

# MASTERING THE BASICS



## BASIC WHEEL ALIGNMENT

**M**odern steering and suspension systems are great examples of solid geometry at work. Wheel alignment integrates all the factors of steering and suspension geometry to provide safe handling, good ride quality and maximum tire life.

Front wheel alignment is described in terms of angles formed by steering and suspension components. Traditionally, five alignment angles are checked at the front wheels—caster, camber, toe, steering axis inclination (SAI) and toe-out on turns. When we move from two-wheel to four-wheel alignment, we add setback and the vehicle thrust angle into the equation. Rear wheel camber and toe also must be checked for a four-wheel alignment.

### Tire Wear & Directional Control

Camber, toe and toe-out on turns are tire-wear angles. If they're incorrect, the tires will wear unevenly and faster than normal. Because camber is related to steering axis inclination, SAI also can be considered a tire-wearing angle. Caster and setback are *not* tire-wear angles unless *extremely* out of specification. All alignment angles are directional control angles, which means they affect steering and vehicle control.

Troubleshooting a complaint about vehicle handling, ride or vibration starts with knowing what a particular alignment angle does and how all the angles work together. Before you plunge into system diagnosis, take a moment to think about the system operating princi-

ples. Therefore, let's review these basic alignment angles with an eye toward typical complaints and troubleshooting.

### Caster

Caster is the tilt of the steering axis of each front wheel as viewed from the side of the vehicle. Caster is measured in degrees of an angle. If the steering axis tilts backward—that is, the upper ball joint or strut mounting point is behind the lower ball joint—the caster angle is positive. If the steering axis tilts forward, the caster angle is negative. Caster is not measured for rear wheels.

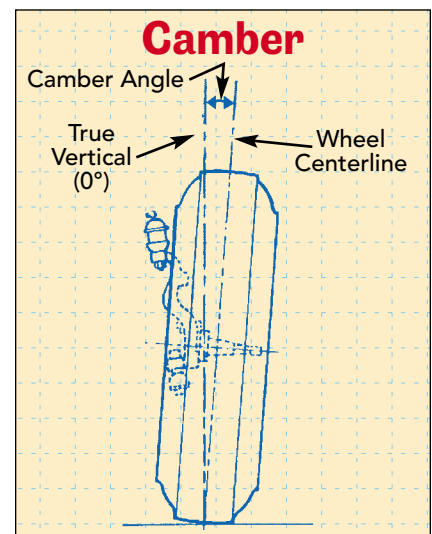
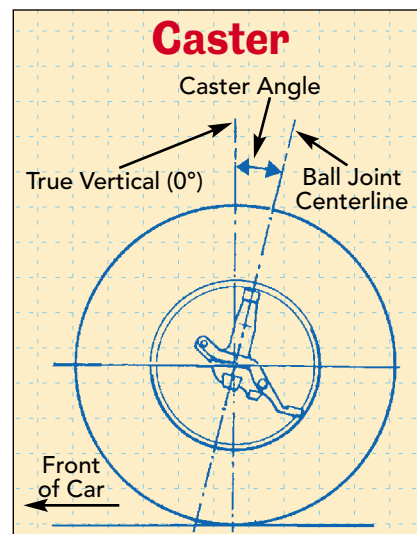
Caster affects straightline stability and steering wheel return. High positive caster makes the front wheels want to go straight ahead. A normal amount of positive caster provides stability and makes the steering wheel straighten out after turning. On the other hand, positive caster increases

the effort needed to turn the wheel. Power steering allows the use of more positive caster than would be acceptable with manual steering.

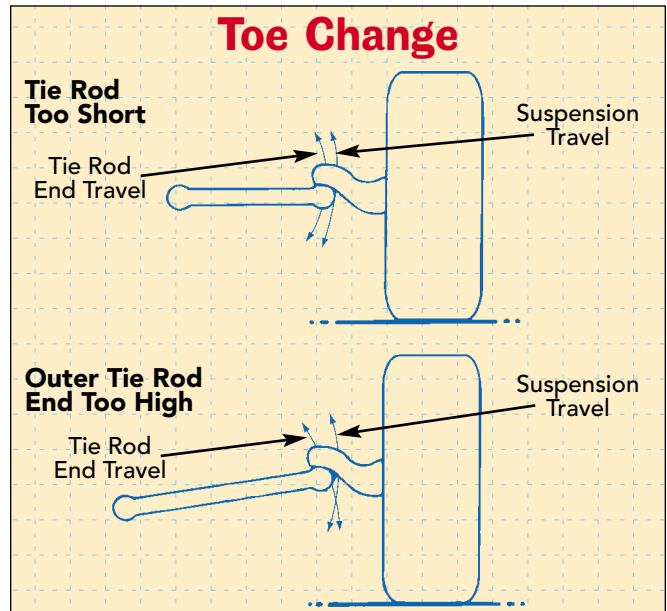
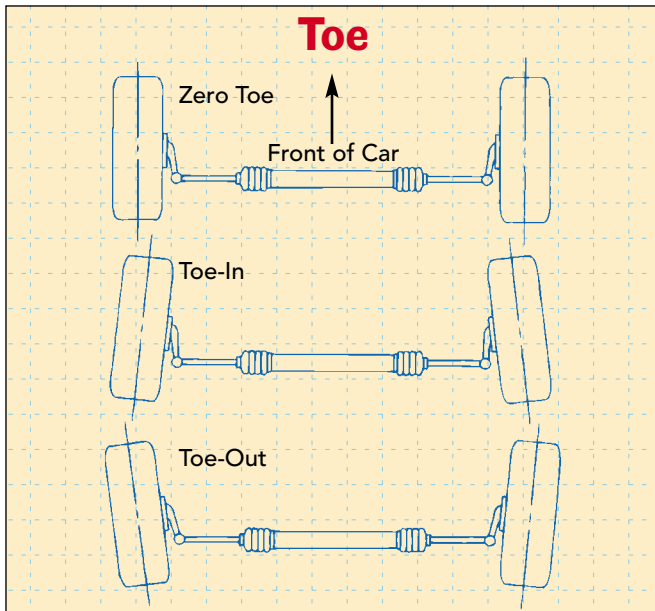
Too little caster can make steering unstable and cause wheel shimmy. Extremely negative caster and the related shimmy can contribute to cupped wear of the front tires. If caster is unequal from side to side, the vehicle will pull toward the side with less positive (or more negative) caster. Remember this when troubleshooting a complaint of vehicle pull or wander.

### Camber

Camber is the tilt of the wheel from true vertical as viewed from the front of the vehicle. Like caster, camber is measured in degrees of an angle. If the tire appears to tilt outward at the top, the camber angle is positive. If the top of the tire tilts inward, the camber angle is negative.



BY KEN LAYNE



Zero camber—a perfectly vertical wheel and tire—causes the least tire wear. Positive camber causes the outer tread of the tire to wear more than the inner tread; negative camber has the opposite effect. Engineers design small amounts of positive or negative camber into vehicle suspensions to aid handling and steering. Normal camber angles have little visible effect on tire wear, but extreme camber causes noticeably abnormal tire wear and shortens tire life.

Positive camber, like positive caster,

affects straight-ahead stability and steering wheel return. As the vehicle turns, the outside suspension tends to rise on the wheel because of positive camber. When the wheel returns to straight ahead, the vehicle's weight presses down on the steering axis and helps straighten the wheel.

Negative camber resists the tendency of the tire to slip sideways during cornering. It also can increase steering effort. Most cars and light trucks are designed with positive camber, but many

race cars and some high-performance street vehicles have negative camber.

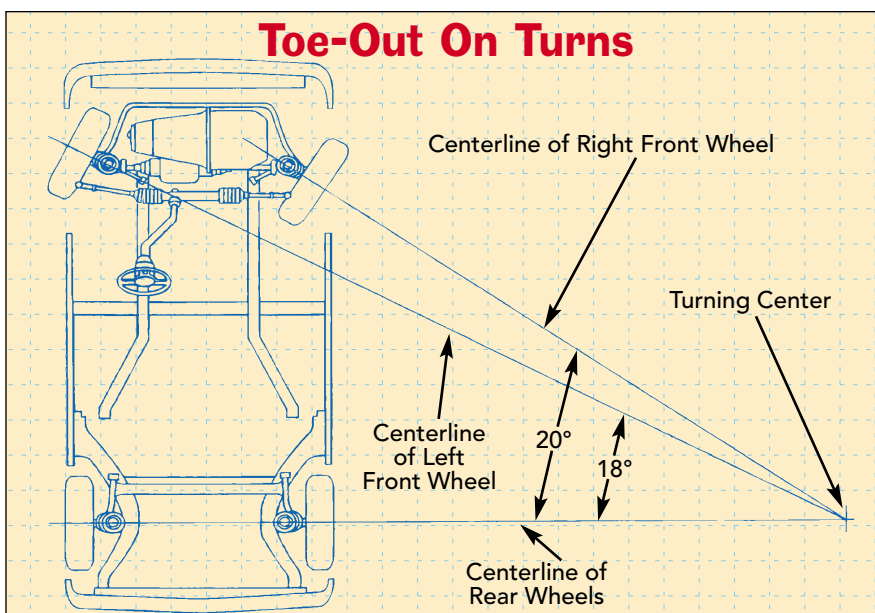
Rear wheels usually have zero camber, but some independent rear suspensions are designed with some amount of (usually negative) camber angle. If front camber angles are unequal side to side, the vehicle pulls toward the side with the greater positive camber. Unequal rear camber also can affect vehicle handling.

## Toe

Toe is how the wheels are aimed, as viewed from above. A pair of front or rear wheels aimed inward at the forward edges have toe-in; wheels aimed outward have toe-out. The toe angle for front or rear wheels is measured in fractions of an inch, millimeters or fractions of a degree.

Zero toe—wheels aimed straight ahead—causes the least tire wear. Extreme toe-in or toe-out causes feathered wear across the tire tread. Too much toe-in wears the outside tread edges, with feathered edges on the inside of each tread row. Too much toe-out has the opposite effect.

Front wheels are usually toed in on rear-drive vehicles and toed out on front-drives to compensate for changes in the steering linkage and tires when the vehicle is moving. When the vehi-



cle is moving, toe decreases (or disappears) because the wheels straighten out under acceleration and the steering linkage flexes slightly.

Toe change, or bump steer, occurs when a steering tie rod is the wrong length or is installed at the wrong angle. The outer tie-rod end moves up and down as the suspension compresses and extends. If tie-rod length or angle is incorrect, it pulls or pushes the steering arm and aims the wheel in a new direction. The driver feels this when the steering wheel jerks to one side as the car goes over a bump or dip.

## Toe-Out on Turns

Toe-out on turns also is called turning radius, or the Ackerman angle. As a vehicle turns, the outside front wheel turns at a lesser angle than the inside wheel. This causes the front tires to toe out during cornering.

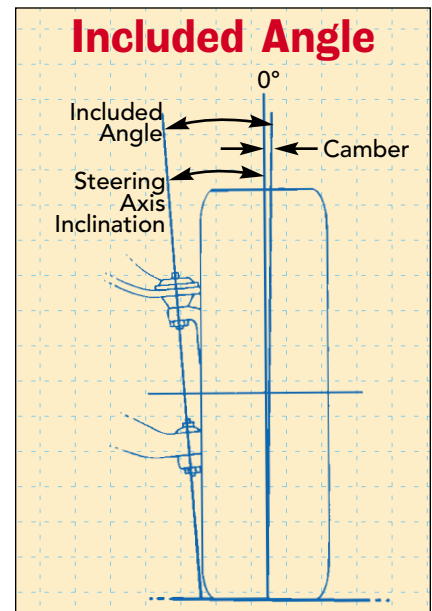
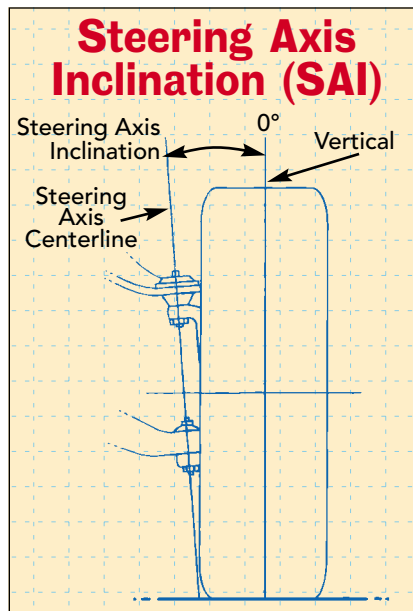
Some amount of toe-out on turns is necessary because the outside wheel must turn on a larger radius than the inside wheel. If wheel turning angles were equal, the outside tire would scuff as it tried to turn on a shorter radius.

Toe-out on turns is designed into a vehicle's steering geometry and must be equal in both right and left directions. Toe-out on turns is not adjustable. Angles that are unequal from side to side or out of specification are caused by vehicle damage.

## Steering Axis Inclination

Steering axis inclination (SAI) is the tilt of the steering axis from vertical as viewed from the front. It's an angle formed by a line through the centers of the lower and upper ball joints of the strut mount. Like caster, SAI affects steering feel and stability. In a suspension that doesn't have much caster, high SAI can provide solid steering feel and stability.

SAI plus the camber angle form what's called the included angle. If camber is positive, the included angle is greater than SAI; if camber is negative, the included angle is less than SAI. Knowing the SAI, camber and included angle can help you diagnose problems in the steering knuckles and suspension.

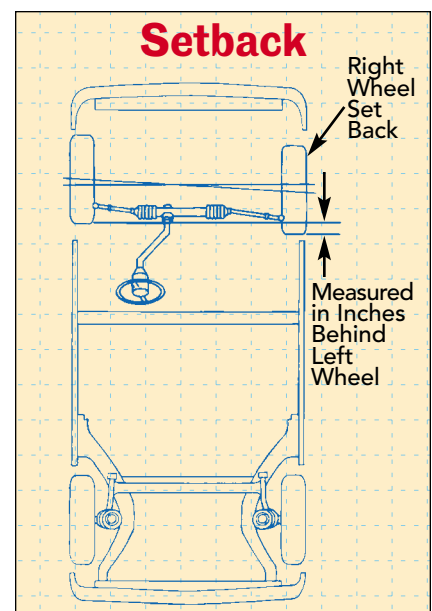
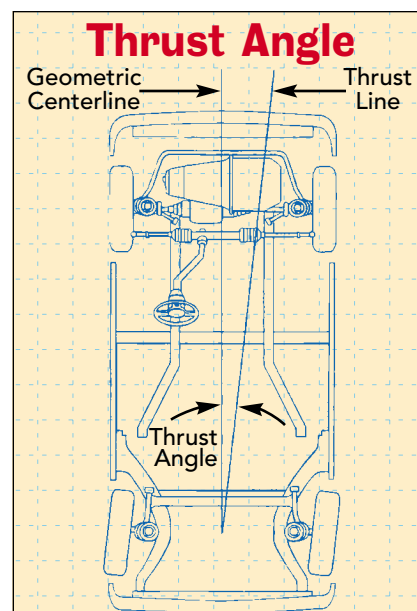


## Thrust Angle

The thrust angle is the angle between the vehicle's geometric centerline and the direction in which the rear wheels are aimed. If the rear wheels point straight ahead, the thrust line and the geometric centerline are the same, and there is no thrust angle. When a vehicle is being driven straight ahead, the rear wheels steer it along the thrust line, so a zero thrust angle is ideal.

Adjusting rear toe should correct

the thrust angle, but the rear suspension design may not allow toe correction. If a thrust angle can't be eliminated, align the front wheels to the thrust line rather than to the vehicle's geometric centerline. Aligning the front wheels to the centerline with the rear wheels driving along a different thrust line can result in any or all of the following: a crooked steering wheel, incorrect front camber and toe while moving, accelerated tire wear or pull.



## Setback

Setback is a condition in which one wheel on an axle is in front of or behind the other wheel in relation to the chassis. Setback is actually designed into some vehicles, such as old Ford trucks with twin I-beam front axles, but incorrect setback most often results from collision damage. Extremely uneven caster also can cause setback at the front wheels.

## Ride Height

Strictly speaking, ride height is not an alignment angle. It can, however, affect other angles, especially caster. Many manufacturers specify ride height measurement positions for alignment adjustment. Ride height often is measured

at the bottom of a front or rear rocker panel or the top of a wheel well. Because vehicle body panels are not the most accurate data points (with the possibility of collision damage), ride height is more accurately measured from points on the suspension or frame.

Many trucks are fitted with a variety of wheel and tire sizes, suspension options and lift kits. Therefore, truck manufacturers often specify different caster angles for different ride heights on the same basic truck model.

## Start With the Customer Complaint

Customers rarely complain about “an incorrect Ackerman angle,” “too much caster” or even worn control arm bush-

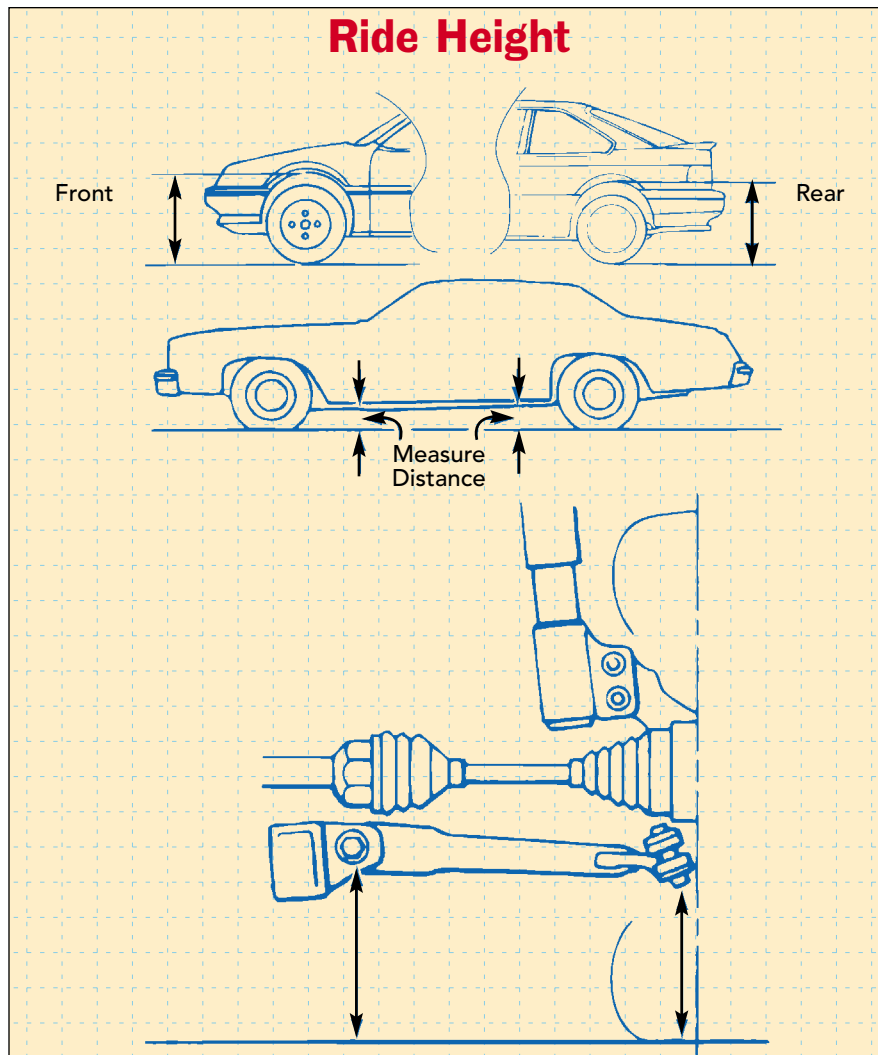
ings. Their complaints usually identify the *effects* of steering and suspension problems rather than the causes. Owner complaints that relate to wheel alignment generally relate to poor handling, hard steering, vibration or tire wear. The first step in diagnosing a problem is to determine the category into which it fits. A careful road test followed by a thorough inspection will get you off to a proper start.

## A Final Word: Check the Tires

Before you begin your road test, take a close look at the tires. Most cars and light trucks should have four tires of the same size and tread pattern. At least the pair on each axle should be the same size and have approximately equal wear patterns.

Next, check the tire pressures. Occasionally, you’ll find a tire that’s overinflated, but probably two-thirds of the tires rolling down the highways today are underinflated. Bring all four tires to their recommended inflation pressures. Most car owners will be surprised by how a simple tire pressure check can solve problems like vehicle wander, brake pull, hard steering and a spongy ride.

During your road test evaluation and alignment measurements, remember the basic purposes of alignment angles and how they all work together to maintain vehicle motion balance. M



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## Answers to Previous Assessment Quiz

(Battery Operation & Testing, Apr. 2002)

1-C 2-C 3-D 4-C 5-B  
6-C 7-D 8-B 9-A 10-C