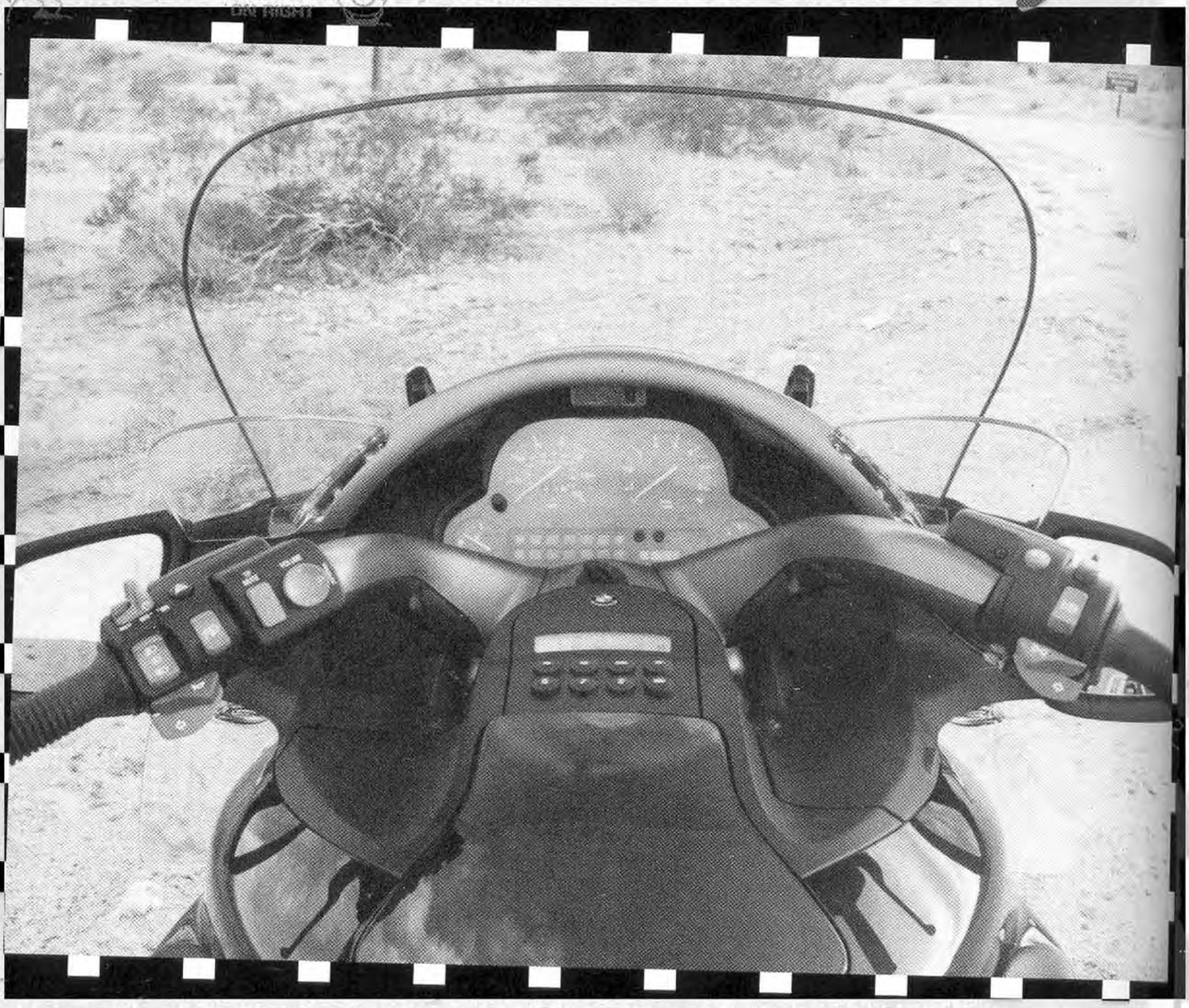
Motorcycle Dynamics

MOTORCYCLE



DYNAMICS

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CHAPTER 2
MOTORCYCLE DYNAMICS

What Keeps It Balanced?

You can get down the road pretty well on your two-wheeler without having to know a lot of details. Once your bike is in motion, it's relatively easy to keep it balanced more-or-less in a straight line. If the bike wanders a bit in the wrong direction, just lean it back toward your intended line. If you want to turn, all you have to do is lean the bike in the direction you want to go. Simple, huh? Well, maybe not so simple. There are a lot of riders around who demonstrate over and over that they are only partly in control of their motorcycles.

Drifting Dan really wants his sportbike to make a nice crisp turn from a stop onto that narrow road, but as he nervously eases out the clutch, the bike seems to take command and swings wide over the centerline. Wandering Wanda wants her cruiser to just motor down the middle of the lane, but it sometimes creeps over toward the edge of the pavement, then back toward the centerline. Wobbling Willie does fine at speed, but when he rolls into the parking lot for the breakfast meeting, his new heavyweight touring machine seems intent on wobbling over toward parked cars, and it's a constant sweaty struggle to keep it between the lines.

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One major reason Dan, Wanda, and Willie have difficulty getting their motorcycles to cooperate is that they don't really understand how motorcycles balance and steer. Drifting Dan panics when his sportbike swings wide, and when he attempts to muscle the bars back toward his lane, the bike seems to go even wider. Dan doesn't realize he is actually steering the bars in the wrong direction. Wandering Wanda is paranoid about running wide, and she's absolutely terrified of corners, but she is afraid to try that countersteering she's heard about. Wobbling Willie breaks out in a sweat when his shiny touring machine points itself at car fenders, but he has yet to learn that it is primarily pushing on the grips that controls direction, not simply slamming his knees against the tank.

Dan, Wanda, and Willie have a common problem in their struggle to control their motorcycles. They all understand that you have to lean the bike to change direction. They just aren't sure what really makes it happen. What they need to know is that to lean right, push on the right grip. To lean left, push on the left grip. If your machine tries to snuggle up to a parked car on your right, pushing on the left grip will lean it away from a fender-bender. It's called countersteering because you momentarily turn the front wheel opposite (counter) to the way you want the motorcycle to lean. It also helps to look in the direction you want to go. If you don't want to cross that centerline, look ahead down your lane, don't gawk at the line. Even novice riders who haven't mastered countersteering often gain considerable control just by getting their eyes up and looking where they want the bike to go.

Those are the two big secrets for the average situation: countersteer, and look in the direction you want to go. Now, go out and play. Before you thumb the starter, though, let's note that there are a lot of hazardous situations out there that demand more skill than the average situation. For example, let's say Drifting Dan zooms out of a tunnel in the mountains, smack into a 50-knot crosswind gusting from his right, slamming into the bike and pushing it toward the centerline. What should he do? Dan needs to push hard on the upwind grip to lean the bike over and maintain enough muscle on the grip to hold the bike leaned over but in a straight line. In this situation, he needs to push on the right grip to lean the bike toward the right. With the bike leaned over but not turning, steering isn't going to feel normal, so Dan needs to apply pressure on the grips to make the motorcycle go where he wants it to go, and not just think lean.

Such situations remind us that balancing isn't just a simple matter of nudging on the low grip. To prepare for a wide variety of situations, it might be helpful to look a little deeper into the dynamics of how two-wheelers balance and steer. If you get confused with any of this, I suggest you go out to the garage and try the suggested experiments on your motorcycle.

And, as we get started on balancing dynamics, you should be aware that not everyone agrees about how it works any more than people agree about love or war. From time to time, even experts get into arm-waving arguments about small details, pens hastily scribbling diagrams on lunchroom napkins. What I'm going to offer here is the opinion of one aging moto-journalist/instructor, based on thirty-plus years of arm-waving discussions and napkin scribblings. Also note that for what follows, motorcycle means two-wheelers, not rigid sidecar rigs or trikes.

Two-Wheeler Stability

Occasionally, you'll see a rider let go the grips and lean back in the saddle at freeway speed. You may marvel at the naiveté of a rider willing to ignore hazards such as a groove in the pavement that might instantly yank the front end into a tank-

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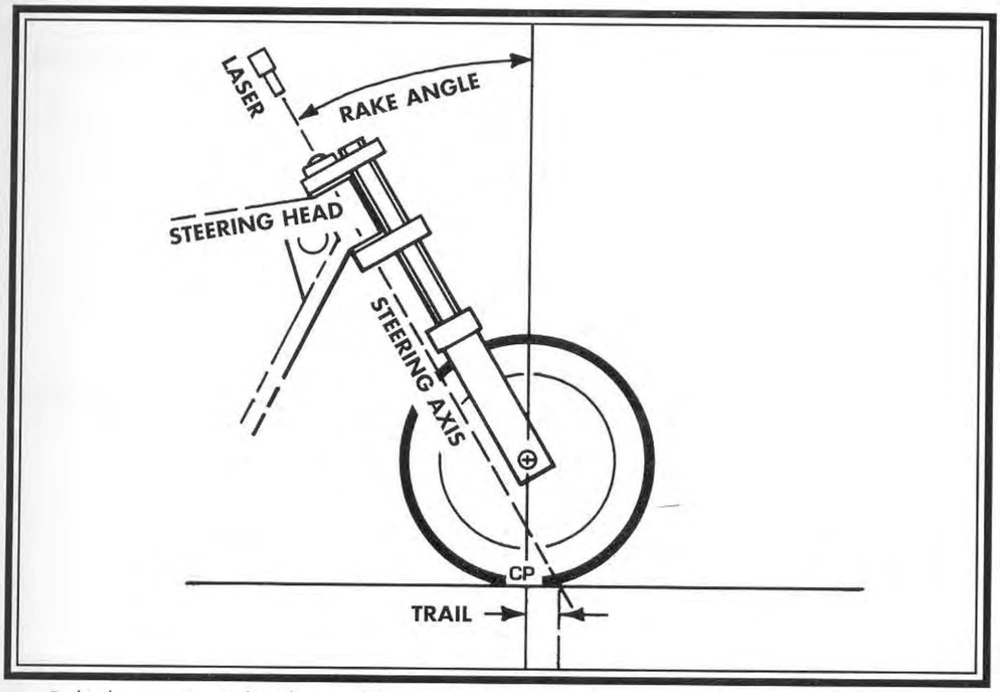
slapper, but hands-off riding is a great demonstration of the unique stability of a motorcycle. The front-end geometry automatically stabilizes a bike in a straight line, self-correcting for minor changes in lean angle.

The simplistic suggestion is that this self-centering action is just a result of the castering effect of the front tire trailing behind the steering pivot axis, similar to the front wheels of a shopping cart at a grocery store. But two-wheelers are quite a bit more complex than shopping carts, partly because they lean into turns. The self-balancing action of a motorcycle's front end is a result of the combined effects of a number of details, including rake, trail, steering head rise/fall, mass shift, contact patch location, and tire cross section.

Rake/Trail

If you stand off to one side of your motorcycle and observe the angle of the front forks, you'll notice that the top of the fork tubes are slanted back. And if you look closer, you'll see that the fork tubes aren't exactly in line with the steering head. When we talk about rake we're talking about the angle of the steering head leaning back from vertical.



Trail is the measurement along the ground between the steering axis and the contact patch.

You've probably seen choppers with really long, flexing forks. And at the other end of the spectrum you may have observed off-road bikes with almost vertical rake angles. In general, greater rake produces greater straight-ahead stability at speed, and less rake produces low-effort steering. When test riders refer to heavy steering they are talking about a machine that is so stable in a straight-ahead situation that it requires a lot of muscle to get it leaned over and hold it into a turn. What they mean by a flickable machine is one that is relatively unstable, and can be easily leaned over or straightened up with very little muscle. Sportbikes have rake in the 24-degree range, while cruisers are closer to 30 degrees. But rake is only part of the equation.

While you are standing off to one side of the bike, imagine a laser beam passing through the steering head until it strikes the ground. The laser beam represents

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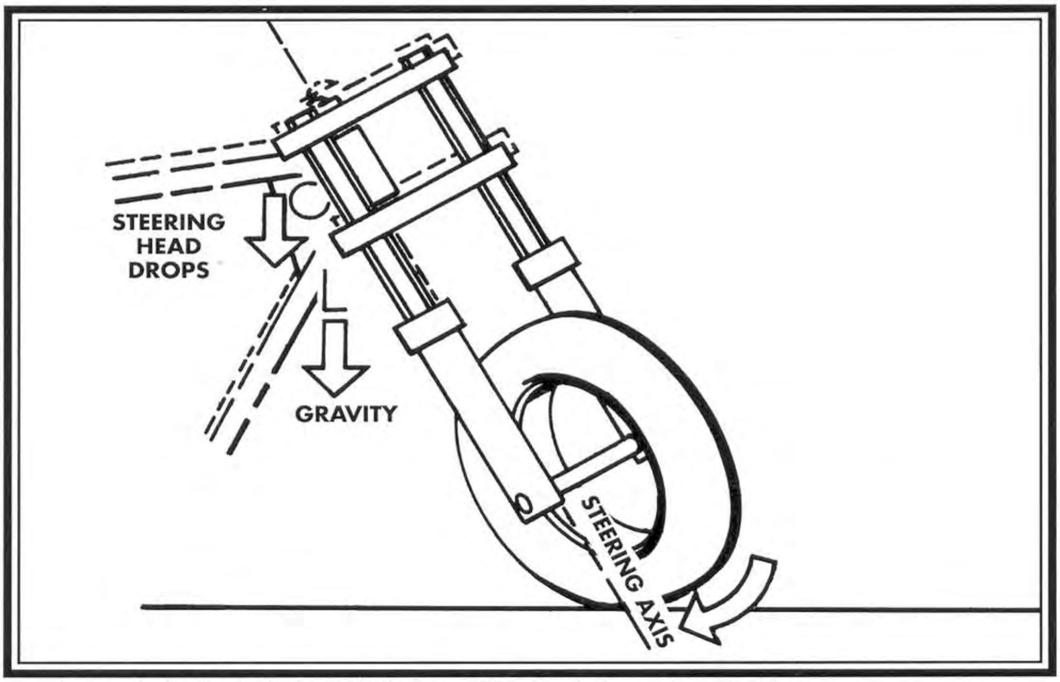
the pivot center, or steering axis, of the whole front end. For most machines, the steering axis strikes the ground somewhere ahead of where the front tire is sitting on the surface (the contact patch). The distance along the ground from the steering axis to the center of the contact patch is called trail because the contact patch trails behind the steering axis. Typically, street bikes have trail somewhere in the 3- to 6-inch range. In general, longer trail results in a machine that resists leaning into corners, and shorter trail results in quicker, easier steering, or perhaps even a machine that wants to fall into corners. Since rake and trail are interdependent, the figures in bike reviews are usually given as rake/trail.

Steering Head Rise and Fall

One of the interesting results of rake/trail is that the steering head rises and falls as the front end is pivoted from one side to the other. The greater the rake, the more the rise and fall. You can see this for yourself. Straddle your bike, get it balanced vertically, and observe the elevation of the top of the steering head as you turn the handlebars from straight ahead to either side and back. When you turn away from center, the steering head drops. When you turn back to center, the steering head rises.



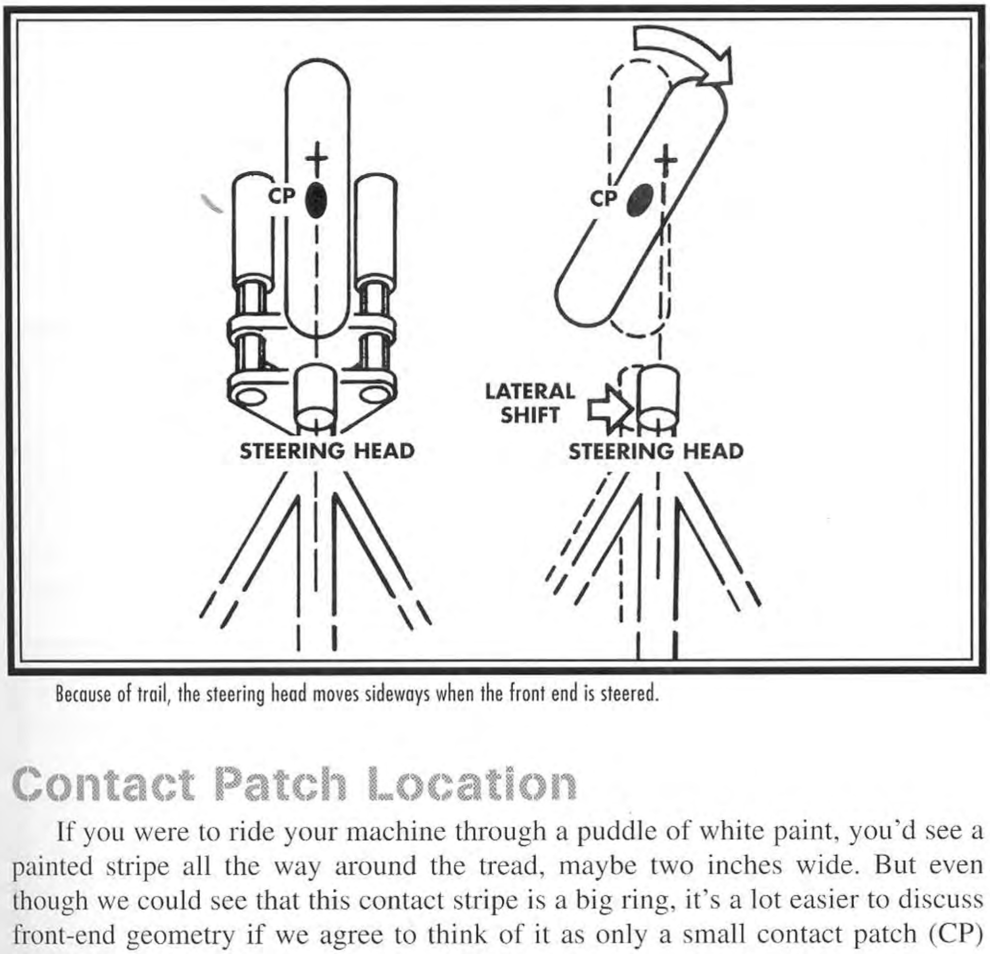
Because of rake, the steering head actually rises and falls when the front end is steered.

Now remember, gravity is pulling down on the bike, which is supporting perhaps half its weight on the steering head. So gravity actually helps turn the front end away from center and resists the front end returning to center. That's not a bad deal, since engineers can balance steering head rise and fall against other steering forces.

Mass Shift

While you are straddling your bike, you might also note that when you turn the handlebars, the steering head also moves sideways (laterally). If you turn the bars to the left, the steering head (and the whole front of the bike) shifts laterally to the left of the contact patch. With the front wheel pointed toward the right, you'll feel gravity pulling more on the right because the mass has been shifted to right of center.

In other words, steering can actually shift much of the mass of motorcycle and rider away from center, even if the wheels are not rolling. Of course, as the motorcycle begins to roll ahead, it reacts differently than it does when standing still. With the bike rolling down the street, both the steering head and the contact patch move.



Because of trail, the steering head moves sideways when the front end is steered.

Contact Patch Location

If you were to ride your machine through a puddle of white paint, you'd see a painted stripe all the way around the tread, maybe two inches wide. But even though we could see that this contact stripe is a big ring, it's a lot easier to discuss front-end geometry if we agree to think of it as only a small contact patch (CP) where the tire touches the road at any particular moment. Be aware that the location of the CP can shift forward and back, as well as sideways.

Consider what happens when the wheel rolls over a bump. As the tire hits the bump, the CP instantaneously shifts forward, and then follows the bump backward until the tire rolls onto level ground again. If the bump is steep enough (a curb, for instance) the CP can momentarily jump ahead of the steering axis. That's why a steep bump or dip yanks the handlebars around (and why hands-off riding over bumps and grooves isn't a clever idea).

Now, lean the bike over on the sidestand, with the front wheel pointed straight ahead. Get down on your hands and knees in front of the bike, and look back toward the front tire. Observe that the CP has shifted sideways, away from the wheel's centerline. So, as we lean the bike over into a turn, the CP shifts laterally toward the turn.

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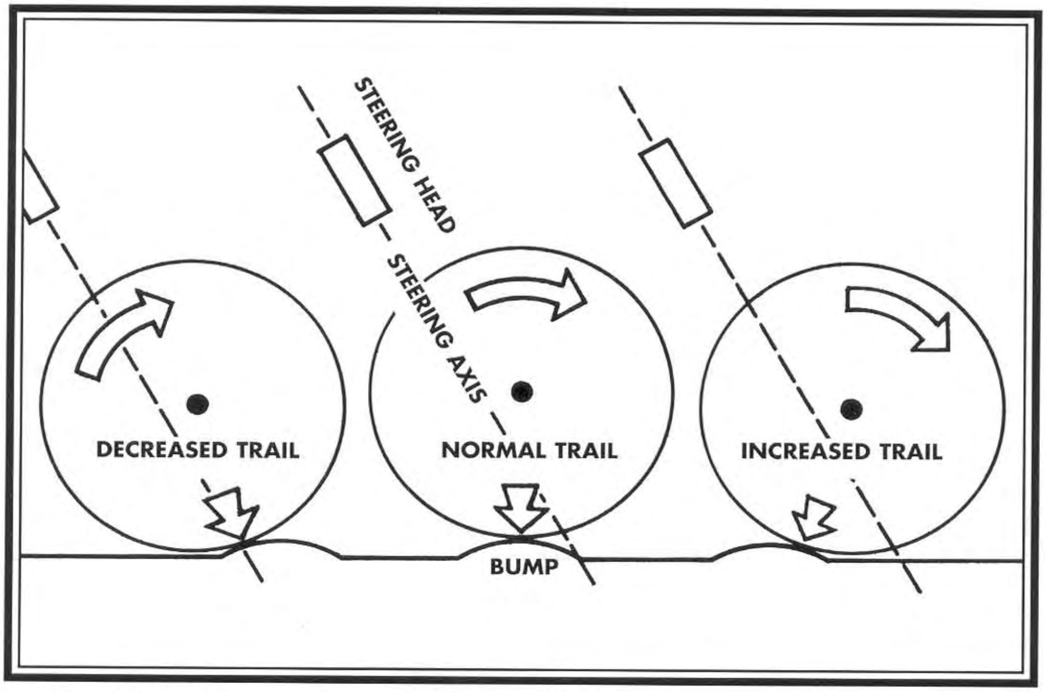
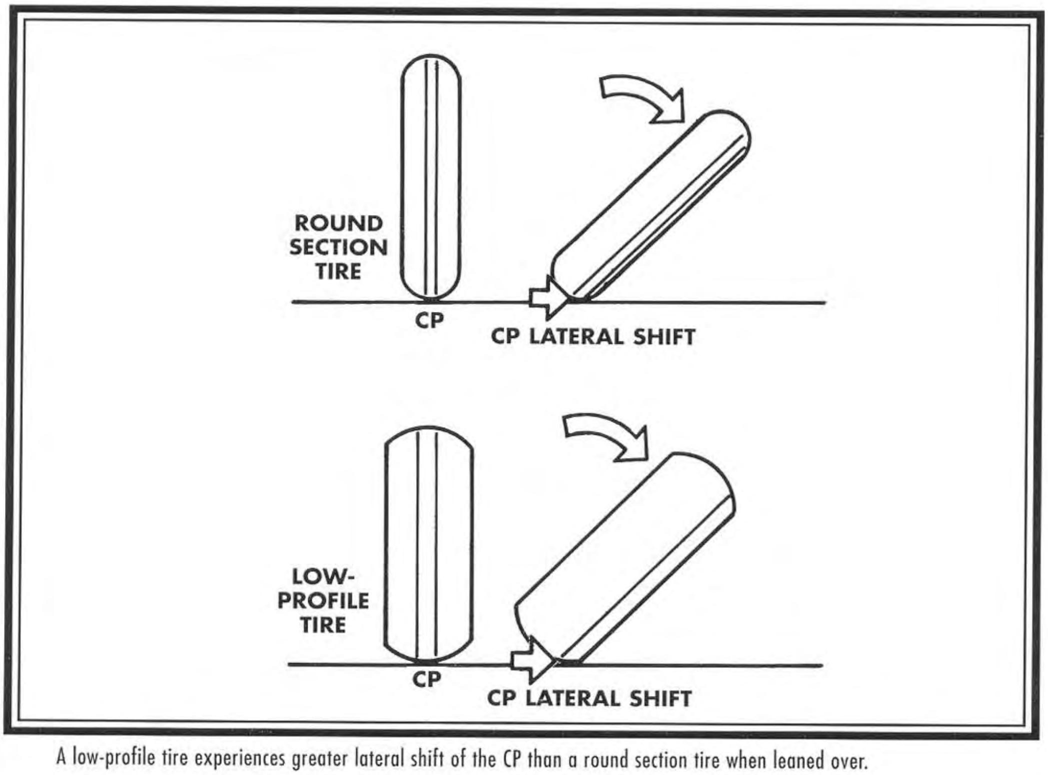


When the front wheel rolls over a bump, trail can decrease or increase.

Tire Cross Section ("Profile")

With a wide, low-profile tire cross section, the CP shifts farther sideways than a narrow, round section tire, for the same lean angle. And the farther out the CP, the greater its off-center drag. The CPs of both front and rear tires shift laterally as the bike leans over, so the sizes and profiles of front and rear tires



A low-profile tire experiences greater lateral shift of the CP than a round section tire when leaned over.

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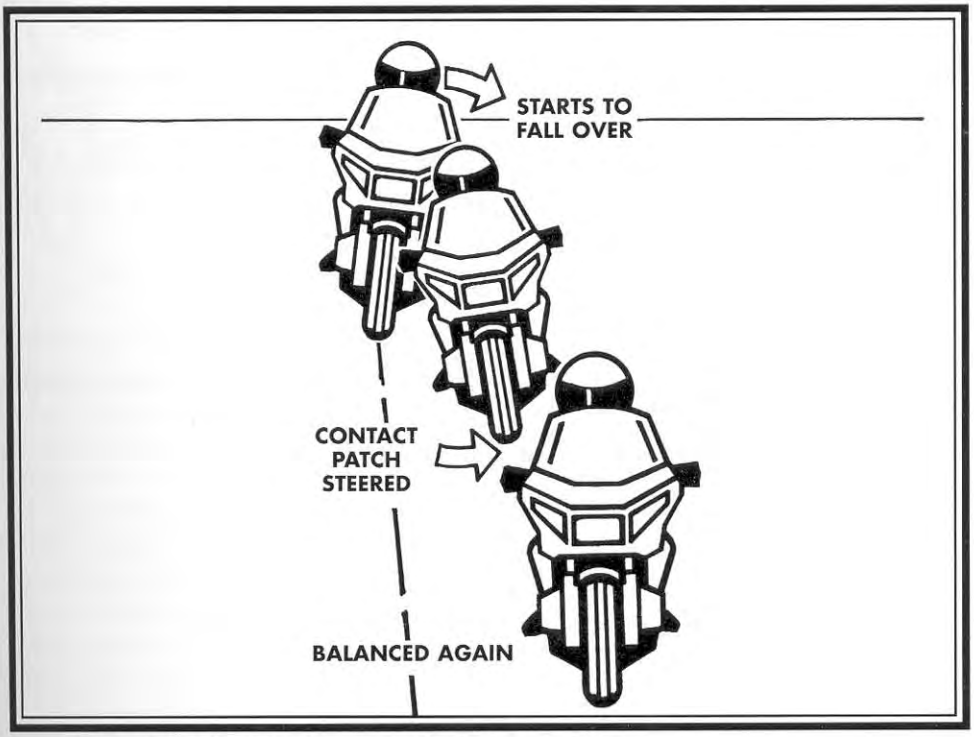
are interrelated. That's one reason changing tires to different profiles or changing just one tire to a different size or profile can change steering geometry, for better or worse.

Self-Balancing

With carefully selected rake, trail, and tire profiles, a machine can have self-balancing dynamics, whether moving upright and straight ahead or leaned over into a curve, and whether at fast or slow speeds. The point I don't want you to miss is that the front-end geometry is designed to countersteer itself into a straight line. If the bike leans over to the right, the CP shifts farther right, causing the front wheel to steer itself slightly tighter toward the right, countersteering the bike back toward vertical. As the machine returns to vertical, gravity, steering head position, and CPs all balance again. This is a delicate balance, and sometimes the engineers have to walk a tightrope between low effort (flickable) cornering and bad manners such as sudden unexpected tucking, uncontrollable oscillations (speed wobbles), or falling into turns at slower speeds.

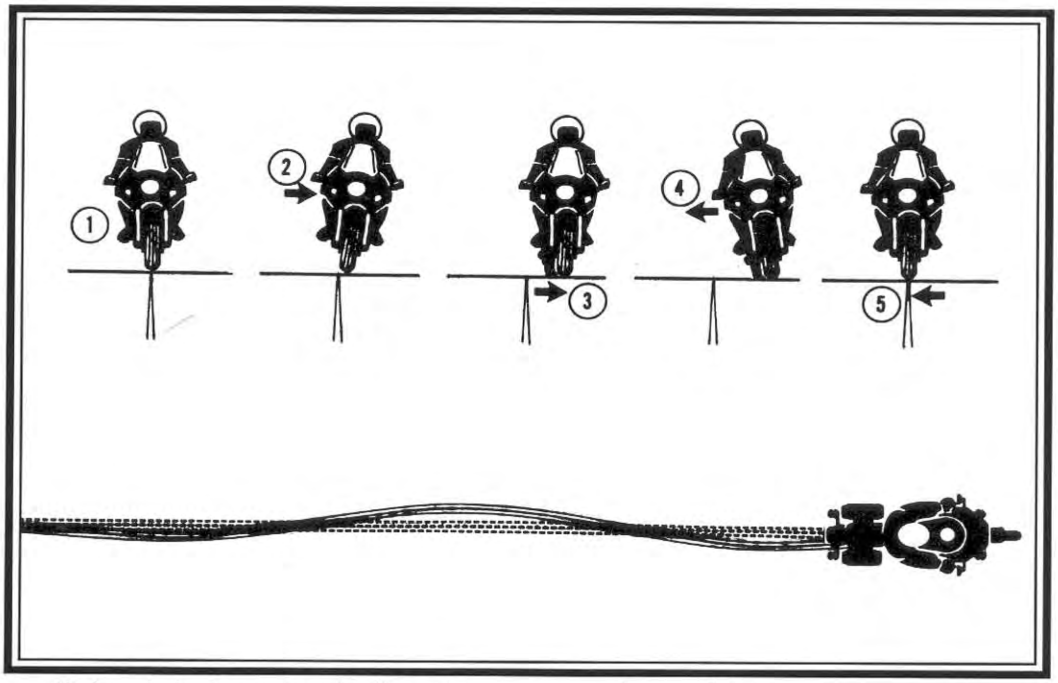


The bike is balanced by steering the contact patch under the center of gravity.

The Snake Track

If you watch a motorcycle cruising down the superslab, you'd swear it follows an absolutely perfect straight line. But if you could measure accurately, you'd discover that it rolls ever so slightly from one side to the other as it balances itself, sort of like a clock pendulum. This self-balancing act is more obvious at slower speeds because the front tire requires more steering input at slower speeds than at higher speeds to get the same effect.

If you were to ride your bike slowly through a puddle of white paint, and then go back and look at the tire tracks, you would see that the front tire sometimes tracks to



The front wheel makes a snake track as front-end geometry continuously restores balance.

the left and sometimes to the right. In other words, the front tire rolls along in a snakelike track as the bike continuously rebalances itself or as the rider makes small corrections.

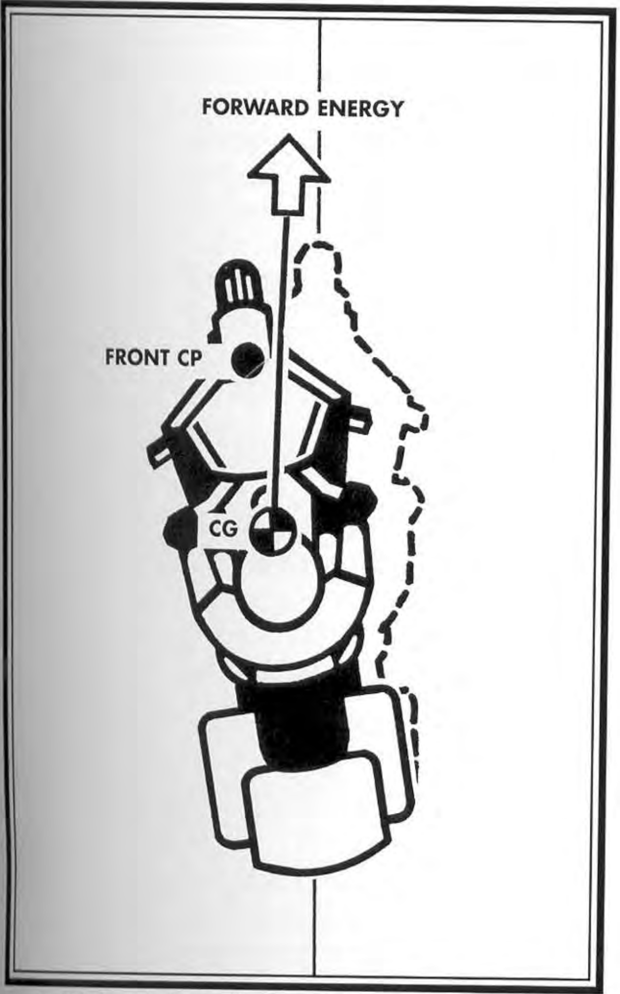
Gyroscopic and Inertial Stability

Two big contributors to straight-ahead stability are the inertial effect of the motorcycle/rider mass, and the gyroscopic forces generated by the spinning wheels. Perhaps the best way to think of inertia is that objects "want" to keep on doing whatever they are doing. Kick a brick sitting on the ground, and you'll discover it doesn't want to move. Throw the brick, and it's obvious it wants to keep moving, at the same speed and in the same direction. Putting a name to this "wanting" is tricky. The popular unscientific term is *momentum*. The correct name for this property of matter is *inertia*, but if we start to add vectors and measurements of force, we need to start calling it *kinetic energy*. To avoid a war over definitions, I usually call it *forward energy*.

A motorcycle, once up to speed, wants to keep rolling along straight ahead. Forward energy contributes to straight-ahead stability by pulling the motorcycle's mass back toward center and by providing a resistance against which the tires can react. For example, if the front of the motorcycle is steered away from center, forward energy attempts to pull it back toward a straight line again.

The wheels of a motorcycle also contribute to stability, but in a different way. Spinning wheels generate gyroscopic energy that resists lateral shifts or leaning. A spinning gyroscope wants to stay spinning at the same angle. Basically, forward energy helps keep the motorcycle pointed straight ahead, and the gyroscopic effect of the wheels helps keep the motorcycle from falling over or lurching sideways.

One of the interesting characteristics of gyroscopes is *gyroscopic precession*. What that fancy term means is that if you hold a spinning motorcycle wheel vertically by the axles and turn it toward the left, the wheel wants to lean over toward the right. Since this seems to correspond to what happens when a motorcycle is leaned into a turn, many people are fooled into believing that gyroscopic precession is the



Even if the front wheel tracks off on a tangent, forward energy attempts to pull the bike back into a straight line again.

dominant force that causes a motorcycle to lean into turns. It's a nice, simple theory, but it turns out to be a fable. First, the demonstration suggested is applicable only if you suspend the wheel off the ground, as when a motorcycle is doing a wheelie. Second, when the motorcycle tire is in rolling contact with the road surface, tire traction enters the equation, and traction can produce stronger forces than precession. Third, the front wheel is connected to the rear "gyroscope" via the motorcycle frame. And fourth, there have been experiments that demonstrate that a two-wheeler can be balanced with a very low mass front wheel. Regardless of what makes it happen, you can trust that countersteering will cause the bike to lean.

Feedback

Part of the confusion over motorcycle balancing and steering is that different machines handle differently and give different feedback to the rider. Ideally, if a rider eases pressure on the grips, the motorcycle should settle into a straight-ahead path. If the motorcycle is leaned over into a turn, releasing pressure on the low grip should allow the machine to gradually lift itself up and return to a stable, vertical attitude again. We call this neutral steering.

By comparison, some motorcycles have a tendency to fall into turns at slower speeds. With such machines, you can initiate a right turn by pushing on the right grip, but once the bike starts to lean, it just wants to keep on falling over. The rider may not appreciate what's happening, but once the bike is leaned over, it is necessary to maintain a pull on the low grip to keep the bike from falling. So, the technique to control lean angle is to push on the grip to make it lean, then pull on the low grip to maintain the lean angle. That can be confusing to the rider who doesn't understand what's happening.

Center of Gravity

When you hear someone attributing a motorcycle's good or bad manners to the elevation of its center of gravity (CG), remember that it's mostly steering geometry that makes a machine feel sluggish or top heavy in turns. Certainly, a cruiser that's built low to the ground will have a lower CG. But some cruisers with a low CG have heavy steering. And there are tall dual sportbikes with the engine mass up in the stratosphere but with flickable manners. Next time you hear of a bike that's described as being top heavy or having a high center of gravity, check the rake/trail numbers and consider the sizes and profiles of the tires. And if your favorite machine has some strange cornering habits, be aware that you can do some fine-tuning by changing tire diameters and profiles.

Body English

Remember Wobbling Willie, who can't seem to control the balance of his big road burner by slamming his knees against the tank? It worked fine with Willie's little 250, but it doesn't work with his heavier 1500cc touring bike. Sure, body English can cause a bike to change direction. But the result you get from throwing your weight around depends to a great extent on the relationship of your weight to the weight of the bike. The heavier the bike, the more it's inertial and gyroscopic stability. For instance, slam your knee into the tank on a contemporary 250 lightweight, and it will head off in a new direction. Slam your knee against the tank of a 1500cc tourer, and it may wobble once or twice and then straighten right back up on its original path. With the larger machine, Willie needs to focus more on countersteering and less on body English.

The next time you are out riding, think about what you're doing to control balance and direction. Are you sitting rock-solid in the saddle and just resting your boots on the pegs? Are you pushing or pulling on the grips? Are you shifting your butt? Are you shifting weight from one footpeg to the other? In a turn, do you place more weight on the inside or the outside peg? Are you pushing or pulling on the low grip? I'm not offering any correct answers here, just pointing out that part of becoming a proficient motorcyclist is figuring out what it takes to control your machine, and what your machine is trying to tell you.

What Makes It Turn?

In the previous section, I discussed a number of factors that cause a motorcycle to balance itself and what a rider can do to help. Now, let's consider what we do to make a motorcycle turn. I'll try to keep the concept of turning as understandable as possible, while still giving you the information you need to achieve better control of your motorcycle.

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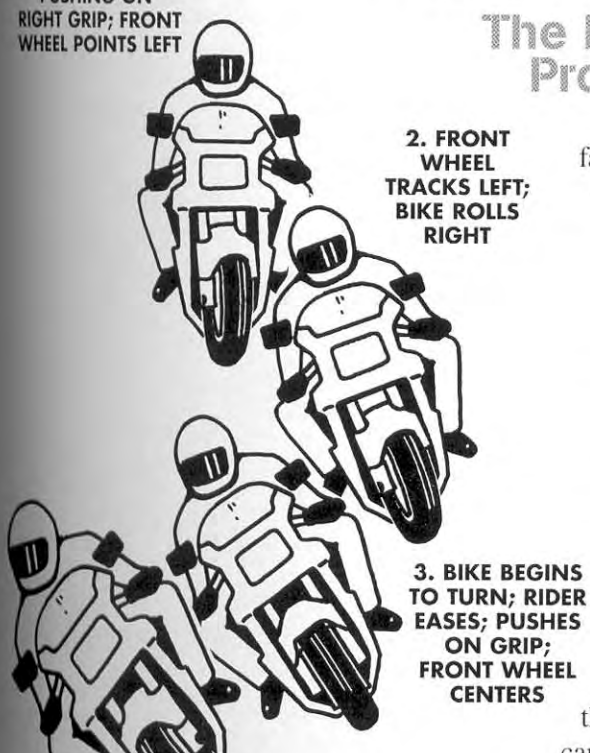
Turning Equals Unbalancing

As I've already pointed out, a well-engineered motorcycle wants to go straight. The front-end geometry automatically steers straight ahead and vertically, while forward energy and gyroscopic forces help stabilize the bike. To get a two-wheeler to turn, we need to get it leaned over. So turning really is a process of unbalancing the bike to get it leaned over, then rebalancing it in a curving path.

Bikes vs. Cars

One of the big differences between how motorcycles and automobiles turn is that a motorcycle must first be leaned over before it starts to turn. An automobile starts to turn as soon as you yank on the steering wheel. The same is true for a trike or sidecar outfit or any other multitrack vehicle. But two-wheelers are different. Even with a flickable sportbike, it may take a full second to get the bike leaned over before it actually starts to change direction. And with a heavyweight tourer, that initial lean may require more than one second.

A lot of arm waving and heated discussion has taken place around campfires about how we really cause motorcycles to turn. The discussions always get around to countersteering, but there are often disagreements on what we really mean by countersteering, and exactly what the forces are that make it work. Let's see if I can clear up some of the mystery.



Countersteering is just the first step in the leaning/cornering process.

The Leaning and Cornering Process

Leaning can be initiated by a number of different factors, including road camber, crosswind, rider's body English, and steering the handlebars. The most powerful factor in leaning is steering the handlebars, so I'll focus on that.

Experienced riders usually refer to a rider's steering input as countersteering because the handlebars are steered opposite, or counter, to the intended lean. Push on the right grip to lean right; push on the left grip to lean left. That's where some of the confusion starts because leaning and cornering is really a process of several steps, while countersteering is just the first step in the process. The process all happens within a couple of seconds, so let's slow down the action and go through it step-by-step. I'll illustrate this leaning and cornering process from the front, and exaggerate the graphic a bit so you can understand what the front end is doing.

Countersteering initiates the lean required for a motorcycle to begin turning. From the saddle, it may appear that the front wheel continues in a straight line while the top of the bike leans over, but what really happens is that the bike and rider lean around the center of mass. The rider steers the front wheel off on a slight tangent, which shifts the contact patch away from the turn. That forces the top of the bike to lean toward the turn.

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For example, pushing on the right grip steers the front wheel off more toward the left, which forces the bike to lean toward the right.

If you have been practicing countersteering for a while, it may seem as if you just nudge on the grip and hold it. But it should be obvious that if the front wheel continues to track off on a tangent, the bike will continue to lean over until it slams into the ground. So when the bike leans over far enough to achieve the turn you have in mind, you ease pressure on the grips enough to allow the front end to steer itself back toward center.

Now that the bike is leaned over, it starts to turn. Tire traction is actually pushing against the road surface to force the front end into a curving path. The front wheel is pointed slightly toward the direction of turn, and the rider applies just enough steering input to keep the bike leaning and turning. Of course, the bike wants to return to a straight line. We usually refer to that as *centrifugal force*. If you were to tie a connecting rod on the end of a string and swing it around your head, you could think of the outward pull on the orbiting rod as centrifugal force and the string as the front tire. With the bike leaned over, gravity is pulling strongly on the turn side, so you can balance centrifugal force against gravity. You can adjust the lean angle by additional small countersteering inputs, if needed.

Push Steering

If you've never heard of countersteering before, or if you haven't figured it out yet, you should probably start by experimenting with the concept of push steering. The simplest way to describe countersteering is to explain that you push on the right grip to turn the bike right, push on the left grip to turn it left. Take your bike out for a spin, get up to 35 mph or so on a straight, vacant road, and consciously push lightly on the left grip. The bike will lean over slightly left and move toward the left side of the lane. Now push on the right grip. The bike will lean slightly right and move back toward the right side of the lane.

This isn't something new because it's how everyone steers motorcycles, whether they realize it or not. A lot of riders concentrate on body English such as elbow-waving or knee pressure unaware that the important input is through the hands. Accurate cornering is much easier once you realize that the primary input is through the grips. Once you've experimented with push steering, it's time to move on. Different machines and various situations provide different feedback to the grips when leaned over in a corner. So you need to understand countersteering as more than simply pushing on the low grip.

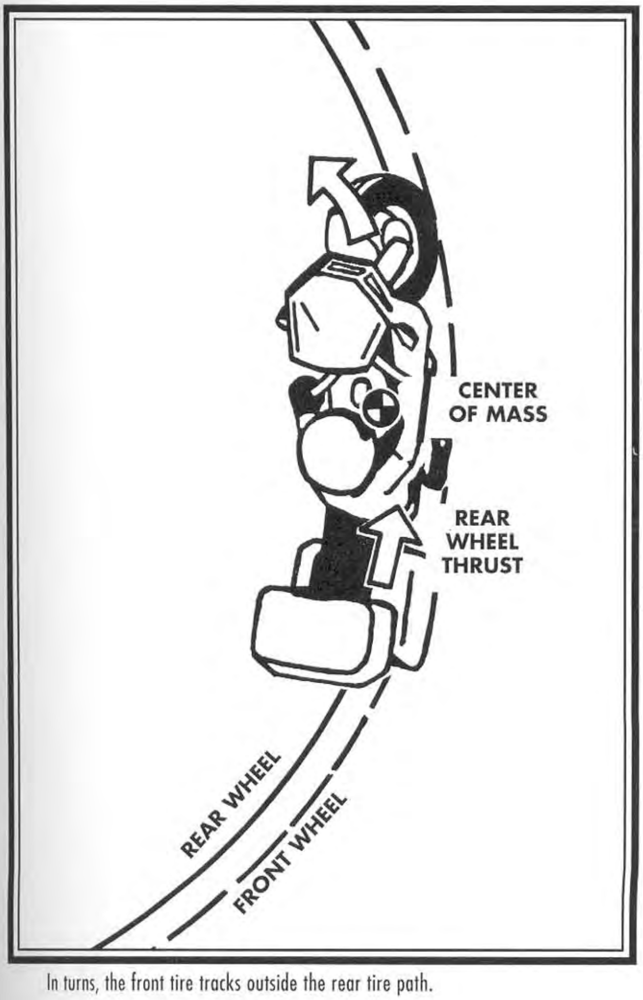
Is It Countersteering?

A fellow rider pointed out an interesting phenomenon about steering input. While leaned over at speed on the racetrack, this rider observed that about half the time he was pushing on the low grip, steering the front wheel slightly away from the turn, and half the time he was pulling on the low grip, steering the front wheel toward the turn, all the while attempting to hold the bike on his desired racing line. He knew whether he was turning the front wheel toward the turn or away from the turn because he was hanging off the bike and could see the front wheel. Does this mean we countersteer only half the time, or is something else going on here?

What this rider's observation points out is that guiding a motorcycle in a curve may require small adjustments of line, not simply constant pressure on the low grip. Remember, front-end geometry steers itself in a slight snakelike weave as the machine attempts to balance itself. Surface camber changes, wind drag, and throttle adjustment can all initiate lean angle changes. It's up to the rider to make inputs through body English and steering to hold the cornering line.

Even with the bike stabilized in a turn, we may still be making slight corrections. For example, if the motorcycle is leaned over in a tight left turn and then a crosswind pushes it over a little too far, pulling on the left grip will keep it from leaning over farther. Are we still countersteering, even though the front wheel is pointed to the left of center in a left turn? Sure.

Confusion over the term *countersteering* is often generated by our focus on the grips, when the action is really down at the contact patch. We should understand countersteering to mean shifting the contact patch opposite to where we want to go, whether that takes a push or a pull, whether upright or leaned over, whether fast or slow, and whether the bars are turned left of center or right of center. To put this another way, countersteering is shifting the contact patch in the opposite direction of the way we want the bike to lean at the moment.



In turns, the front tire tracks outside the rear tire path.

Out-Tracking

When you countersteer, it may seem as if pressure on the grip pushes the bike over without actually pivoting the front wheel. Does the front end actually pivot away from center as the bike leans over into a curve? Yes. The movement is slight, but if the front end isn't free to pivot in the steering head, the motorcycle can't be balanced or turned.

If you could watch a slow-motion video of a motorcycle running through a puddle of paint and then making a figure eight, you would see that the front tire swerves toward the outside during the initial countersteer, then eases back, but it always tracks outside the rear tire in turns. In a left turn, the front tire tracks to the right of center. In a right turn, the front tire tracks outside the rear tire path.

If you'd like another good example of out-tracking, record some motorcycle race footage, and play it back in slow motion. In those shots where the camera is looking back down the straight toward a corner, you can see the lean angle of the bikes head-on. If you mentally plot the path of the motorcycle's CG, you'll see that the bottom of the tires out-tracks, even arcing over onto the rumble strips as the rider uses every last inch of pavement.

Coning

While your bike is leaned over in a curve, you might wonder why it continues to turn even though the front end seems to be pointed straight ahead. Part of the answer is that the front wheel really is pointed slightly toward the curve. The other

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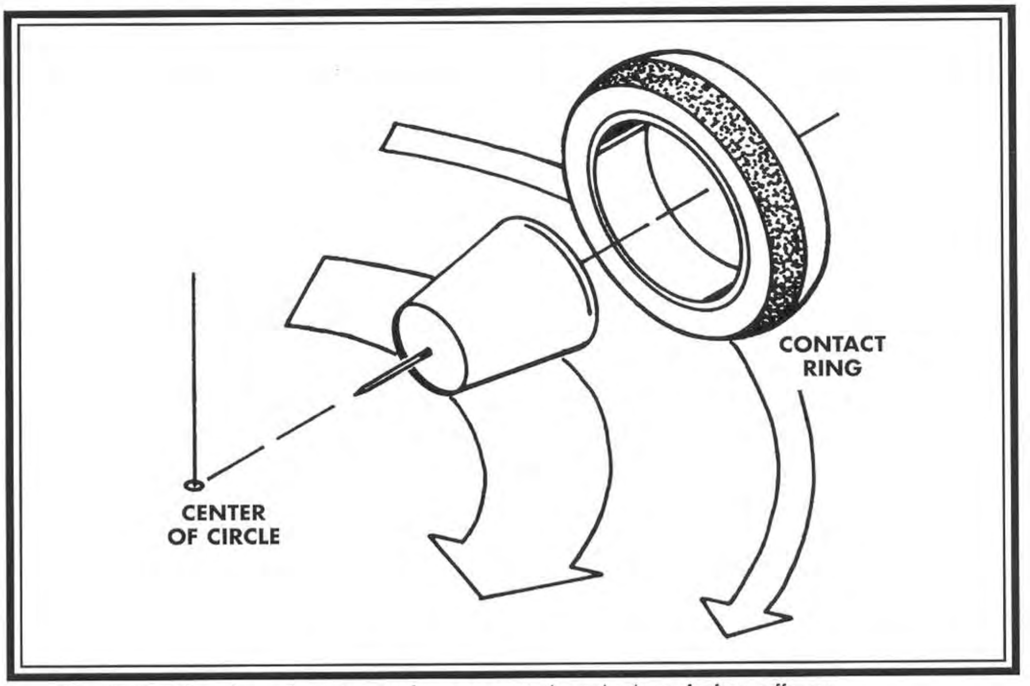
part of the answer is called coning. To understand coning, let's consider the shape of the front tire where it meets the road surface. Although we can see that the top of an inflated tire forms a rounded shape, we have to imagine that the tire momentarily gets squashed flat where it contacts the ground at the CP. But we also know that the tire CP is really a continuous ring around the tread. It's important to recognize that with the bike leaned over into a turn, this CP ring forms a conical



When the tire is leaned over, the contact ring forms a cone, similar to the shape of a foam coffee cup.

shape, similar to a foam coffee cup on its side.

If you nudge the cup forward, it rolls in a circle because the distance around the cup at the closed end is shorter than the distance around the open end. If you stick a toothpick through the center of the cup bottom, the toothpick points approximately at the center of the circle. A motorcycle tire responds similarly when the bike is leaned over. The inside of the tire contact surface covers less distance than the outside. So when leaned, a motorcycle wheel rolls in a circle, with the axle pointed more or less at the center of the turn. In a very tight turn, the axle may actually point at a center that's below the surface of the ground.

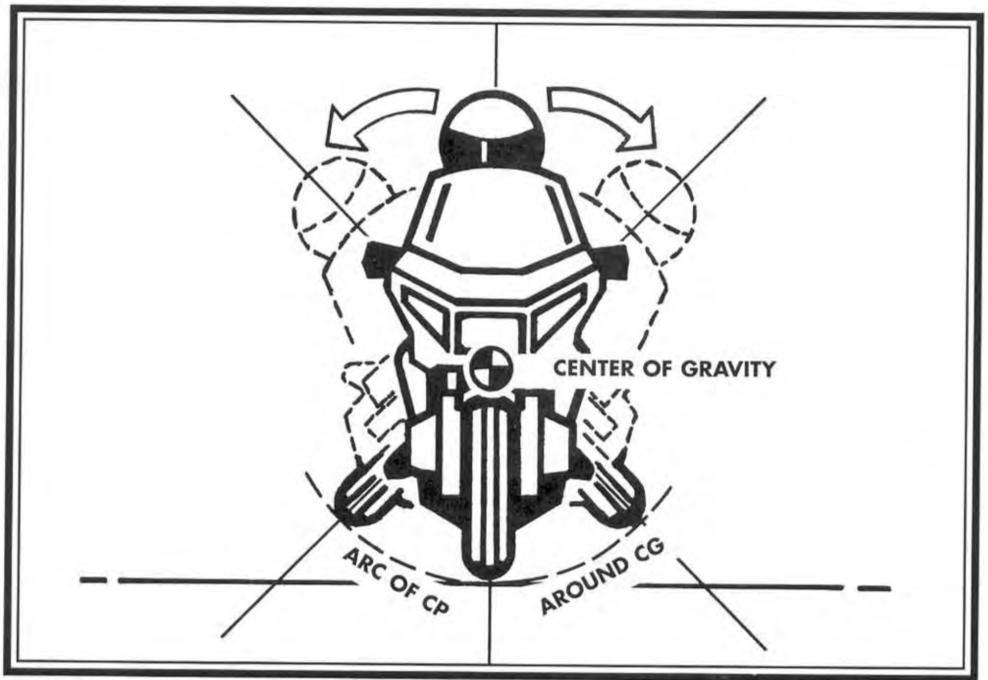
Fast Flicks

The more muscle you put into countersteering, the harder the front tire pushes to lean the bike, and the quicker it will lean (up to the limit of traction, of course). And the longer you hold pressure on the grip, the further over the bike will lean during the countersteering input. Those are key points to remember when riding a twisty road where you need to lean the bike left, right, left in a series of turns. Remember, it may take one second to get the bike leaned upright from a tight turn, and another second to get it leaned over the other way before it changes direction.

Is it possible to muscle the handlebars hard enough to snap the tires loose? Yes. You may have seen this in a road race, where a bike suddenly snaps into a heart-stopping wiggle in the middle of an S-curve, or the front tire loses its grip, and the bike crashes off on a tangent.

Remember, a motorcycle leans (rolls) around its center of mass without a lot of resistance, but resists being pushed up, down, or sideways. That's why a bike speeding over a lumpy bridge on the Isle of Man can go airborne.

Even if you aren't flying over a steep bridge, the bike's inertia will momentarily resist gaining or losing altitude. When a bike is rolled into a turn, the mass needs to lose altitude, and the inertia momentarily resists the pull of gravity, so we must expect less tire traction. But when rolling up out of a turn, the suspension must push the mass upward again, which substantially increases traction. If you consider the arc the contact patches would follow during a quick left-right flick, you can understand why the tires may lose traction as the bike is leaned over, but the bike squats on its suspension as it is rolled back toward vertical. What this means to you as a rider is that the front tire is more likely to lose traction when you are countersteering hard into a lean than when you are pulling it back up again.



The bike wants to lean around its center of gravity, so the tires may temporarily lose traction as the bike is leaned over, and gain traction as the bike is lifted up out of a curve.

U-Turns

If you're paranoid about slow speed U-turns, you're not alone. Heavyweight machines can be a handful at slow speeds and in tight quarters. The novice technique is to drag the foot-skids, turn the bars to the stop, feather the clutch to creep around, and finally discover that the bike has a larger turning diameter than the width of the road (usually discovered just as the front tire threatens to bounce off the pavement onto a loose gravel shoulder).

The trick for tight U-turns is being aware that as the bike leans over further, the turn becomes tighter. So, rather than drag your boots on the ground with the bike vertical, what's needed is for you to lean the bike into a steep angle. The technique is to lift your butt off the saddle, place most of your weight on the outside footpeg, lean the bike w-a-a-a-y over, and keep the engine pulling. It's okay to slip the clutch if needed to keep the engine from stalling, but squeezing the clutch in a tight turn is usually followed by the sound of a bike hitting the ground. Don't try to coast around

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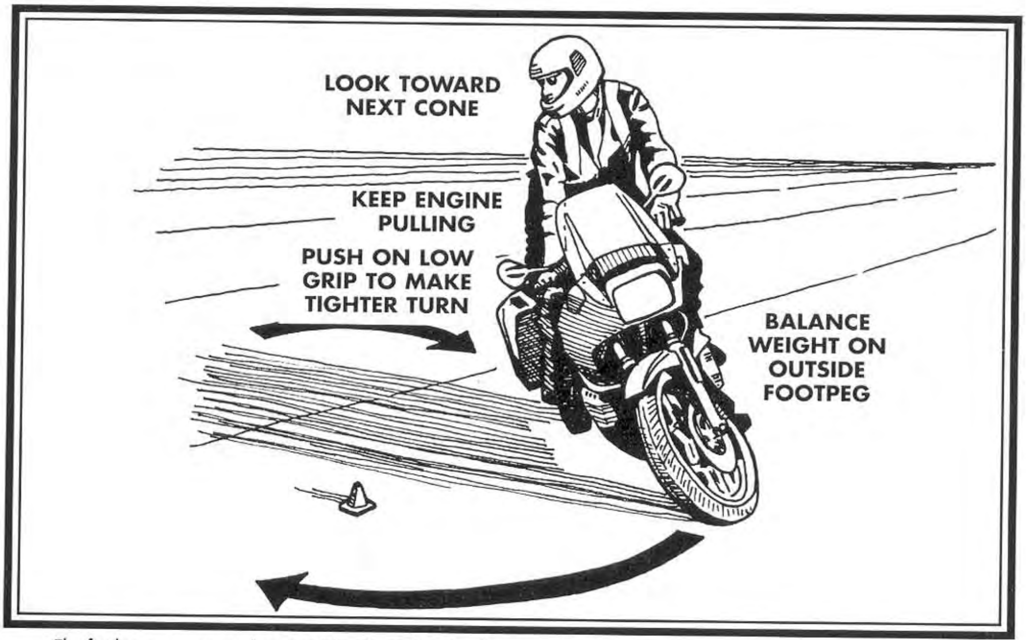
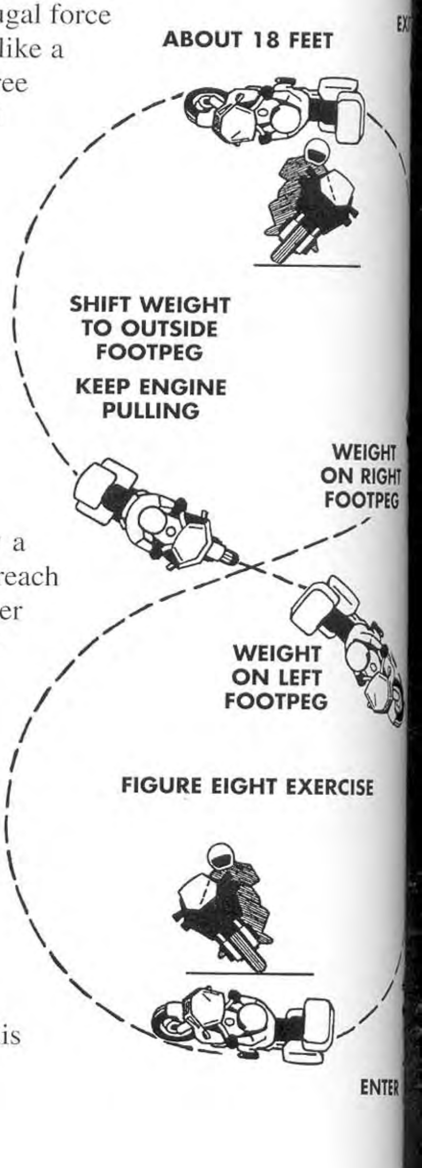


The farther over you can lean the bike, the tighter it will turn.

a tight turn; you need to keep the engine pulling to balance centrifugal force against gravity. In tight turns, it helps to swivel your head around like a barn owl, and look where you want to go. Staring at the ground three feet ahead of the bike may result in finding yourself on the ground right where you were looking.

If the bike seems to go wider than you want it to, you need to lean it over further. Grab those grips and push it over. To avoid any confusion over whether you are pulling or pushing on the low grip, imagine pushing both grips toward the turn to lean the bike over further, and pushing both grips away from the turn to keep it from falling over, or to straighten it up. By now, we know this is really countersteering, but at slow speeds your particular machine may give you some strange feedback.



Ergonomics

If you've been ho hum about the subject of ergonomics (how a rider fits on a motorcycle), consider that how you sit on a bike and reach toward the grips has a lot do with steering control. You'll have better control of the bike if you can reach the grips in a natural position with your arms slightly bent and your feet braced down, not forward. So, if you find your motorcycle difficult to control, take a close look at the ergonomics. It's not just a comfort thing.

Practice

Here's a warm-up exercise for you to practice. It's just a long figure eight in a box. Most motorcycles can actually make a figure eight in an area 18 by 40 feet. It helps to mark the boundaries of the box with cones. Enter at one corner, make a tight turn, another tight turn in the opposite direction at the other end, and continue out the far end. If tight turns make you nervous, this exercise is just what you need to practice. Shift your weight to the outside peg, push both grips in the direction you want to go, and keep the engine pulling. Don't slip the clutch. If you can't stay within the 18-foot width, move the cones out to 20 feet at first, and then pull the box in as you gain skill and confidence.

If you don't have time to lay out the figure eight exercise, try making a figure eight before you park the bike at the end of a ride, or practice a few figure eights as you arrive in the company parking lot each morning. Anyone can ride straight because the bike is doing most of the balancing. It's in the tight turns where we find out who can ride and who is just going along for the ride.

Cornering Habits

We've discussed the basics about how two-wheelers balance and turn. Now, we're ready to take the rubber to the road. First, I'd like you to answer some questions as honestly and realistically as you can about how you control your machine in corners. And if you aren't really sure what you do, take your bike out for a spin and focus on your habits while cruising down your favorite twisty road.

Next time you're out riding, focus on your habits while cruising down a twisty road.

- **When turning, do you follow more-or-less the center of the lane, or do you follow a different "motorcycle" cornering line?**
- **Approaching a sharp turn, do you brake or just roll off the gas?**
- **If you brake, do you brake before leaning the bike, or do you drag the brakes as you continue around the corner?**
- **If you brake, do you use both brakes, just the front brake, or only the rear brake?**
- **When rounding a turn, where do you tend to focus your vision? Do you look down at the pavement in front of the bike, at the curb to one side, at the pavement farther around the corner, or where?**
- **Do you lean your head with the bike, or do you keep your eyes level with the horizon?**
- **To lean the bike, do you just think lean or do you consciously countersteer?**
- **As you lean the bike into the turn, do you hold a steady throttle, roll off the throttle, or roll on a little more power?**

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Now, some riders might think such questions are silly. If you've managed to get your motorcycle down the road for thousands of miles without having to think about such boring little details, why do you need to start now? Well, if you're happy with the way you ride and don't feel you could use any improvement, you can stop reading here and get back on the bike. But during your ride, you may start to notice other motorcyclists who wobble through turns, cross the centerline, or suddenly decelerate in corners, forcing you to take evasive action to keep from running up their backsides. You'll probably agree that *those* folks need some cornering help.

Of course, you might want to close the bathroom door, stare at that rider in the mirror, and see if he looks like one of those folks who can't quite put their bikes where they want to. However you perceive your skill level, let's see if we can help you improve your cornering tactics.

You've probably seen a lot of riders who think that cornering is just a matter of stuffing the bike through the bends by grunt and feel and cranking on more throttle until the tires start to squeal. But improving your cornering control (and yes, your cornering speed) is mostly a matter of technique, not fearless throttle twisting. We need to be doing the right things at the right time. That's why I asked those tricky questions. Now, obviously, big sweeping curves such as those on freeways don't need any special tactics. But those twisty back roads really challenge your skills, and there are even a few tricky freeway ramps that tighten up or change direction. The tighter the curve, the more important it is to use the right tactics.

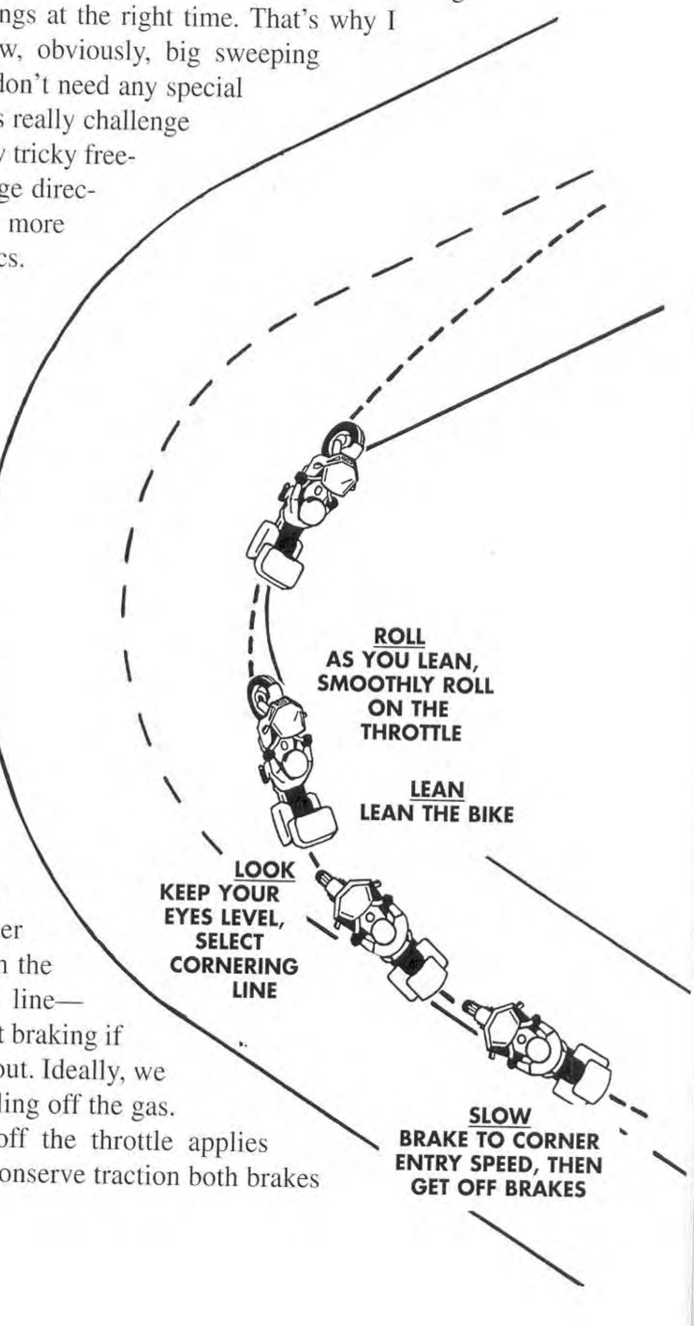
Slow, Look, Lean, and Roll

Different riding schools have different ways to describe the correct cornering techniques. One of the most concise descriptions is the slogan *Slow, Look, Lean, and Roll* used in state rider training courses. Having a slogan helps you remember the details.

Slow

Approaching a curve, you need to decelerate to a speed at which you predict you can make the turn. Most of the time, we roll off the throttle approaching tighter curves. It's smart to decelerate with the bike vertical—while in a straight line—because that allows maximum-effort braking if needed, without the risks of a slide out. Ideally, we apply both brakes in addition to rolling off the gas.

Why brake? Because rolling off the throttle applies braking only to the rear wheel. To conserve traction both brakes



should be used. First, you should be prepared to brake hard for a turn that you discover is tighter than expected. Second, if a hazard comes into view only as you lean over, you should be prepared to use both brakes to the limit of tire traction. If front braking is part of your cornering habits, your survival reaction will be to brake harder on the front, which helps avoid a rear wheel slideout.

Look

Before you dive into a corner at full chat, you really ought to figure out where the road goes, scrutinize the surface for loose gravel and horse poop, and any other debris, and determine whether that's a deer about to leap out of the flickering shadows or just spotted leaves. Note that you'll get the best view of what's happening from the outside of the curve. So, for a right-hander, you'll get the best view if you point the bike way over toward the centerline while you're still decelerating.

When you're ready to dive into the curve, swivel your head around to point your nose toward your intended line. Sure, it looks cool to just shift your eyes behind your blue aviator sunglasses, but turning your head actually helps provide directional control and a smooth entry into the turn.

Lean and Roll

With the bike slowed and positioned for best view, and your chin pointed toward where you want to go, it's time to lean the bike over and roll on a little throttle. Now, there are a number of ways to cause a motorcycle to lean over. You can shift your weight in the saddle, punch your knees against the tank, push down on one footpeg, or apply a little pressure to the handlebar grips. How your machine responds to any of these inputs depends on a variety of factors such as rider-bike weight relationship. But regardless of weight, the most accurate way to lean any two-wheeler is by pressure on the handgrips. Push on the right grip to lean right. Push on the left grip to lean left. Yep, that's correct: Push right to turn right. Hold enough pressure on the low grip to get the bike leaned over and pointed where you're looking, then ease up on the pressure to hold a stable line.

Wait a minute, you may be thinking. I understand that bit about push right to turn right, but back up to that business about rolling on the throttle as I lean over. You're kidding, right? Won't rolling on the gas push the bike wide or cause a rear wheel slideout?

Well, the answer will be obvious as soon as we think through some details. First, as the bike leans over, it's as if your tire diameters shrink. If you don't ease on a little throttle as the bike leans over onto the smaller diameter contact ring of the tires, you won't even be maintaining the same bike speed. And rear wheel compression braking is very much like dragging the rear brake. So rolling on a bit of throttle as you lean over doesn't waste traction, it conserves traction.

What's just as important, rolling on the gas helps balance weight between front and rear, helps stabilize the bike in the middle of its suspension, and maximizes leanover clearance. If you just try to hold a steady throttle through the curve, the bike is more likely to wobble and bobble as it changes lean angle.

What's wrong with just rolling off the gas and letting the bike slow down, you may ask. Well, a trailing throttle not only uses up traction for engine braking but also causes most bikes to squat on their suspension, eating up leanover clearance. If you find your machine making sparks at the apex of a turn, check out your throttle habits. The correct technique is to ease on more throttle progressively to keep the

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engine pulling smoothly all the way through the curve, which not only smoothes out your line and conserves traction but also maximizes leanover clearance.

Speed 35

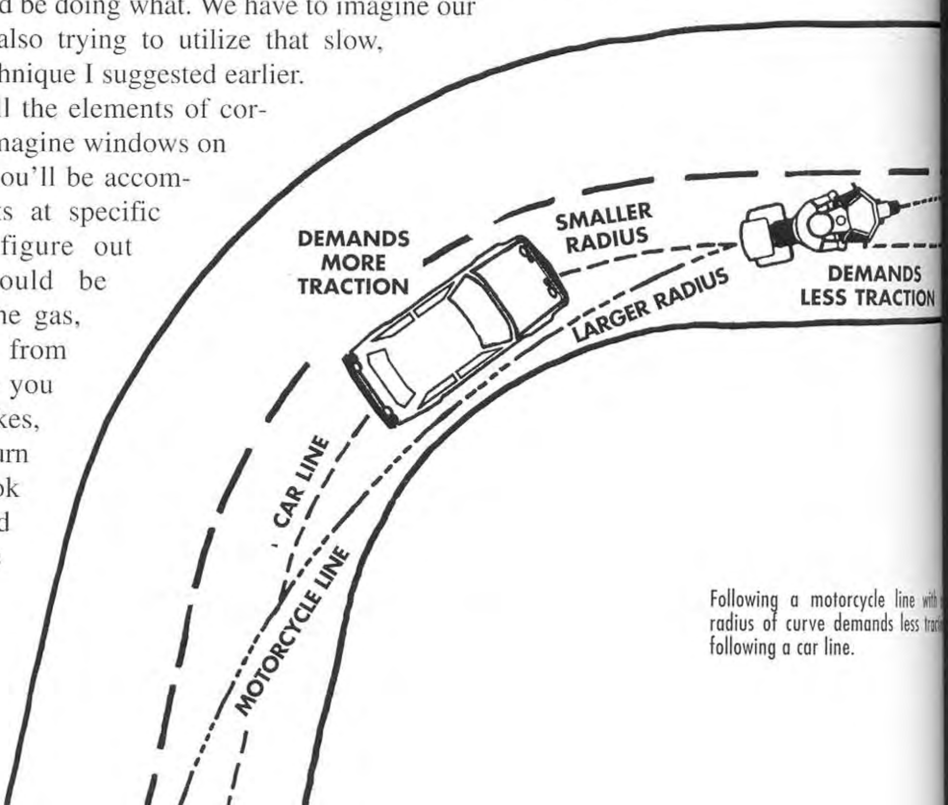
I usually get a chuckle from speed signs that say 35, when I know I can make the curve without a lot of drama at 50 or 55. Okay, the signs are posted for everyone, including top-heavy hay trucks. So, is there a rule of thumb for motorcyclists? Yep. But you won't find it posted on a sign. The ideal entry speed into a curve is the speed that will permit a gradual throttle roll-on through the rest of the curve. You'll have to figure out what that speed is, based on what you discover about the road. The key is if you couldn't gradually roll on the gas all the way through the last several turns, it means your entry speeds are generally too high. If you find yourself panicking in mid-corner and snapping off the throttle, it's a message you didn't decelerate enough before leaning the bike over. Sage advice about curves is to go in slow and go out fast.

Cornering Lines

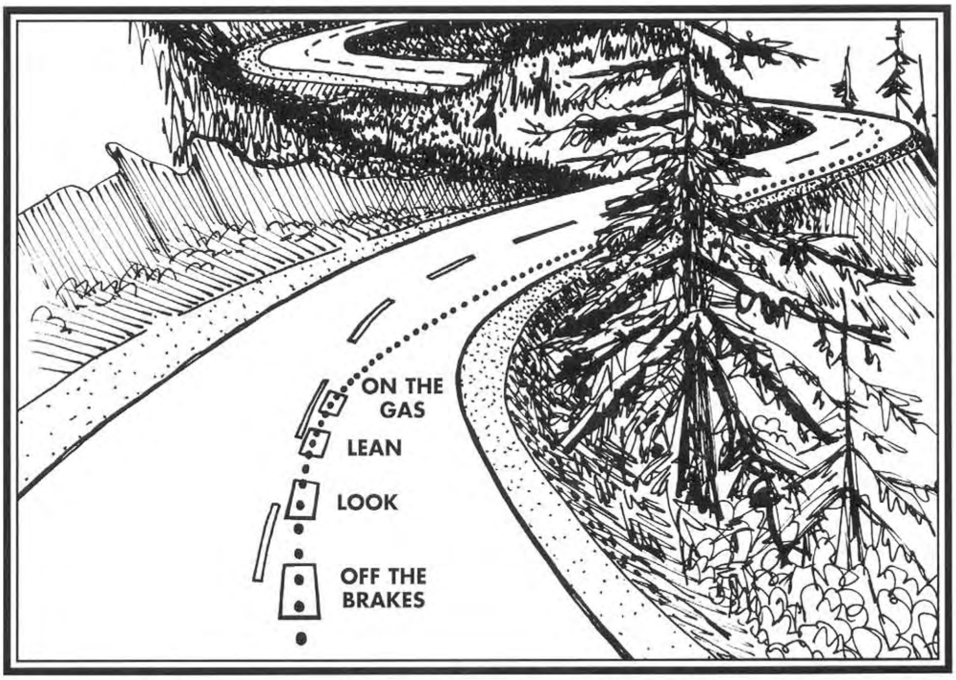
I know a lot of riders who are paranoid about leaning their machines over too far and dropping the bike. If you're concerned about slide outs, it's time to get serious about cornering lines. One of the unique advantages of two-wheelers is their ability to follow a path of travel, or line, that is different from the curve of the pavement. Think about this: side forces on the tires are least when a bike is traveling in a straight line. The straighter the curves, the less risk of a slide out. If you ride around a curve following a car line, your tires are using more traction than if your path of travel followed a straighter motorcycle line. What's just as important is that sudden steering to change direction also demands more traction and eats up ground clearance. A smooth, gradual, stabilized arc is better than a line with constant corrections.

So a big part of cornering is to decide where the pavement goes, and then plan the straightest line that smoothly arcs through the turns. This isn't easy because there aren't special motorcycle markings on the surface to give you any hints about where you should be doing what. We have to imagine our intended lines while also trying to utilize that slow, look, lean, and roll technique I suggested earlier.

One way to put all the elements of cornering together is to imagine windows on the pavement where you'll be accomplishing specific tasks at specific locations. You can figure out where the bike should be leaned over and on the gas, so mentally back up from that window to where you need to be off the brakes, where you need to turn your head to look through the turn, and then way back to where you need to start slowing down.



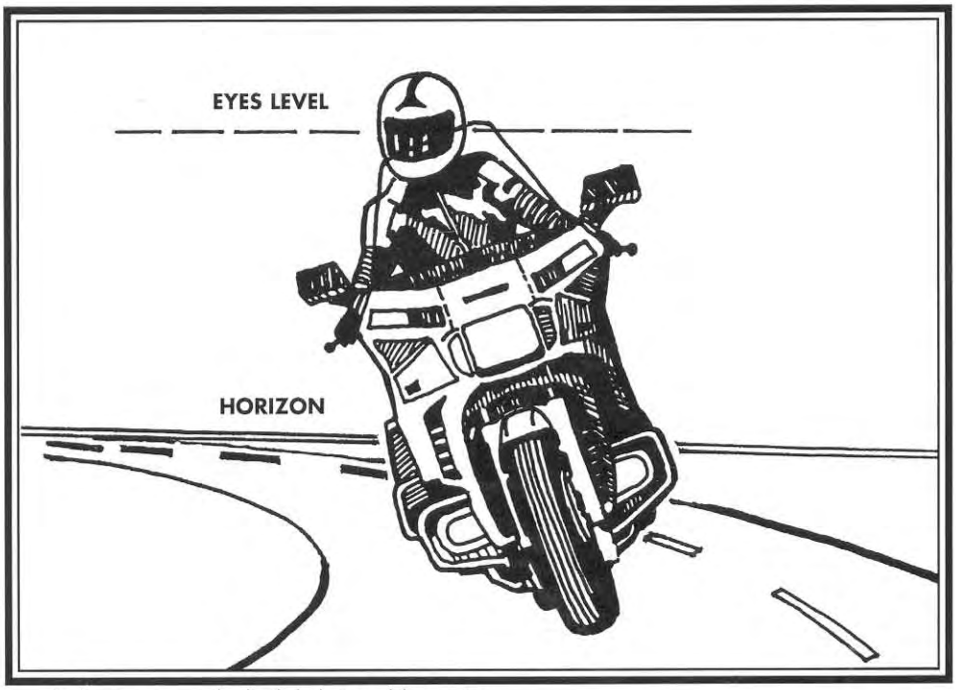
Following a motorcycle line wit radius of curve demands less tra following a car line.



It may be helpful to imagine windows where you need to be off the brakes, look through the corner, lean the bike, and roll on the gas.

Eyes Level

Many riders find it helpful to tilt their heads to keep their eyes level with the horizon while cornering. It's not easy to calculate the curvature of the road at speed, and it's even more difficult if you're trying to triangulate everything at a slanty visual angle. Tilting your eyes level seems to help keep things in perspective. See if it works for you.



Try keeping your eyes level with the horizon while cornering.

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Practice

If you have verified that your habits are good, you're well on the right track to faster, more controlled corners with less risk of slideouts. But if your habits aren't anything like what I've just outlined, it's time to practice some specific skills. One good way to practice is just to take a class at your local motorcycle training site, where an instructor can help you correct any bad habits. But sooner or later you need to take your skills out on the highway.

Why not find some twisty road that's not too busy and focus on the techniques I've described? Slow down to give yourself more time to think about each of the actions. For example, if you know you can stuff the old road rocket down Twisty Hollow Canyon at 50 mph, slow down to 35 and concentrate on doing the right actions at the right locations and the right moments. If you have trouble getting it right, slow down even more until you can do all the steps in sequence, including swiveling your chin around toward the curve and easing on the gas all the way around the turn. Remember, it's the techniques, not just bravado, that lead to better cornering habits. And if you're looking for higher speeds, the correct techniques are essential.

Making Sparks

If your cruiser or tourer has limited leanover clearance, you'll need to be a little more clever about turns. The giveaway is that your machine makes grinding sounds and leaves trails of sparks in every sharp curve.

First off, when you get back from a sparkly ride, check your suspension. Ideally, your suspension should be in the middle of its travel with the bike loaded as you normally ride. The best way to check suspension travel is to sit on the loaded bike and have someone else do some measurements. If you normally carry a passenger, get the passenger on board, too.

If you discover that your machine sits too low when loaded, first jack up the shock springs to maximum preload, and if that doesn't do it, figure on replacing the springs with stronger ones. Sagging front fork springs may be acceptable with spacers to increase the preload. If your suspension has air, carefully add a bit of pressure. Adjusting suspension toward the middle of its travel not only increases leanover clearance but also helps keep the tires in contact with the pavement.

If you've jacked up the shock springs but your low-slung cruiser still makes sparks, you can either lose some weight, or modify your cornering lines. Within limits, you can adjust where you make the tightest part of your corner. For example, you can follow more of a V-shaped line that decelerates on a straighter entry toward a shorter, slower turn, then exits on a straighter line. Sure, you have to slow way down for the tight part of the V, but you can accelerate harder exiting on a straighter line.

If leanover clearance is limited, try modifiying your cornering line to be more like a V.