rule is to keep the front wheels pointing in the direction you want the car to go. i.e. if the care is pointing 45 degrees too much to the right, you need to set the front wheels 45degrees left.

Understeer

Understeer, generally thought of as the bane of the lives of most motorsport participants, is when the front wheels lose grip in a turn and in effect just carry straight on or the car turns much less than the angle of the wheels would normally dictate.

Again, the throttle techniques used to correct the skid are different if you are in a rear, front or all wheel drive car, but in general. There are generally three methods of recovering from understeer.

Slow Down

If you have the time and road left, you can simply hold the steering where it is and let the car slow down to a point where the front wheels grip. In this situation it is important to remember 3 things.

1 - Less is more with regard to steering, the front wheels are more likely to grip if they are pointing more in the direction of travel.

2 - Brakes are the food of understeer. If you stand on the brakes you are likely to lock up the front wheels and create even worse understeer than you had already.

3 - When the front wheels grip it can suddenly snap into oversteer due to the sudden change of direction, which can occur.

Feather Steering

As discussed, the front wheels will grip much quicker if the front wheels are pointing in the direction of travel. It requires a serious amount of mind over instinct but can be very effective if you straighten the front wheels and try to gently edge them round again. The idea is, you straighten the front wheels to regain grip and then ease the steering back to the point where it is about to lose grip again which gives you maximum steering.

Handbrake

This is a bit of a last ditch attempt and should be well practiced off road before attempting it on the road. The only thing which has less grip than an understeering wheel is a locked wheel. If you whack on the handbrake and and lock up the rear wheels, the front wheels will automatically have more grip than the rear wheels. This will almost certainly throw the car into oversteer, which is infinitely more controllable than understeer.

General

Check out the causes, effects and cures of oversteer and understeer for each type of car in the Front, Rear and Four wheel drive sections.

ANTI-LOCK BRAKES

Anti-Lock Brakes are a serious breakthrough in road safety but are not always as good as they are cracked up to be. There are situations where ABS is a distinct disadvantage. The idea behind ABS is based on the fact that maximum braking occurs when the wheels are just about to lock. A skilled driver can balance the brakes at exactly that point producing perfect braking. ABS tries to emulate this by sensing when the brakes lock and releasing them momentarily so they start to spin again providing more grip and then re-apply them. The general rule is that they can do this 50 times a second. Whether this is true or not is up for question but certainly some manufacturers produce extremely high quality ABS.

When is ABS a disadvantage?

On loose gravel or deep snow ABS can be a disadvantage. On these surfaces it is beneficial to lock the wheels due to the resulting build up of gravel or snow in front of the wheels. When you hit the brakes in snow, the ABS senses the wheel instantly locking and instantly releases the brakes allowing the wheels to ride over the slippy snow. The computer will then re-apply the brakes which will instantly lock and will instantly release, and so on.

TRACTION vs TORQUE

In a straight line, the grip the tire has on the road surface can only be broken under normal circumstances by torque applied to the wheels. i.e. Braking or Accelerating.

Braking

In general the tires are at their most efficient when on the point of losing traction. On tarmac, you will get the maximum braking performance out of a tire when it is on the point of locking the wheel. If you brake any harder the wheels will start to lock, which, on tarmac, will reduce your braking performance. Similarly, if you release the brake slightly, you will be braking slightly less. Duh!

Accelerating

In the same way as braking, you will gain maximum acceleration out of the tires on tarmac when they are at the point of losing traction (just about to slip or spin). Whilst wheel spins are a laugh and a good way of getting attention from 12 year olds, it is usually reducing your acceleration performance. There are a couple of extra aspects to accelerating, however, which mean that it is probably better to have some controlled wheel spin than to not spin the wheels at all.

ACCELERATING

Accelerating from a standing start is a balancing act of wheel spin and engine revs. If the revs are too low, the engine will bog down and you will not be providing the tires with anywhere near the maximum torque they can deliver to the road. If the revs are too high, you will exceed this max and spin the wheels.

If you can accurately balance Traction vs Torque you will get the maximum possible acceleration. In the real world however this is not possible every time. Due to the fact that you are in first gear, and therefore putting the maximum torque to the wheels, and the fact that the road surface and in particular, the changes in road surface have a greater effect at slow speeds, you would have to be a complete god to instantly and accurately adjust the throttle and clutch to account for it and keep the Traction vs Torque at max. The only way this is really possible is to have really high revs and balance using the clutch. The only problem here is that your clutch will last about ten minutes is you keep that up!

For this reason, the best method is to use *controlled* wheel spin. Build the revs up to just into the power band. Smoothly let out the clutch so that the wheels gradually start to spin and balance the spin to be just before they are starting to bite again. Keep this up until you are at a high enough speed that the wheels could grip and you would still be in the power band.

POWER BANDS

All engines are tuned. Some more accurately than others and some to do completely different jobs than others. Performance cars are usually tuned to provide maximum power. Unfortunately this comes at a cost. An engine will naturally produce more power at a certain rev range (usually in the higher end of the revs, but rarely at the actual top). This means that you will have a peak in power at a certain point. If you want to tune the engine to produce more power it will usually increase difference between the peak power and the normal power. This means that a performance engine will produce more power but must be used correctly.

The rev range at which the engine is producing the most power is known as the power band. If you want to drive your performance car to its potential, you have to learn to drive it in the power band.

BUMP-STEER

Bump steer is a term seldom discussed with regard to road cars. Yet, almost all road cars will have a Bump-Steer set-up designed in from the factory.

What is it?

Bump-Steer is the amount of change in toe angle in the two front wheels throughout the entire travel of the suspension.

So... *What is it*?

When a car is standing still, it will almost certainly have a front toe angle. If you have a positive toe angle (toe-in), the front wheels will be pointing inwards (towards each other) slightly. A negative toe angle and the wheels will be pointing outwards slightly (toe-out). In most road cars, this angle will change as the wheels move through the full range of suspension travel. The Subaru Impreza (apart from the RA) has lots of bump-steer tuned in at the factory.

Why?

Almost all 4WD cars are prone to 'lift-off oversteer'. When you lift off the throttle or brake, you load up the front tires with weight and therefore grip and take the same away from the back tires. If you are turning at the same time, the chance of oversteer is very high. Subaru must have taken a decision that the majority of drivers can cope with understeer more than oversteer (which is very true), and in the interest of safety spend time and money tuning out the majority of the 'bite' of lift-off oversteer by playing with the bump-steer settings.

Why is it a problem?

Many people counteract bump-steer by tuning in static toe-in. This means that, as the bend approaches and you get on the brakes, the suspension starts to compress and at some point the bump-steer will forces the wheels to be parallel.

This helps, but… What happens mid bend? Lets say you are going round a right hander. The left suspension is compressed and the right is slightly extended. This means that the front left wheel is probably slightly toeing out, and the front right is toeing in! Now throw a slight bump into the road, which only one of the tires hits! This can NEVER be a true handling car. It may however be safe for the average driver as it takes away the need to be quite as accurate.

IS IT REALLY NEEDED?

So you want rid of that damn understeer you get every time you go into a tight 2nd gear bend? Or are you sick of the snap oversteer which is characteristic of your car? The first place to look when changing the handling of your car is at the way you are driving it. If your car will not do something another car will do, it is likely that a contributing factor is your driving. When a works rally team starts testing a new car, the test driver must make the best of a bad job. In other words, the car will not be handling that well, so he must drive around the problems.

It is possible to produce almost any handling trait in almost any car by driver input alone. Even the most understeer prone front wheel drive car can be made to oversteer wildly. Even the most tail happy rear wheel drive car will produce terminal understeer if properly motivated. The other strange thing is that the same input may produce totally different results in different cars. With this in mind it is important to assume that the handling trait may be caused by something you are doing, which does not agree with that car.

Why is important to set it up?

It is all too often the case that people make changes to a perfectly good car to counter-act a trait caused by themselves. The result can be a car which is incredibly challenging on the limit. Let's say we have a rear wheel drive car. It rains all the time and we live on an island with no other road users. But for some reason there are plenty of well-made roads around, including roundabouts, etc (weird huh?).

Every morning we come to a wet roundabout, charge in on the brakes, come off the brakes and turn the steering hard right (going clockwise round the roundabout) and then get back on the gas, expecting the tail to swing round. It doesn't swing round for some reason, so we keep turning the steering wheel more and more and pressing the throttle, until we are on full throttle and full steering lock. The car just plows straight on and we have to back off to avoid hitting the kerb. We then just try to make the best of a bad job and get out of the roundabout, gradually winding the steering lock off and keeping the throttle at about half. Then suddenly the car snaps into harsh oversteer with no warning and we end up facing the other way thanking the lord there are no other cars on our island.

Well, this does not sound like a well-balanced car. It is a Rear Wheel Drive Car! I gave it loads of power on a bend and it understeered??? Aren't they supposed to oversteer like mad? I then came off the throttle a bit and tried to just drive out of the roundabout smoothly and it suddenly snapped into oversteer with less steering and less throttle than when I was trying!!

Well, as you probably know, what happened there was…
We entered the corner on the brakes. The front suspension was compressed due to the braking. We came off the brakes and the front suspension rebounded. At the point where the suspension was at about full travel, we started to steer. This is the point where the fronts have the least grip, so the front tires were not able to produce their best level of lateral grip to turn the car. At the same time we went back on the throttle which further reduced the weight on the front and therefore the grip level. We then continued to turn the wheel which forced the front tires beyond their optimum slip angle causing them to produce even less turning forces, etc, etc.

We then realize this isn't going to work so we come off the gas a bit and start turning the wheel back. The weight has gone back onto the front suspension now to the fronts will produce more grip, but they are still well beyond their optimum slip angle. As the steering comes off, the tires reach their perfect angle and suddenly produce huge amounts of lateral grip and therefore turning forces. The front of the car lurches right and the back of the car struggles to keep up. There is enough torque going to the rear wheels to help break traction so the car spins into huge oversteer.

If we had changed the set-up to produce more oversteer, the car would have become more violent in the second part of the above and less of a problem in the first.

If we had set it up to produce more understeer, the car would have been worse in the first part, but more manageable in the second.

Which would have been better?

Well the truth is that we don't have enough information to decide which is better because there is too much driver error to contend with.

But is would be easy for a driver to assume their car is producing the problems which are actually being caused by errors they were making.

TYRES

The most important part of your set-up.

People will often spend all manors of cash on their suspension, anti-roll bars, wheels, etc. and completely ignore the tires.

Your tires are the single most important part of your handling set-up. Why? They are the ONLY thing which make your car speed up, slow down, turn left and right, etc. Everything else is wasted if the tires cannot produce what the other components request. If we take an extreme. Lets say we have the most gripless, Teflon coated, playstation, Hollywood tires you have ever imagined. These tires produce almost zero grip. The car often slides off the camber of the road when parked! This thing oversteers in the garage! You get the picture…

Put a new engine in the car producing 1200BHP and tell everyone about it. When someone challenges you to a drag race in their 1.1 Corsa van carrying ½ a ton of bricks, they will wipe the floor with you. The problem is that the torque that the engine can send to the wheels cannot be transferred to the road by the tires. All that power, therefore, is completely wasted.

The same is obviously true of cornering, if you have the most expensive and well set-up suspension in the world, the car can still only do as much as the tires.

The idea then, is to have tires which can cope with the demands of the other components. Now this does not mean just stick the most sticky tires you can find on your car. OK, that will give you lots of grip, but it could also completely cock up the handling of your car. If the tires produce ten times the grip (when cornering) that the suspension set-up is designed for, the car will not handle how it was supposed to. Outside suspension will be compressed more that it was supposed to be, ARBs will be flexing more than they were supposed to be, etc, etc. Tires are a vital part of the set-up of your car, and just like all other aspects, it affects everything else.

Mismatched Tires

Another HUGE mistake people make is to mismatch tires. Lets say we put the fabulous 'Bridgestone S0-2's on the front wheels and 'Happy Shopper OK's on the back. We are no longer giving the car an opportunity to handle in the way it was designed / set-up. You have taken away it's ability to react in the way it was intended to.

When cornering, the 'Happy Shopper OK's are going to give up way before the 'S0-2's which means you will go into violent oversteer. People will drive round on this kind of set-up for years and years without realizing it is a problem and saying "Well I've done this for 40 years and never had a problem matey!!". The problem is, this trait will never become visible until you push the weakest tire over its limit. For 40 years, Mr. Naïve has been driving around under the limit of the weakest tire. The second an emergency happens and that weakest tire is pushed beyond its limit, the car will behave in an unpredictable way. So if you want your car to behave and allow you to explore its limits under your full control, you must have the same brand and same model tire on every corner.

Tread Depth / Grip

In general, a road tire will grip a wet road better with a deeper tread, and a dry road better with a lesser tread. It is all about how much rubber is in contact with the road. In the dry a slick tire (no tread) has the opportunity to put the entire width of the tire onto the road. This means that a huge amount of actual rubber is in contact with the road.

In the wet however, things get a bit more complicated. Water is sitting on the surface of the road. If a slick tire rolls along this road, it will ride over the top of the water. This means that the tire is separated from the road by a layer of water. Not good for grip! So the tread pattern comes into effect. The tread pattern is designed to squeegee the water through the channels of the tread and allow the blocks of rubber contact the road in place of that displaced water.

Tire Width

If everything was easy and simple there would be a nice formula which would say "The wider the tire, the greater the grip". Well unfortunately things aren't that simple. In the wet, the tire has to be forced onto the road with enough force to squeegee the water out of the way. The wider a tire gets, the less pressure per square inch it forces onto the road, as the weight is distributed across a wider area. This means that squeegee effect is lessened until such a point that it is non-effective and the tire blocks just ride over the top of the water. In the dry it is not as straight forward. In simple terms, the more tire you can get on the road, the more grip you are going to produce. So this should follow that the wider the tire, the more grip, but there are a couple of other aspects to this…

Un-sprung weight is a MAJOR factor when setting up a race / rally car (discussed in another article). The bigger the tire (and therefore wheel) the greater the unsprung weight.

What about F1 Cars?

Why do F1 Cars have wide rear wheels and small front wheels? They are producing so much power that they need to have a big patch of rubber to channel the power to the road. But on the front they need to keep the un-spring weight down to maintain as much grip as possible.

DRIVING TECHNIQUES

SEATING POSITION

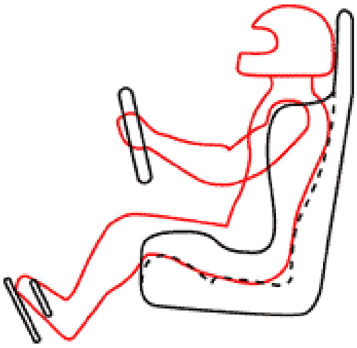
One of the first things to prepare before you even turn the key, is a proper seating position. This is often overlooked, or improperly imitated, resulting in poorer car control and premature fatigue.

If you look at a variety of racecars, you will see a variety of seating positions. In the open-wheel CART and Formula cars, it appears that the driver is almost laying down with arms fully outstretched (they are not). In a full-bodied NASCAR-type car, you see the driver more erect and almost cramped against the steering wheel. Neither position is the correct one for your streetcar in road racing. The body of the open-wheel car is very shallow in height, and the cockpit is very narrow. This shape determines much of the driver's position. The driver's legs are relatively straight out with a slight bend in the knee, and the feet just barely below the hips. The pedals in many of these cars are almost touching each other. The pedals also require little more than a flexing of the ankle to go from 0-100% depression. The driver's arms have little room for movement, but the steering requires extremely little turning input by the driver. In the open-wheel car, function (driver's seating position and controls operation) follows form (the shallow and narrow cockpit).

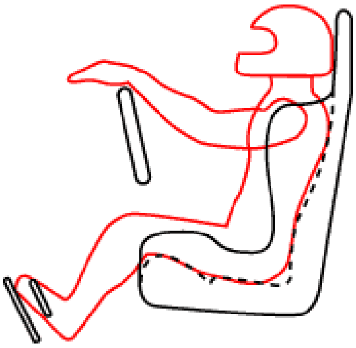
In a NASCAR type car, many things are completely opposite. The driver sits very erect, and is very close to the steering wheel. In fact, the driver can almost lay his whole forearm on the steering wheel. Why the big difference? The cars themselves are larger, heavier, and have large front tires. Additionally, on even the large speedway tri-ovals, the percentage of time spent turning is much higher than on a road course. All this adds up, and means the driver's right arm and shoulder is going to get tired much sooner. Sitting erect and close to the steering wheel allows the driver to utilize more of the shoulder and back muscles.

In driving a streetcar on a road course, whether the car is stock or fully race-prepared, neither of the above-described seating positions is correct. The seat should not be "layed down" to make you look like a formula driver, and neither should sit as close as the NASCAR driver.

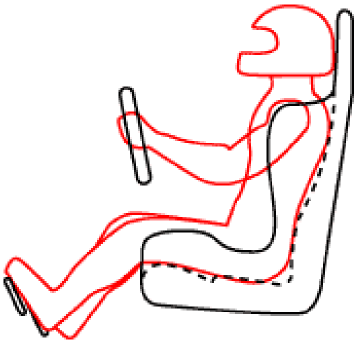
There are three main aspects to setting the correct seating position. Each of these is described under the illustrations to the right. In a street car, it is possible that some balanced compromise of these three parameters is needed as the fixed position of the pedals and steering wheel may not be perfectly matched to your arm and leg lengths. In a racecar, or a streetcar you spend the money on, the pedal arms can be modified, and a steering wheel with a specific dish dimension (the depth of the mounting plane to the face of the handling ring) can be selected to allow a perfect match to your needs.



First, sitting in the seat itself, the driver's back should be flat against the back of the seat with the buttocks squarely tucked into the corner created at the intersection of the seat back and bottom. The underside of the legs should be in contact with the seat bottom. The purpose of this position is to provide as much surface contact between the driver's body and the seat. This has safety benefits as well as providing the driver with the most tactile feedback as possible.



Second is the arm position. When the driver is tightly strapped into the seat as described above, the arms when fully extended should allow the wrists to rest at the top of the steering wheel. This allows the arms to be slightly bent at the elbow when fully extended for a turn. The purpose of this position is to prevent the arms from being overextended during turns (the shoulders should not need to lift from the seat back even to do a full arm crossover). Overextending the arms will cause them to tire quickly, and will cause the driver to lose sensitivity to the vibrations in the steering wheel.



Third is the leg position. When any of the pedals are fully depressed with the ball of the foot on the pedal (not the toes), the leg should still be bent at the knee. This is to prevent overextension as described for the arms. Additionally, given that most hobbyists are driving their streetcars, be sure that the knees are not against the underdash or steering column. In fact, there should be several inches room to prevent injury in event of a collision. The right leg in particular will need enough knee room to allow the ball of the foot to be on the brake pedal, and the heel to be on the gas pedal for heel-toe downshifting

STEERING

The steering wheel is where you will get most of your feedback of the track surface from the front tires, suspension, and brakes. As simple as steering may seem to be, for maximum control and smoothness, there are definitely some techniques you should be aware of.

Your hands will spend a great deal of time on the steering wheel, so for both sensory input and comfort, how the steering wheel feels in your hand is important. Depending on the size of your hand, you may want a wheel that is thicker or thinner. The exact style, size, and construction is up to you. If you're thinking of changing from the stock steering wheel, choose one that is comfortable gripping the wheel with your driving gloves on.

Steering Wheel Grip

The proper grip of the steering wheel starts with the hands at the 9:00 and 3:00 positions. Contrary to the 10 and 2 o'clock positions you probably learned in driver's school, you have greater range of motion and control with your hands in the 9 and 3 o'clock positions. The palms should be cupping the outer diameter of the wheel, with the thumbs wrapped around the ring and resting on top of the cross brace. The heel of the palm should be positioned to apply a slight pressure on the front of the wheel for stabilizing your arm movements--don't make your thumbs do all the stabilizing. Most stock steering wheels in sports cars, and even sedans, today are properly designed for the 9 and 3 positions with padded thumb detents.

The grip itself should be relaxed--just tight enough to maintain control and good contact for sensory input. A tight grip on the wheel will tire your hands and arms quickly, and more importantly will significantly reduce the sensitivity to the vibrations needed to sense the control limits of the vehicle.

While it is a natural tendency to grip the wheel tightly while corning, no amount of squeezing on that wheel will increase the traction of your tires! However, the more relaxed the grip (without losing contact with the wheel), the more of that traction you will be aware of. It is a learned response to relax your hands (in fact, your entire body) during high g-force cornering, but it is something that you must force yourself to learn as quickly as possible. It will increase your sensitivity to the car's traction limits, and improve your awareness of the car's handling.

Something to practice to ensure your hands, arms and shoulders are relaxed before entering a corner, is to take a deep breath during the straight beforehand. Breath deep, relax your muscles, and exhale. Another thing to do when you're in a long enough straight and clear of other cars, is to relax one hand at a time and wiggle the fingers (leaving the palm and thumb on the wheel). Doing this often will keep the muscles in the hand, wrist, and forearm from cramping.

Steering Wheel Control

When turning a corner, lead into the turn by "pushing" the wheel with the hand opposite the turn (left hand for a right turn), and stabilizing the wheel with the other hand. Push the steering wheel through the 12:00 position rather than pulling it towards the 6:00 position when turning. For large steering inputs like a turn, the pushing arm has more control because the wrist stays in a firm position. The opposite wrist becomes quite bent and will not provide smooth control. "Pulling" the wheel is effective for small steering inputs such as moving across the track width where the action is really limited to a movement of the wrist, and not the whole arm. If you're a puller right now, it will take a little re-training to make this comfortable, but in the long run it will make you a smoother driver.

One of the critical keys to maximizing speed through corners is smooth car control, which comes from smooth steering. If the car is to travel on a smooth consistent arc, then the steering input must also be a smooth consistent turn. The purpose of this smoothness is to maximize the traction of the tires. To understand this, take a sheet of paper, place it on a table, and place a book on the paper. Pull the paper slowly across the table gradually increasing the speed. The book stays on the paper. Now, start to drag the paper again, but at some point suddenly jerk the paper. The book loses traction and slides across the paper. We'll talk more about the tire's perspective of this later, but for now the motion of dragging the paper is like your steering input. The traction of the tire is significantly influenced by your ability to provide smooth turning. Sudden jerks in the wheel will be like sudden jerks on the paper, and the tire will slide. The smoother driver will have more traction, and will have higher corner speeds.

It is common to think you *are* turning smoothly, when in fact you are turning on a smaller, tighter, and jerkier radius than you need to. In car video can be a great help to watching yourself, and recognizing where you need to be smoother. A typical tip off to a driver that needs to be smoother is when a car tends to understeer during the first half of a turn. More often than not this is caused by the driver's lack of steering smoothness than by car setup problems.

The proper hand positions are 3:00 and 9:00 with the thumbs wrapped around the ring resting on the crossbrace, the palms cupping the outer diameter of the ring, and the heels of the palm applying a light pressure to the front of the wheel. The grip should be relaxed—just tight enough for control and good sensory input

Most corners can be driven through without moving the hands from the 3 and 9 positions in a sports car. This allows your arms a little more than 180 degrees of wheel turn. Note in this photo that the thumb of the right hand is kept under the crossbrace of the wheel. This provides extra stability.

If a corner requires a little more steering input than 180 degrees, the following technique provides the most control. This should get the car through even slow, tight, 90-degree turns. Let's look at a right turn for the example

Just before the turn-in point, relax the grip on the right hand and slide it along the wheel to the 11:00 position (don't take your hand off the wheel). This places both hands close together at the start of the turn.

Keep both hands close together, and progress through the turn. This hand position allows about 260 degrees of steering wheel movement placing the right hand about 6:00.

When unwinding from this position, leave both hands tight on the wheel until the right hand reaches 9:00. Relax the right hand grip slightly, finish leading the unwind with the left hand, and allow the wheel to slide through the right hand.

For hairpins, or switchback corners, you will likely need to use a hand over hand action. Some drivers like to start a large steering input like this by placing the leading hand at the 6:00 position, and turning a full 360 degrees before involving the other hand. This seems to simply the action, but it has the drawback of having only one hand on the wheel for quite a while. The control is not likely to be as smooth, the sensory input is halved, and in a racing situation in traffic, the ability to maintain control if bumped is reduced. Smaller, repetitive hand moves in a hand over hand situation is better.

SHIFTING

You may think shifting is a no-brainer function, but in a sport where the difference of winning may be 1/100th of a second, every detail counts. This discussion is to point out how to use the shifter, and we're assuming the use of a typical H-box shifter in a streetcar for this.

Many people fall into two bad habits on the street when shifting. First, "Hollywood" has taught everyone that it looks cool to always leave your right hand on the shift knob. Wrong! You may as well tie your hand behind your back as leave it on the shift knob. Your hand belongs on the steering wheel--always. When you need to shift--shift, and get your hand back on the wheel. Don't even rest it on the shifter for a few seconds a head of time to "get ready." Every time your hand leaves the steering wheel you've given up 50% of the tactile feedback you have from your hands, and 50% of your capability to control the car. If you're racing with other cars around you, you never know when you may get tapped. Even when racing alone, mechanical failure may cause handling trouble. You'll want both hands on the wheel when that happens.

The second bad habit some people have is shifting with excessive force. Too tight a grip, and slamming from one gear to another will actually slow your shifting down, and cause excessive mechanical wear. Proper shifting uses an open palm grip on the top of the shift knob, and a gentle but fast guide from one gear to another. We repeat---all shifting is properly done with the hand open and cupped over the top of the knob, not wrapped around it like a fighter plane control stick.

To shift from the top of the H to the bottom, start by forming a cup with your palm and fingers. Place the palm of the hand over the top of the shift knob. Using the underside of your fingers and your palm against the knob, use a smooth straight-line motion to guide the lever to the next gear. Assuming the shift lever has a fairly short travel, the action involves your wrist for the majority of the movement. Do not attempt to slam it or force it faster than it wants to go. If you are locking your wrist and moving your whole arm at the shoulder, you are using too much force.

To shift from the bottom of the H to the top, again start by forming a cup with your palm and fingers. This time when you place the hand over the shift knob, the emphasis of contact is on the heel of the palm. Start with the wrist slightly bent up. Push the lever using the palm heel in a straight line using your wrist to extend the position of the palm heel while following through with a gentle push of the arm. This shift is more arm motion than wrist.

When shifting across the H such as between 2nd and 3rd gears, do not try to make a conscious jog in your hand movements. The linkage needs very little input to make the diagonal path across neutral. Your shift should almost look like a straight diagonal line. Making a distinctive zigzag through neutral is strong-arming the shifter and will slow the shift down.

Using smooth, soft control of the lever does not imply doing it slowly. A gentle force of the lever will allow the shift linkage to move freely through its natural motions. If you strong-arm the motion you will end up forcing the linkage through lines that have more resistance. This will slow the shifting down. Use as much wrist movement as possible in place of moving the whole arm.

Some of you may be tempted to learn the techniques of "speed shifting"--shifting without using the clutch--in the interest of saving time. Many schools and professional racers have shown over and over that there is no speed or lap time advantage to this, and it carries a much higher risk of gearbox damage.

Shifting from the top of the box to the bottom, form an open cup with your hand, and place over the shift knob with the inside of your fingers and the palm of your hand making contact. Guide the lever quickly, but without strong-arming it. Push it, but don't slam it. The movement is primarily from the wrist. If you're locking your wrist around the shifter like a fighter-plane control stick, you will actually be slowing your shift down

Shifting from the bottom of the box to the top, cup your hand over the shift knob, and using the heel of the palm, push the lever into the next position. This shift involves more arm motion than does a top to bottom shift, but again--no choke holds or body slams--the shifter is a precision machine, not a wrestling opponent.

PEDALS

This section covers a few basics about the use, and the design and layout of the foot pedals, and prepares for the discussion of the heel-toe downshift.

How many pedals are there? Did you guess four? In a manual transmission car there should be four pedals:

- Accelerator (gas)
- Brake
- Clutch
- Rest (or "dead" pedal)

The rest pedal is a permanently positioned pedal pad at the far left to rest the left foot on. It provides a place to stabilize the leg when not using the clutch. In a street car without a racing seat or racing seat belts, the rest pedal is effective for bracing yourself around corners, but if you have a proper seat and belts, don't get into the habit of pushing hard against the rest pedal--relax and let the seat and belts do their job.

The first thing to get straight about using the pedals is that they are operated with the ball of the foot (the bony part just behind the toes), and not the toes. Secondly, you must be able to depress the pedals all the way with the ball of the foot while still having some bend in the knee. You cannot have the needed control and sensitivity in operating the pedals if the leg is completely outstretched. (See the Seating Position article for more positioning details).

Every pedal must be used smoothly. Stabbing at the accelerator or brake pedal in particular will cause sudden shifts in weight distribution on the car's suspension and will unsettle the car. Do this at the wrong time, and a loss of control is inevitable.

When applying either the brake or gas pedals, ease into it allowing a smooth transition to the full pressure needed. "Easing" does not necessarily imply being overly slow about it. A rapid but smooth and controlled transition is what is wanted. Avoid sudden jerky movements in either braking or accelerating.

One of the pedal control techniques used in racing is the heel-toe downshift. To maximize the speed and smoothness through a corner, it becomes necessary to do some cockpit acrobatics and operate the steering wheel, shifter, clutch, brake, and accelerator all at the same time. The problem is that there are five functions to perform and only four limbs to do it with. Something has to do double duty, and it turns out to be the right foot.

Refer to the *Heel-Toe Downshift* article for details of the technique itself, but the short of it is that prior to the entry of a corner, the right foot will need to operate the brake pedal and the accelerator at the same time.

Chances are the pedals in your streetcar are not going to allow you to properly do the heel-toe down shift as it will be too difficult to operate the brake and gas pedals at the same time, and you will need to have the pedals changed. After-market pedal kits are used to replace the stock rubber covers on the pedals. The clutch and brake pedals will be bigger to give you more sensory feedback. The gas pedal will be larger, but will also have an extension on the lower left corner allowing it to be more easily reached during the downshift. Some after market pedals intended for the fashion conscious will have simple bend tabs to hold them in place over the stock pedal pad. This has no place in a car used for racing. Be sure to get quality pedals designed to be bolted onto the steel pedal plate in place of the rubber pads.

Also, you may need to use shims to raise either the brake pedal or gas pedal to allow comfortable reach when operating both pedals. The brake and gas pedals should be close to the same height at the time you need to operate both simultaneously. When the brake pedal is fully depressed, its height should be roughly equal to the height of the gas pedal when it is not pressed. This allows for more comfortable and controllable heel-toe maneuvers.

Heel-toe Downshift

The heel-toe downshift is a fundamental technique to driving fast through corners. During a heel-toe downshift, you'll be steering with the left hand, shifting with the right hand, clutching with the left foot, and working both the brake and gas pedals with the right foot -- all at exactly the same time.

It takes some getting used to, and it takes repetitive practice to become smooth, and have it be second nature. At first it takes a lot of concentration. You're doing a lot of things at the same time. Besides working on all the controls, you also need to be sensitive to the tire grip during braking, you have to be watching your reference points heading into a corner, and to make matters worse, if you're racing, you might have to be looking for traffic. However, after a couple of weekends of practice, you'll get the hang of it, and in no time you'll be able forget about your hands and feet, and concentrate on the track.

On the street when you approach a corner, you were probably taught to complete your braking before the corner, coast through the turn, then as you straighten out from the turn downshift, and start accelerating again. This works on the street, but it is entirely too slow a process for the racetrack.

For racing, the time spent transitioning from braking to accelerating must be absolutely minimized. You're racing! You don't want to be wasting a bunch of time coasting while you're switching between pedals (even if it is only 1/2 of a second). To maximize the speed and smoothness through a corner, it becomes necessary to do some cockpit acrobatics and operate the steering wheel, shifter, clutch, brake, and accelerator all at the same time.

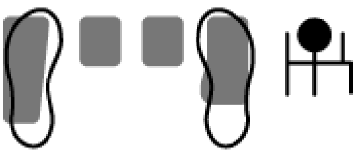
On the race track, as you approach a corner, your right foot comes off the gas pedal and presses the brake with the ball of the foot. Before the braking is done, you need to shift gears so when the braking is done you can immediately be back on the gas. When the braking is almost done, your left foot pushes the clutch pedal in, and your right hand downshifts. However, while you've been slowing down, the engine speed has dropped. If you let the clutch out now, the car will jerk severely as the engine works like a huge brake. If you're at the edge of traction limits (which you should be), you'll lose control of the car. To prevent this, something needs to rev the engine back up to the right speed before the clutch is released. The right foot is closest, so it is elected to tap the gas pedal. Even though the right foot is busy braking, you swing your right heel over the gas pedal and give it a short push (a "blip" as it is called) to rev the engine while the left foot also lets out the clutch (the ball of the right foot is still on the brake). The amount of blip, and the clutch release timing need to be perfected so there is a perfectly smooth transition when the clutch engages the engine. Meanwhile, the heel is rotated back off the gas, the ball of the right foot has still been braking, and has been easing off as the car approaches the turn-in point. The downshift should be completed before the braking is complete, and before the turn-in. As the engine and transmission are engaged, the braking reduced, and the turn-in begun as the foot makes a smooth transition back to the gas pedal. At first only enough gas is applied to sustain the initial corner speed, and then you gradually accelerate out of the corner.

The above description is the "what" and the "why" all mixed together, so let's look at the just the steps involved in the "what" part again:

- Lift the right foot from the gas pedal and press the brake pedal
- Just before the braking is done, the left foot depresses the clutch pedal
- The right hand downshifts (the left is still on the steering wheel)
- The right foot is still applying, but easing up on the brake pressure, then rotates so the heel is above the corner of the gas pedal
- The right heel gives a quick push of the gas pedal to rev the engine quickly (the ball of the foot is still on the brake easing up even more)
- The left foot releases the clutch, the right foot rotate off the gas
- The right foot completes the braking
- The right foot slides over to the gas pedal to assume the normal position only to maintain some pressure to sustain the vehicle speed through the first part of the corner. Then accelerating out of the turn.

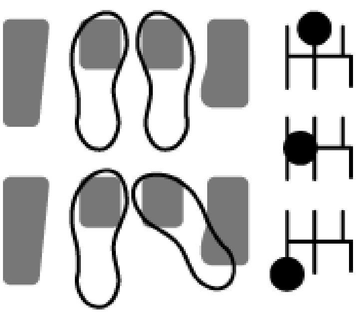
The whole sequence above from the second bullet to the last takes less about half a second. This takes quite a bit of practice to get right. The whole idea is to transition between braking and accelerating with absolutely no delay, and with perfect smoothness. Done correctly, there should be no jerking of the car during the downshift and transition back to acceleration.

One other note about the above description: We have assumed the use of a streetcar, and a street transmission with synchros. If you're using a true race transmission without synchros, then you need to modify the above shifting with a double-clutch procedure. To do this, the clutch is pressed in, the shifter moved to neutral, and the clutch released. Then the accelerator is blipped, while the shifter is in neutral (again with the heel, while the ball of the foot continues to brake), the clutch pressed back in, the shifter placed in the lower gear, and the clutch released. This is required for maximum longevity of the transmission. If you expect to get in a racecar some day that is likely to have such a transmission, it's a good idea to practice this shifting technique with your streetcar as well, even though it technically is not necessary.



The downshift begins with a full throttle acceleration towards a corner

Lift the right foot from the gas pedal and press the brake pedal

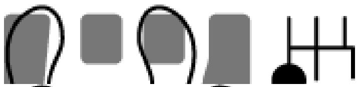


Just before the braking is done, the left foot depresses the clutch pedal.

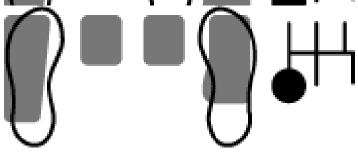
The right hand begins the downshift.The right foot is still applying, but easing up on the brake pressure as the car approaches the turn-in, then the foot rotates so the heel is above the corner of the gas pedal.

As the shift passes through neutral, the right heel gives a quick push of the gas pedal to rev the engine quickly (the ball of the foot is still on the brake easing up even more).

The left foot releases the clutch, the right foot rotates off the gas. Done correctly the RPMs generated by the throttle blip above matches the RPMs needed, and as the clutch is released the engine engages smoothly with the current wheel speed. There should be no forward or braking lurch when the clutch is let go



The right foot completes the braking with a smooth release



The right foot moves over to the gas pedal to assume the normal position at first only to maintain the pressure needed to sustain the vehicle speed through the first part of the corner. Then pressure is gradually applied to accelerate out of the turn.

BRAKING AND ACCELERATING

One of the keys to good race driving is smoothness, and this most certainly applies to the use of the brake and accelerator pedals.

Braking

On the street, braking and accelerating are done at relatively low levels compared to the vehicle's capability. The tire's traction limits are rarely maxed out. Sure, you can romp on the gas and spin the tires at a light, or slam on the brakes and slide the car a little, but it’s very easy to bring the car back under control.

In the rain, or especially the snow, you know you have to be much gentler and smoother with the brakes and with the accelerator. If you lose control on a wet or snowy surface, it can be much harder to regain control. There is much less traction to work with.

Braking and accelerating when racing on a road racecourse, even when dry, is treated something like driving on a wet surface--gently and smoothly. Braking and accelerating are used in conjunction with the corners--you brake going into them and accelerate coming out of them. Because the objective is to have the car moving as fast as possible through the corner, the tires will be utilizing most of the available traction (done right they should be using 100% of the available traction). The driver must be very smooth with the use of the brakes going into the corner and the accelerator coming out of the corner. A sharp change in braking or power at these points will upset the car's traction balance just as quickly as if you were driving on ice. Working within the last 1% of traction means there is no reserve to call upon to gain control of the car back. Even the pros very rarely recover a car that has lost control. It's not because they don't know how, it's because there's no traction left to work with. It is imperative to learn how to be consistently smooth in braking and accelerating on a road course.

There are three phases in braking. First, braking begins with a rapid, but not instant, application of as much braking force as possible. How rapid the brakes can be applied will depend on the suspension in the car. The stiffer the springs and shocks, the more rapidly maximum braking can be applied. Soft springs will have significant forward roll, which will require a little longer and smoother ramp-up of braking to keep the car stable.

Second, once the car settles onto the front tires, you'll be trying to minimize the length of the braking zone, so it will require taking the tires to the edge of locking up. You'll need to be very aware of the vibrations in your foot from the pedal and in your hands from the steering wheel to feel that small difference (therefore racing shoes are highly recommended. You just won't feel much from the pedals in Air Jordans). The car will travel some distance using a fairly constant brake pedal pressure.

The third phase is towards the end of the braking zone when the vehicle has been slowed to near its final speed. Gradually release pressure off the pedal making the transition from full to zero braking force as smooth as possible. During braking, the front tires are under heavy load, which increases the available traction. A sudden release of the brakes will abruptly reduce the load and reduce the traction potential of the front tires, which at this point is needed for turning into the corner.

The turn-in is one of the points where the car will be the most sensitive to sudden weight transfer transitions as though it were being driven on ice. Indecisive braking resulting in a last second extra tap, or a sudden release of the brake pedal will unsettle the car's handling and force the driver to slow down to gain control and hopefully avoid a spin.

As the braking zone completes, and you ease off the brake pedal, you will have to apply some throttle to reach a steady state of neither acceleration nor deceleration. Depending on the shape of the turn, the steady throttle zone will vary, but with a typical late-apex corner, it will be from the turn-in to just before the apex.

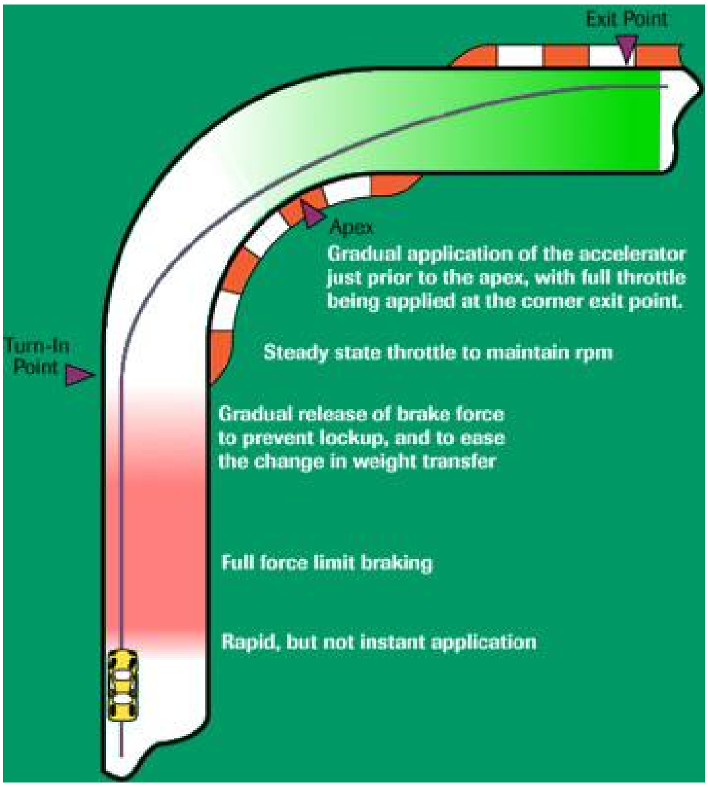
Accelerating

From this point to the turn's exit point, the use of the accelerator must be equally smooth for the same reasons they were for braking. Through the turn, the car will have settled with a certain loading of each tire. A sudden change in that with the accelerator can also upset the available traction on one or more tires and cause a loss of control. Controlled use of the accelerator is a matter of depressing and releasing it in smooth motions. Don't make sudden jerks in pedal position.

In a typical streetcar, applying the accelerator smoothly isn't as difficult to master as smooth braking. Once a car is moving fairly fast, most streetcars just don't have enough horsepower to really cause trouble under most acceleration circumstances. Even the factory exotics and highly modified street cars rarely have more than 400 horsepower, and in a car weighing 2500 to 3200 pounds, that just isn't an overabundance of power to learn to control. The typical professional open wheel cars weigh 1500-1800 lbs, and have 700-900 horsepower. That's about 5x the power to weight ratio of your typical street sports car.

Nevertheless, whether its relatively easy to control or not, the introduction of 5 hp too much at the right point, and you may as well have an extra 900. Coming out of a turn, as soon as the car begins to straighten out, gradually apply more power the straighter the car gets. Use smooth consistent pedal pressure--indecisive on and off stabs will end up being slower than a smooth increase.

Because most streetcars aren't overly sensitive to rough throttle control (although there are definitely some exceptions), it's easy to develop bad habits with the accelerator. Even though you may not have to be ultra smooth to maintain control, having the discipline to develop smooth control will still improve lap times, and should you have the opportunity to drive a higher horsepower car, you'll have the skills to keep the car pointed in the right direction.



Braking and acceleration into and out of a typical corner.

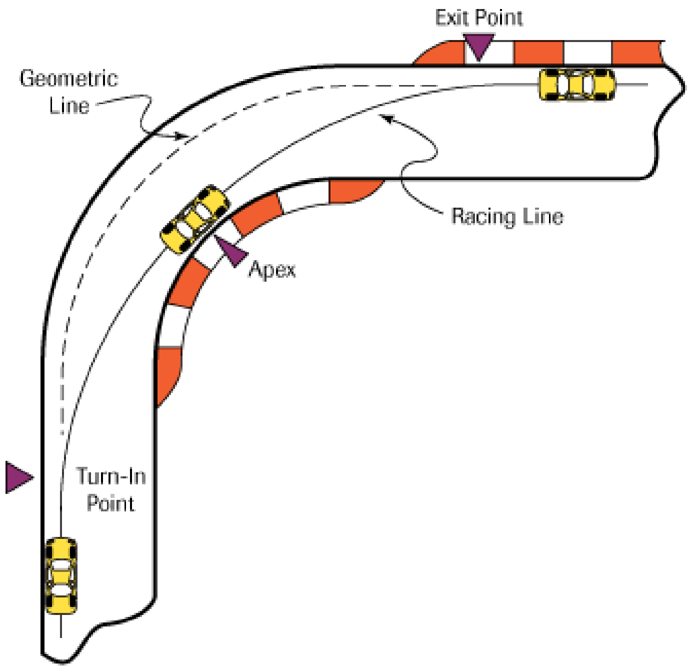
CORNERING

In the end, road racing comes down to cornering. Assuming equal cars, the driver able to sustain the highest speeds through the turns will have the lowest lap times. To get terminology cleared up first, every corner is made of three parts. We'll call them the entry, the apex, and the exit. The entry is where turning begins. The apex is the point where the car reaches the furthest point on the inside of the turn. The exit is where the car is driving straight again.

The objective in driving through a corner, or a series of corners, is to have the fastest possible speed at the exit of corner, or the last corner of a series. It is not necessarily to have the fastest speed going into the corner, nor even the fastest speed in the middle of the corner. The last corner exit before a straight is the most important segment. The speed of the exit determines the speed during and at the end of the straight. If you can increase the average speed of an entire straight, that will have greater impact that a faster average over the shorter distance of the entry to the turn, or through the turn itself.

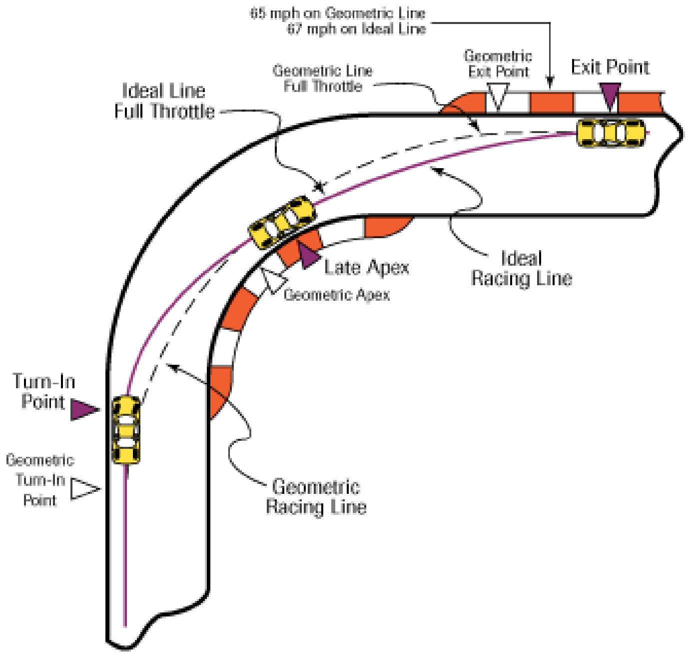
The path, or "line" you drive through a corner will determine the exit speed. In general, the fastest line through a corner is the one that allows the greatest radius, or straightest path. As a car can go faster around a large corner than it can around a tight corner, the shortest path around a corner is rarely the fastest.

To illustrate these concepts so far, the classic teaching aid is to look at a 90-degree bend. In the illustration below, the dotted line follows the path of the road. The solid line indicates a path, which maximizes the radius of the turn, or attempts to make the turn as straight as possible. As you can see there is significant difference in the tightness of the turn which follows the even the outside of the road compared to the one, that utilizes the whole width of the road surface.



As mentioned, the objective in any corner is to have the highest exit speed. In addition to increasing the corner radius, this also involves taking a line, which allows the earliest possible point of getting back into the throttle. To do this, the car must be straightening back out on the corner exit path as early as possible. We can modify the above corner line further to allow this.

The illustration below now shows the previously noted large radius path in the dotted line. The solid colored line shows a path known as the "late apex." This path moves forward the point at which the car reaches the corner apex. The late apex straightens out the exit path of the car, and therefore allows the driver to apply the accelerator earlier. This increases the exit speed, and in effect lengthens the straight, which allows for higher speed at the end of the straight.



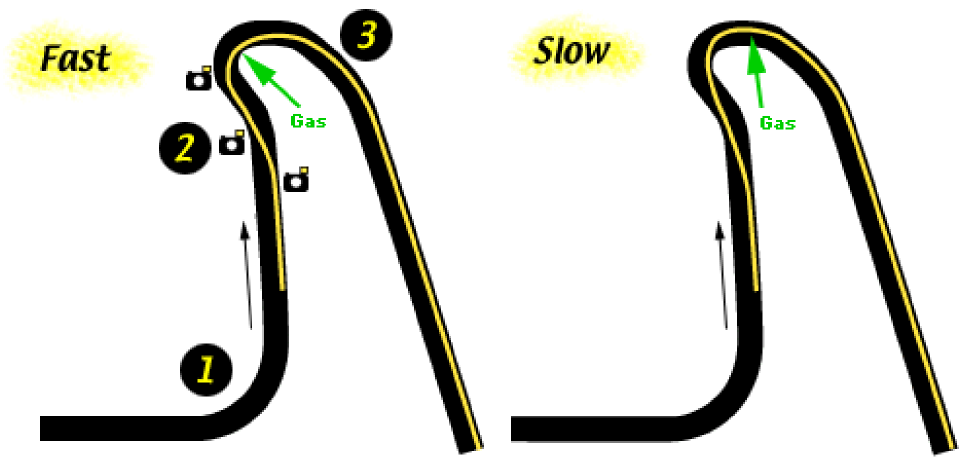
While the geometric racing line is faster than the natural line of the road, there is still a faster technique for most corners. The technique is called using a late apex. By delaying the turn-in point, and beginning the turn with a slightly sharper bend, the car can be aimed to apex later than the geometric apex point. This straightens out the second part of the turn, allowing the driver to apply the accelerator earlier. The car will have to slow down a little more at the turn in phase, but exit speed will be higher. That exit speed gives the driver that much more speed on the straight which will result in lower lap times overall.

This approach works for corners, which require hard accelerating cornering out of them, which will be most of them. However, there are many types of corners, and combinations of corners, which require some analysis to understand the best approach.

Complex Corner Sets

Not all corners can be taken on the classical racing line. Sets of corners sometimes require a different approach to maximize the exit speed of the last corner. For each illustration below, a track segment will be shown, the fastest line indicated, and some possible lines you might be tempted to believe are better.

Cornering Examples:



Fast Line

The objective in this turn set is to maximize the exit speed coming out of the hairpin. The straight after the hairpin is longer than the one leading into it after turn 1, therefore maximizing speed coming out of turn 3 is more important than maximizing speed heading into turn 2.

To do this, the driver must drive a line, which allows the earliest acceleration point. Planning the line by working the corners in reverse (because the highest priority one is the last one), the driver would want to late apex the entry to the hairpin to allow early acceleration out of it (show by the green arrow). To carry the highest speed possible into that late apex, the line to the apex must have as large a radius as possible (the radius prior to the green arrow). To accomplish a large radius entry into the hairpin, the left hand bend of turn 2 must be entered with a very late apex, allowing the car to travel the far left side of the track through turn 2, then into a wide radius late apex for the hairpin.

This line creates a very short straight through turn 2 into turn 3. Depending on the speed of the car coming out of turn 1, the braking line through turn 2 is likely to be too short. Additionally, because of the sharpness of the hairpin, it will be easy to create understeer entering the turn from either too sharp a turn-in or not easing off the brakes smooth enough. This is a very tight corner set and a common mistake will be to brake very hard through the short straight in turn 2, jump off the brakes quickly for the turn-in to the hairpin, and sharply turn the wheel. This will create a lot of understeer, and slow the car significantly.

To maximize the speed through the hairpin, it will be important to come off the brakes smoothly, and have a smooth turn in. To set up for this, most braking may have to be done before the turn-in to turn 2, the trail braking through the turn-in, and easing up through the apex of turn 2. Entering the short little straight of turn 2 a little too slow is not going to cost as much time as entering it too fast, understeering and going wide through the hairpin, and delaying the point of getting back onto the gas. Such a mistake will cost several MPH of top speed down the following straight.

Slow Line

This line might be your first instinct. It carries higher speed into the corner set by taking a straight path between the two bends of turns 2 and 3. This reduces the initial turn-in, and delays the braking point. It will feel much faster heading into the turns, and that segment will indeed be faster than the fast line alternative shown.

However, that fast entry line causes an early apex on the right hand bend heading into the hairpin. An early apex pushes the car to the outside of the track early to carry speed through the initial part of the corner. After that, a very tight turn after apexing is required to stay on the track. Compared to a late apex for the second bend, this requires a slower speed through the hairpin, and delays the point where you can get back on the gas. This line is faster for a short distance through turn 2, but is much slower along the entire straight after turn 3.

VISUAL FIELD

One of the first things you were probably taught when learning to drive was the simple principle of "look where you want to go." You were told, "don't look at on coming traffic, look at the cars in your lane in front of you." "Don't stare at the dividing lines, look at the road between them." "Don't look at the wall beside you, look at the lane in front of you." All sound, practical advice, and the same goes for racing.

If you've played, or even watched, just about any sport, you'll notice that the player is constantly looking forward, and not at what he's doing. In basketball, soccer, or hockey a player does not watch himself handle the ball or puck. Rather, he looks down the playing field at where he wants to go or pass. The player’s field of vision is not the few feet in front of him, but the whole field before him and beside him. The more of the field area the player can see and keep track of, the greater are his abilities to avoid opponents, plan a path through the field, and anticipate the movements of others. The distance and amount of territory the player can keep track of is called his visual field. This requires the combination of two distinct skills. First, the player must look farther ahead than his immediate surroundings. He has to look where he wants to be, not where he is. Second, even though the human eye has a narrow field of focus (only a small portion of what the eye sees is in focus), the player must be able to distinguish activities in those areas that are not currently in focus.

These skills are critical to race driving as well. It should be apparent how they would apply to road full of cars driving for position, but they are equally important for a single car to navigate an empty track at maximum possible speed. There is a tendency by inexperienced drivers to focus with a tunnel vision right in front of the car. It's a natural reaction. The amount of information the driver is thinking about can be overwhelming, and it is easy to become visually fixated on what is happening right in front of the car. Looking farther ahead requires taking in even more input. At first, it can be very difficult, but as the driver develops shifting, braking, and traction sampling skills into “second nature” habits, he can spend more conscious time expanding his visual field.

An every day example of these skills at work can be drawn from the scenario of trying to walk faster than everyone else through a crowded sidewalk. Think of how you do this. Whether you're conscious of it or not, your brain tries to anticipate the movements of those in front of you. By gauging the rhythm and timing of your speed along with the speed and position of others on the sidewalk, your brain calculates when and where "openings" should appear that you can walk through. In order to make these calculations in time to be useful, you must look a certain distance ahead of where you are. The faster you want to go, the farther ahead you need to look. If you were to look at the ground, or only a couple feet in front of you, you would frequently bump into people. You achieve a certain level of fluid movement through the crowd by looking ahead and anticipating your environment’s changing conditions, while keeping tabs on your immediate surroundings through peripheral vision. Your body responds automatically by adjusting speed, and your side-to-side position as you “dodge” the people around you.

This same technique applies to driving on the track. A driver cannot be focused on where he is on the track. He has to be focused on where he wants to be next on the track. To drive the smoothest and fastest line through a corner, or a series of corners, your brain must get input from far enough down the track to calculate the smoothest lines, and anticipate the amount of steering and pedal input to use.

Driving through a corner consists of four phases, and requires that the driver be looking ahead at least one, if not two, phases at a time. The first phase is the braking zone before the turn. The second is the turn-in, the third is the apex, and the fourth is the exit. If the driver is focused only on the current phase where the car is, he will not be driving smoothly or as fast as is possible through the corner. Each phase will seem like a surprise and will be driven as a jerky sequence of four lines rather than as one fluid path.

To describe the use of an expanded visual field through the corner sequence, we'll describe a typical turn after a long straight. As you approach a corner, your focal point will be the braking reference point. A few car lengths before you reach the braking point, your eyes must focus on the turn-in point. From your peripheral vision, you will notice the braking reference point and apply the brakes. Your eyes are still focused on the turn-in point, and as you approach and get within a few car lengths, your eyes must now look to the corner apex. Keeping the eyes focused on the apex reference point, use your peripheral vision to notice the turn-in reference point and begin the turn-in. Now, as you are approaching the apex, stay focused on the reference point until a few car lengths away, where you will once again shift focus to the next point, which is the exit reference point. You will drive through the apex looking at the exit point, not the apex marker. As you approach the exit point, your focus should now shift to looking down the straight, and you will use your peripheral vision again to drive out to the actual exit point as you reach it.

In some situations such as tight chicanes or esses, you may need to be looking through several corner reference points, and driving through them almost entirely with your peripheral vision.

Using your peripheral vision while also focusing in the center of your vision takes some practice--especially at the speeds involved of race driving. If you have already been track driving for a while, at first, this technique may slow you down due to the uncertainty of using your peripheral vision. However, once you get used to it, you will notice that you'll hit your reference points more consistently, and you'll carry a couple more miles per hour through turns you thought you were already maxing out. Developing these skills can takes a few weekends on the track. However, stick to it. Develop the skill first, and then bring up your speed. In the end you'll go much faster.

To practice looking ahead, make sure that you are looking through the center of the height of the front windshield. Several school instructors will even suggest that you put a thin tapeline on the windshield as a reminder to be looking above it farther down the track until you fully develop this as a habit. These skills can also be practiced during street driving. Around street corners or on windy roads, practice keeping your focal point well ahead of where you are driving, and "seeing" with your peripheral vision.

1 - As you approach the braking zone and turn-in point, focus on the turn-in reference point.

2 - A few car lengths from the turn-in point, shift your focus to the corner apex. Use your peripheral vision to keep track of the turn-in point and initiate your turn.

3 - As you approach the apex, shift your focus to the corner exit point. Drive through the apex using your peripheral vision.

4 - Finally, as you near the corner exit point, change your focus to look down the straight or the next turn if it is close

PASSING

Passing is typically achieved under three circumstances: you utilize your car's greater horsepower or momentum exiting a corner to pass on a straight, you pass under braking by controlling the preferred driving line entering a corner, or you take advantage of your opponent's mistakes.

First Rule

It is the responsibility of the driver initiating the pass to ensure that it is done safely. Where you pass, and how you pass must be done in a manner that your "opponent" is aware of.

Second Rule

Blocking is illegal. Swerving, whether it's six inches or six feet, to keep another car from getting beside you is blocking. Most organizations will allow you one move to protect your position. Repeated left-right moves is blocking.

Third Rule

If another driver has legitimately placed his car beside yours, leave room for the other car to carry a line through the corner. You don't necessarily have to give him the optimum line, but cutting a car off that results in forcing it off course is poor racing, and if the officials see it as deliberate, you're subject to penalty. Racing is not a roller derby. Eliminating your competition is not one of the objectives.

Passing under braking or on a straight close to a corner requires a little more planning than a simple pass on in the middle of a long straight. The object of passing in the braking zone is to control the inside line to the upcoming corner. By placing your car between the other car and the corner apex, the other car must yield to give you room to continue your driving line through the corner. In this manner you have essentially "controlled" the preferred line into the corner.

The potential downside to making this move is that your car will not be taking the turn on the optimum line. You may control the corner entry, but if you have to slow down too much, or make too early an apex, the car you've just passed may carry more speed or a better exit line, and pass you right back coming out of the corner.

During practice sessions, you will need to not only practice the optimum racing line for fast laps when you're clear of traffic, but you will want to practice some passing lines. Move in from the edge of the track where you'd normally drive, brake a little farther and turn in a little later. Practice taking a line that puts your car in the middle of track coming out of the corner, or a least far enough over from the edge so as not to leave enough room to be passed on the exit. (Hogging the road so there's not enough room to pass, but still avoiding the swerving, is not blocking). By practicing these passing driving lines, you'll be ready to use them, and there's less chance that you'll cause an accident when attempting a pass.

GENERAL TECHNIQUES

Whilst mechanical orientation forces us to change the way we drive on the limit, there are still some techniques, which are the same in any car. Some of these techniques are **more** beneficial in say RWD but they require no difference in technique to make them work in any. These techniques are what this section is for.

HEEL & TOE

There are many myths surrounding Heel & Toe. It is actually a very simple concept. Heel & Toe is merely used to blip the engine revs up to match the speed of the wheels during downward gear changes. There are however a few reasons why you would want to do that.

Why Heel & Toe

The main use for heel and toe is in Rear Wheel Drive and particularly on slippy / loose surfaces or when on the limits of braking. Let's take the later as it applies more to every day situations...

Under Heavy Braking

When braking on the very limit, say for a corner, the majority of the cars weight is supported by the front tires. The front suspension will compress, and the grip levels being exhibited by the front tires is hugely higher than normal. At the same time the weight on the rear tires is very small meaning the grip levels they produce is hugely lower than normal. What you have in this situation is an extremely unstable car, which will happily oversteer and try to swap ends at the slightest provocation.

A skilled driver will be making very slight steering inputs to correct and manage any oversteer starting to happen. In this situation, the car is truly on it's very limits.

If you then change down a gear and let out the clutch, the engine braking caused by selecting a lower gear could (and probably would) be enough to break traction to the rear wheels and unsettle the car to a degree that it may snap into oversteer. Heel & Toe stops this happening by negating that sudden engine braking because the engine revs match the speed of the wheels.

How to Do It Properly

The best way to master this is in stages. Firstly, sit in a stationary car and get the right foot position mastered. Position your right foot on the brake so that you are only using the left hand side of the ball of your foot and your big toe on the brake. This means that the right hand side of your foot will be hovering in thin air near the accelerator.

Now press the brake pedal and pivot your foot around the ball of your foot so that the right hand side of your foot and side of your heel is touching the accelerator. Practice holding the brake at the same position while pivoting your foot enough to blip the throttle. It doesn't have to be a big blip, you probably only need to move the accelerator a couple of inches.

Now, with that mastered...

Lets say you're doing 60MPH in 3rd gear at 3,000 revs.

Start to brake with the left side of your foot as in the stationary practice.

As you change down, press the clutch and pivot your right foot as practiced to blip the throttle. I would strongly recommend doing all this slowly as it pays huge dividends later. What I mean by this is...

Brake very gently, press the clutch slowly, start to build the revs with your Heel & Toeing, and practice matching the revs exactly. If you have got it right, you should be able to let the clutch straight out with no judder or jolt and no change in revs.

If you practice it like this you will not become one of the millions of people who think they are Heel & Toeing properly but are actually just wasting energy.

Heel & Toe is an excellent technique to master as it makes for a more stable car on the limit, which means you can push the car slightly further. It is also very kind to clutches and transmissions if you do it all the time, but will cost you a touch more in fuel.

SHORT SHIFTING

Short-shifting is where you change up a gear before it is needed. In other words, you change up a gear before you have used up the previous gear.

Why would you want to do this?

Well this is a valid question because short-shifting almost always means you will be instantly losing some power and torque due to being in a higher gear than is necessary.

Well there are two main reasons:

One reason is to purposefully take away torque from the wheels. Maybe it is a bump / slippy curve and you will be unable to use the full torque of the gear you would normally be in, so it might be a safer bet to be in a higher gear to reduce the likelihood of sudden wheel-spin, etc. The other (and more common reason) is to save the time taken to change gear. Lets say you have a tight 2^{nd} gear left-hand bend, followed by a long straight. You are at about 2/3 revs as you approach the apex. You can either stay in second gear and use the extra torque to accelerate as quickly as possible. Or you can change up to 3^{rd} before you need to start accelerating and sacrifice the extra acceleration for the time saving in not having to change gear.

A judgment has to be made as to which would be quicker. In race driving this is normally already tried and tested for your formula on the track you are racing on so it is often pre-decided. In rallying it is less clear, and probably slightly less important. The main reasons you would use short-shifting in rallying would be for balance rather than outright time and speed. If there was a twisty section ahead for the next 50 yards and you will need 1 up change in the middle of it, you may decide to get the change done before the complex to avoid upsetting the car mid-way through it.

FRONT WHEEL DRIVE

Front wheel drive, sometimes referred to as 'Wrong Wheel Drive', is both the easiest to drive and the most difficult to fully master. Almost anybody can drive a FWD car fairly quickly, they can appear to be right on the limit when in fact they are only on the limit of the front tires. Exploiting the genuine limits of the entire FWD car can be a real challenge.

The difficulty arises from the fact that you have little control over the rear wheels. In a rear wheel drive car you have control over the front wheels with the steering and the rear wheels with the power. But in front wheel drive both control forces are focused on the front wheels. On top of this, the fact that putting power to wheels creates the reduction of traction, and understeer is the most uncontrollable handling characteristic means the whole set up should be a recipe for disaster.

However.... The advances in suspension and handling setups on road and racecars have lessened these characteristics and turned some front wheel drive cars into extremely drivable cars. Certainly most of the new hot hatches and even some of the older ones such as Escorts (particularly XR3 etc.) have good levels of front wheel grip. The techniques involved in effectively driving a front wheel drive car are quite complex and require serious practice to get right. The most demanding motorsport for front wheel drive car control must be rallying or derivatives where you can be running on loose surfaces and need to find sure fire ways of creating oversteer.

HANDBRAKE TURN

The hand brake is the savior of front wheel drive in many situations. The front wheel drive car is by far the best at handbrake turns and by far the easiest to master them in. Due to the fact that the front wheels are driven and the handbrake acts on the rear wheels you can pull the handbrake without coming off the gas.

To perform a 180 and continue in the other direction.

Slow down to about 20-30ish in second gear, pull the handbrake hard enough to lock the rear wheels and steer smoothly in either direction. The car will start to swap ends. When at about 140ish degrees, hit the gas, drop the handbrake, select 1st gear and dump the clutch, all in one smooth motion (takes practice). This should finish off the 180 and start pulling you down the road amidst a cloud of tire smoke.

LEFT-FOOT BRAKING

Left foot braking is probably the most important technique to master in driving a front wheel drive car effectively. In order to defeat understeer you need to provide more grip to the front wheels than the rear. To be able to commit to a corner completely and at speed you need to be sure that, when you turn in the car isn't going to go straight on (understeer).

Approaching a corner you should slow down as usual using your right foot on the brake, maybe a bit of toe and heel. When in the desired gear but still maybe too fast, swap your feet over, moving your right foot back to the accelerator and your left foot over to the brake.

It is possible with some gear boxes to change gear without the clutch without causing damage, meaning you could use your left foot to brake from full speed and blip the throttle in-between each gear. This should only be used if the gearbox can cope with it, such as a competition straight cut gearbox. Whilst it is possible to do this with a synchro-mesh gearbox, they really don't like it and after prolonged abuse will just end up on the road!!!

Anyway....

You are now using your left foot to slow the car down the last few MPH and about to turn into the corner. If at this point you hit the gas with your right foot, brake with your left foot and turn in, all in one smooth motion, the rear wheels will fully or partially lock. This resulting difference in grip levels will throw the car into oversteer.

From this point, you need to balance the car by steering in the direction you want the car to travel and braking / lifting off the gas for more oversteer, more gas / less brakes for less oversteer. In reality I often just keep the accelerator planted and balance the car using the brakes and steering.

This technique overcomes understeer and allows you to keep the power on through the corner.

LIFT-OFF OVERSTEER

When cornering at speed in a front wheel drive car, the weight distribution between the front and rear wheels is fairly even. There is obviously far more weight on the outside wheels than the inside wheels. This is assuming a fairly neutral throttle position.

If you lift off the throttle at this point, the weight will move from the rear to the front. This will mean that the weight distribution will be likely to be in the following order, most to least: -

Front Outside
Front Inside
Rear Outside
Rear Inside

If you analyze this, there will be little or no weight on the inside rear wheel, but probably a bit of weight on the rear outside wheel. Bags of weight on the outside front wheel (the one which does most of the turning) and a fair chunk of weight on the inside front as well.

If you link this situation with the steering you will have due to the corner, the result will be that the front will continue to turn but the rear will have so little traction that the car will go into oversteer.

Once sideways, the slide can be controlled with opposite lock steering and throttle. More throttle = less sideways.

SCANDINAVIAN FLICK

Used as a way of committing to medium slippy corners at speed by eliminating understeer. Particularly if the entrance to the corner is tight on a surface such as gravel, you need a way of quickly turning into the corner without the possibility of understeer.

Using left foot braking, you should aim to put the car into a sideways skid heading down the road towards the corner whilst the car is pointing in the opposite direction to the corner (e.g. pointing right heading towards a left hand turn).

The car can then be held in that position by flooring the brakes and locking up all the wheels or just balancing the brakes and throttle.

At the point when you want to turn in you can come off the brakes and let the car change direction and swing into oversteer in the other direction. It is then a case of balancing the brakes, throttle and steering using the left foot braking technique to balance the car through and out of the corner.

SLALOM

The slalom in a front wheel drive car is not as simple as in rear wheel drive. The technique will alter depending on the surface, conditions, distance of cones etc. The most effective way of driving the slalom is to build a rhythm and be able to keep up a good speed. The best way of doing this is to overcome understeer by either using left foot braking of throttle off oversteer.

Using left foot braking the procedure would be as follows.

Using a gear with lots of torque at the relevant speed, approach the first cone to the left or right with your left foot hovering over the brake. Turn in and hit the gas aiming for the slightly wide of the opposite side of the next cone. As you steer to change direction hit the brake and the gas to lock the rear wheels, delivery weight and power to the front wheels creating oversteer. As the car oversteers around the next cone wind on enough opposite lock to balance the skid with the power and brakes. When you want to change direction for the next cone, simply come off the brakes and then back on and the car will pendulum round to oversteer in the other direction.

Easy!

REAR WHEEL DRIVE

Sometimes referred to as *Correct Wheel Drive*, rear wheel drive will always be enjoyed by the true sports car driver. Although most manufacturers have turned their back on rear wheel drive, almost all 'proper sports cars' and most of the high-end powerful cars are still produced in rear wheel drive. The beauty of a rear wheel drive car is that you have individual control over the front and rear ends of the car. It is possible to drive a RWD car much more flamboyantly than front or four wheel drive cars by power sliding the car through corners in an oversteer maneuver called the Power Slide. The sheer lack of rear wheel drive cars in current distribution means that more and more people will not experience the joys of a rear wheel drive car. This said, front wheel drive cars are becoming more and more agile and four-wheel drive technology has improved dramatically and improved handling no end.

Some of the manufacturers still producing Rear wheel drive cars are: -

BMW
LOTUS
MERCEDES
JAGUAR
TOYOTA
NISSAN
ASTON MARTIN
PORSCHE
FERRARI
TVR

Well Done To All Of You!!!

POWERSLIDE

Power Sliding is when the rear of the car is held out in oversteer using the power and the front of the car is kept in check using the steering. Because the rear wheels are driven you can brake traction to the rear wheels by simply applying enough power that the tires can no longer hold the road. If the front wheels maintain grip you will go into oversteer.

Once the car is sideways you need to balance the front of the car with the steering and the rear of the car with the power.

Power Steering

Generally speaking, more power means more sideways. If the car starts to swing too sideways you should back off so the rear tires can grip the road a bit. If the rear wheels start to grip you need to quickly add more power to push the rear of the car out a bit. It is important to note that unless you have loads of grunt, both applying and releasing the throttle will not cause and immediate response. Usually, lifting off will react quicker than putting your foot down.

The best way to think of steering is to just keep the front wheels pointing in the direction you want the whole car to travel, regardless of the actual angle of the car.

General

This means you use the throttle to alter the angle of the car (the direction it is pointing in) and the steering to alter the direction it is traveling in. The two work in conjunction with each other.

This technique is used extensively in rallying and other derivatives. Done well it will improve you speed through a corner and out of it (the most important thing in producing good stage times). Practice makes perfect (or costs you a lot of money) but watching a skilled driver you will see little steering movement. The ideal method is to turn in hit the gas and let the car go sideways, set the steering (opposite lock) and steer the car using the throttle. The corner should be timed so that the opposite lock will be smoothly wound off until the car is accelerating straight on out of the corner.

Surface and Power

The whole point of a power slide is reducing the grip of the rear wheels in relation to the front wheels. For this reason you must be constantly looking at the advancing surface and adjusting the power accordingly.

If the surface is about to become slippier, you should be conservative with the power but not back off until the rear wheels are on it. The car should start to slide more due to the slippy surface but coming off the power will reduce the forced lack of grip and hopefully keep the car in check.

If the surface is about to become grippier, you should hit the gas and put the car slightly more sideways in preparation for the impending grip. When the rear tires hit the grippy surface you need to apply enough power to keep the rear wheels spinning.

Important

During a power slide the car is being balanced on its absolute limit. For this reason it is also at its most potentially unstable. If the rear wheels suddenly grip the car can snap into vicious oversteer in the other direction. Knowing when to wind off the lock is one of the most important things to get right. This characteristic is used in motorsport and particularly in rallying, known as a Scandinavian Flick or Pendulum Turn.

SCANDINAVIAN FLICK

Also known as a pendulum turn, this technique is used in motorsport and particularly rallying to provide a quick oversteer turn-in to a corner. The technique is of most use on a slippy surface such as gravel or snow.

When heading towards a corner on such a surface at some considerable speed, it is important to be confident that the car will turn in. If you just plow up to the corner and then turn in, the car will understeer and go straight on unless you slow down considerably. The reason for this is that you can't whack the steering in one direction on a slippy surface and expect it to maintain grip.

For this reason the driver will put the car into a brake maintained skid pointing away from the corner and let the car flick into the corner at the last minute thus inducing instant oversteer and providing grip to the front wheels.

Initiating the Pendulum

The first stage is to put the car into a skid traveling straight down the road put pointing the car away from the corner.

Right Hand Bend on Gravel: -

A good distance from the bend at full speed there are many ways of setting the car up. In the forest there is usually a convex shape to the road with the road dropping off to the left and right. This is ideal for setting up a pendulum. By slight steering to the right and then to the left you will guide the car slightly right and then turn the front of the car left, leaving the rear wheels in the trough on the right. The trick is knowing when to hit the brakes.

At the point when the car is traveling in the correct direction (down the road) and the car is pointing to the left you can do one of two things. By winding on some opposite lock and feathering the brakes you will be knocking off some speed and holding the tail out. The other method is to stand on the brakes and lock up all four wheels putting the car into a complete skid. This will knock off lots more speed on gravel as the gravel builds up in front of the tires and improves braking. You should still wind on the appropriate opposite lock, even though the direction of the front wheels is not really important at this point. When you reach the point you want to flick the car to the right you just need to come off the brakes and the car will flick round to the right and you will then be in an oversteer power slide maneuver.

HANDBRAKE TURN

The handbrake turn is used for very tight turns such as tight hairpins. The idea is to change the direction of the car a quickly and in a shorter lateral space as possible whilst overcoming understeer.

To turn the car through 180 degrees using a handbrake turn the following procedure should be followed.

On Tarmac

Slow the car down to about 15-20 miles per hour in second gear. Dip the clutch and pull the handbrake hard enough to lock both rear wheels. With your remaining hand, steer smoothly in either direction. The car will swing round pivoting around the front wheels. When the car has nearly gone 180 degrees, straighten the front wheels, release the hand brake and apply the brakes.

If done properly, the car will now be stationary, pointing in the opposite direction. It is worth noting that the car will go through 180 degrees and stop spinning if left to its own devices. It will not go past 180 degrees without intervention. More info on this can be found in the Driving Science Section.

You may want to spin the car through 180 degree and drive off in the opposite direction. This can be done as follows.

Follow the same procedure as above and at the point when the car is at about 140 degrees, drop the handbrake, select 1st gear and boot it all in one smooth motion

DOUGHNUT

A Doughnut is the art of spinning the rear of the car around the front wheels. So called because it creates a circular collection of skid marks in the shape of a doughnut.

This is a really tricky technique and requires lots of practice and lots of rear tires to get right. Having a limited slip differential will help matters as explained in the Driving Science Section.

Starting a Doughnut is tricky in itself, posing the problem of creating quick oversteer but not too much as to just do a sudden 180 degree spin and stop. One way is to start off in 1st gear, get up a bit of speed start turning dip the clutch and pull the hand brake, when the car starts to skid hit the gas, drop the hand brake and let the clutch out.

It is then a case of practice to get the hang of balancing the power to produce a smooth doughnut with the front wheels staying roughly where they are and the rear wheel pivoting round them. This looks really cool if you get it right but is costly on tires, diffs and engines. But what the hell!!

SLALOM

The slalom is a real test of car control. It is best practiced with a row of cones set out in a straight line. The idea is to weave in and out of them as quickly as possible. In a rear wheel drive car the quickest way is to let the front wheels take the short route through the course and let the rear wheels swing around behind them.

Turn in just after the first cone and hit the gas. The car will start to oversteer and you need to correct with a bit of opposite lock. Keep the power on to hold the tail out and lift off at the point you want to change direction. The car will quickly swing round in a motion similar to the pendulum. Catch it with opposite lock in the other direction and hit the gas again, and so on. This is well worth practicing as it can seriously improve your car control

LEFT-FOOT BRAKING

Left foot braking in a rear wheel drive car is quite unusual. It's first use is to aid stability in corners, and help keep turbos spinning by holding the car at the correct speed with the brake and keeping your foot on the gas. Apart from this, it has recently been adopted by some drivers as a disaster recovery. If you are tanking into a corner, particularly in the wet and the car goes into massive oversteer you may wind on the opposite lock. If it has gone too far it may be possible to floor the accelerator and hit the brake with the left foot.

The idea is that you will keep the rear wheels turning due to the power of the engine, but will lock up the front wheels. This puts more grip to the rear wheels and less to the front, hopefully bringing the car straight. This is really only a last attempt technique for recovering previously irrecoverable situations. If you were to use it as a general driving technique you will be one of the slowest drivers on the road... I mean track!