

# MLR – Steering and Suspension Study Guide

---

## Table of Contents

MLR – Steering and Suspension Study Guide .....	1
Unit 1: STEERING AND SUSPENSION OVERVIEW.....	2
Chapter 1: Introduction to Steering and Suspension.....	2
Chapter 2: Steering and Suspension Systems and Operation.....	14
Unit 2: STEERING AND SUSPENSION SERVICE .....	24
Chapter 1: Steering System Service .....	24
Chapter 2: Suspension System Service.....	33
Unit 3: WHEEL ALIGNMENT .....	46
Chapter 1: Wheel Alignment Service .....	46
Unit 4: WHEELS AND TIRES.....	59
Chapter 1: Wheel and Tire Design .....	59
Chapter 2: Wheel and Tire Service.....	68

## Unit 1: STEERING AND SUSPENSION OVERVIEW

### Chapter 1: Introduction to Steering and Suspension

A vehicle chassis is made up of several systems that all work in unison to provide a safe and comfortable ride. The chassis includes the frame (or unibody), brake system, steering and suspension systems, and wheel assemblies.

#### *Steering and Suspension Systems Overview*

##### Steering Systems

The steering system works with the suspension system to provide directional control with a comfortable amount of steering effort. It must do this while allowing for the necessary movement in the vehicle's suspension system. Some parts serve both systems. The steering system consists of a steering gear, steering linkage, a steering column and a steering wheel. Two types of steering systems are widely used in today's vehicles: rack and pinion steering and "conventional" steering.

##### Rack and Pinion Steering

Rack and pinion steering transmits circular motion from the steering wheel to a pinion that meshes with teeth on a flat rack. The pinion moves the rack in a linear direction, steering the wheels. Rack and pinion steering can be found on cars, mini-vans and small SUVs. It is simpler and less expensive to produce than conventional steering systems.

##### Conventional Steering

Conventional steering transmits the circular motion from the steering wheel through a gear that moves an arm through a back-and-forth arc, acting on a set of linkages to steer the wheels. It is also referred to as "recirculating ball" or "worm gear" steering, for the type of gear it uses, or "parallelogram," "trapezium," or simply "linkage" steering, for the shape formed by the linkage set. This type of system can be found on most rear wheel drive cars, light trucks and full size vans.

##### Suspension Systems

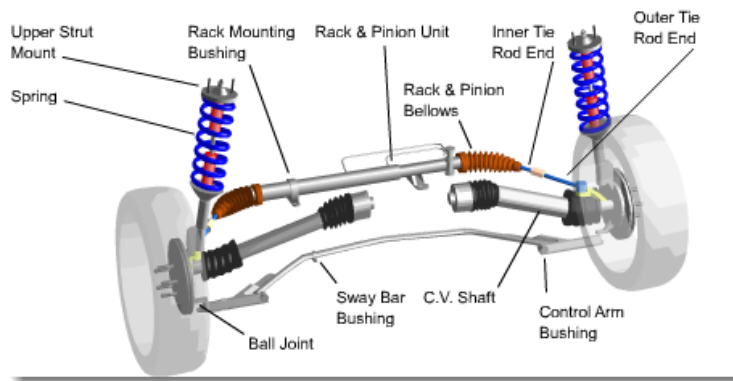
The suspension system supports the vehicle, allowing the wheels to move up and down over irregularities in the road. It cushions the ride for the frame, engine, transmission, and passengers, while keeping the tires in firm contact with the road under all conditions. Suspension system parts include springs, dampening devices (shocks), ball joints, steering knuckles, and spindles or axles. Two types of front suspension systems are widely used in today's vehicles: the MacPherson strut suspension and the short/long arm (SLA) suspension. Early automobiles and some medium- and heavy-duty trucks and four-wheel drive vehicles have a straight axle (I-beam) front suspension, and up until recently some light trucks were built with a variation called a twin I-beam suspension. Many rear suspensions still use a straight axle.

### MacPherson Strut Suspension

The MacPherson strut suspension combines a coil spring and a shock absorber into a single unit on each side. The strut is attached to the body at the top and to a lower control arm through a ball joint at the bottom.

The other end of the control arm attaches to the frame and pivots on rubber bushings. The steering knuckle is rigidly mounted to the strut. This suspension is lighter and smaller than the SLA design, and can be found on smaller vehicles with rack and pinion steering. It is commonly used on front-wheel drive cars.

#### **MacPherson Strut Suspension with Rack and Pinion Steering**

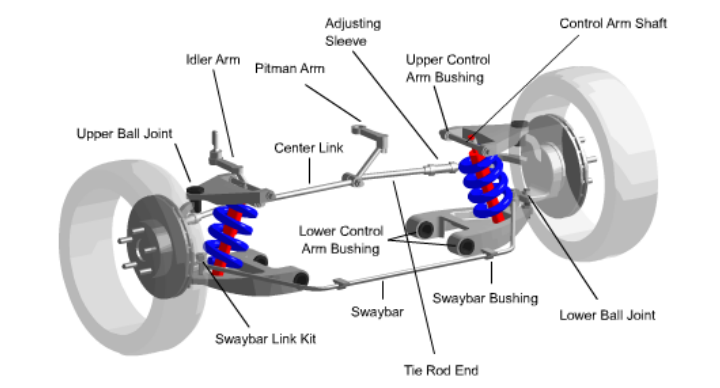


### Short/Long Arm (SLA) Suspension

Each side of the SLA suspension consists of two control arms attached to the frame at one end and the steering knuckle at the other. The arms pivot on ball joints at the steering knuckle, and on rubber bushings at the frame. A variety of spring arrangements may be used; a coil spring placed between the two arms is the most common, but the spring may be mounted over the upper control arm, or it may be a torsion bar attached to the lower control arm.

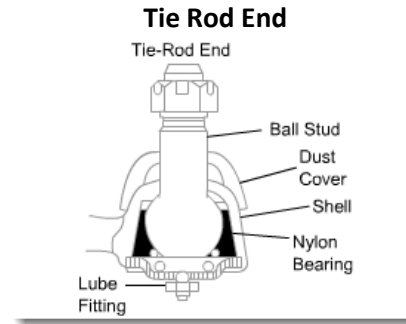
Using a shorter upper arm allows the track width to remain constant at the road surface during spring compression, eliminating the tire slide or scrub that would occur if the arms were of the same length. A conventional steering system is commonly used with this suspension, which may also be referred to as a conventional suspension.

#### **SLA Suspension with Conventional Steering**



### Tie Rod Ends

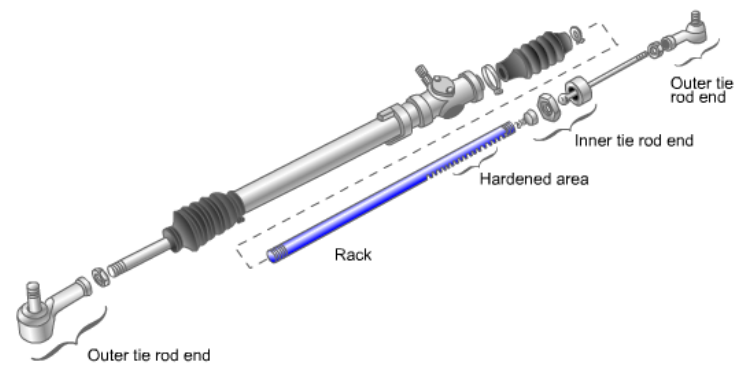
A tie rod end, like a ball joint, is a ball-and-socket joint, and they are similar in internal construction. The shell and bearings hold the ball in the unit. Usually, a spring preloads the ball firmly into the bearings to prevent backlash and looseness, which cause wear and wheel misalignment. The tapered ball stud fits into a tapered hole in a steering knuckle or other component, and when the castellated nut or locknut is tightened, it draws the stud into a tight fit. Inner tie rod ends on rack-and-pinion units are normally threaded onto the end of the rack and locked in some fashion.



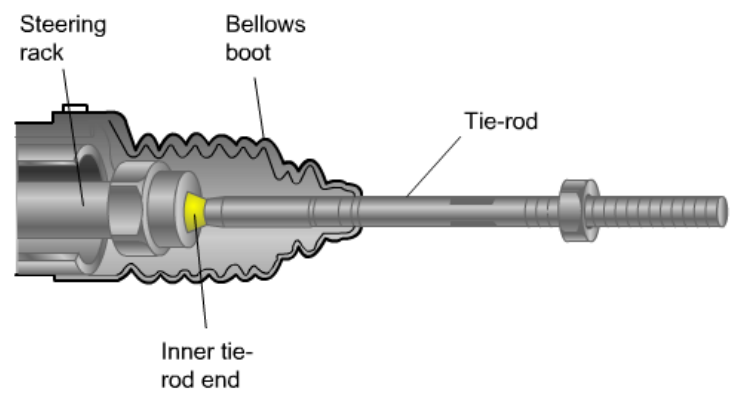
Tire rods may be lubricated and sealed at the factory, or they may have a hole in the shell into which a grease fitting is threaded. A rubber dust cover or boot fits over the opening to the ball stud and protects the socket from dirt and moisture.

The rod portion of a tie rod end is threaded into the tie rod assembly. The threads may be internal (hollow rod), or external, and left- or right-handed, depending on the design and the location in the steering linkage. These threads are much more than just a means of fitting the linkage together – they are used to adjust the length of the tie rod assembly to set **wheel alignment** (toe).

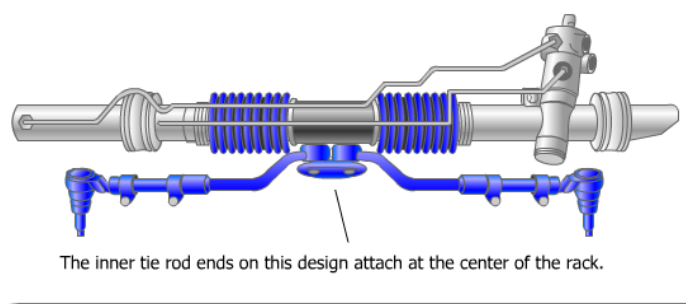
### Inner and Outer Tie Rod Ends on a Rack and Pinion Unit



### Inner Tie Rod End on a Rack and Pinion Unit

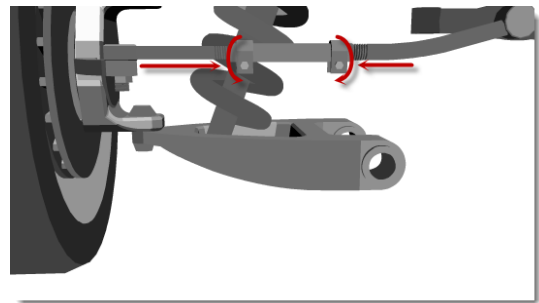


### Inner Tie Rod End on a Rack and Pinion Unit



Tie rod ends on conventional steering systems are usually externally threaded. An inner and outer tie rod end threaded into a **tie rod sleeve** completes the tie rod assembly, one assembly for each side of the vehicle. The tie rod sleeve, or adjusting sleeve, is a turnbuckle that is left-hand threaded on one end and right-hand threaded on the other.

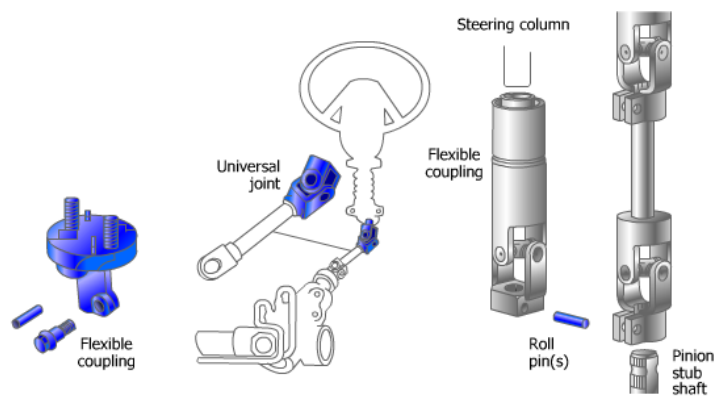
The inner and outer tie rod ends are correspondingly threaded. This allows for the lengthening or shortening of the tie rod assemblies to set the alignment, as we mentioned previously. We will cover this in more depth in the section on alignment; for now, just note that toe is the amount the wheels point inward or outward at the front, relative to each other.



### Steering Column Assembly

The steering column assembly includes the steering wheel, steering column, steering shaft, ignition key mechanism and switch, and often a flexible coupling and universal joint. The steering column also contains turn signal mechanisms and horn controls, and may have a tilt mechanism for driver adjustment, an anti-theft steering lock mechanism, headlight and dimmer switch controls, windshield wiper and washer controls, cruise control, transmission gear selector, and other components.

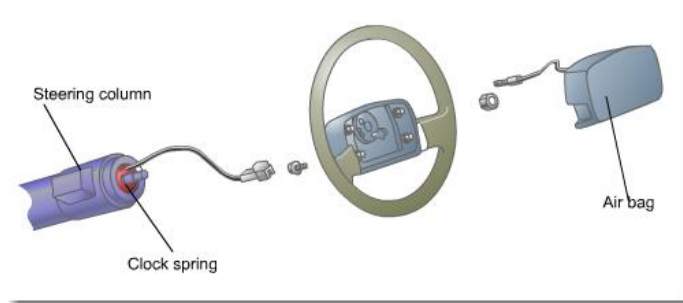
Since the 1970s, steering columns have incorporated collapsible components to enhance driver safety. These columns are designed to crumple or slide together (“telescope”) during the impact from a collision. The column shortens and absorbs force.



Late model vehicles are equipped with an air bag (Supplemental Inflatable Restraint, or SIR) in the steering wheel as part of the Supplemental Restraint System (SRS). Consult the vehicle service manual before attempting to service a steering column. The Vehicle Identification Number (VIN) will indicate if a vehicle is equipped with an SRS. The SRS must be disabled to prevent accidental deployment of the air bag. Procedures for disabling the SRS vary depending on the make and model of the vehicle. The diagnostic module may keep the air bag activated for up to 30 minutes after the battery has been disconnected. Follow the manufacturer's procedure for de-activating the SRS, and take precautions such as securing the negative battery cable where it cannot make contact with the battery, and disconnecting the yellow wiring harness.

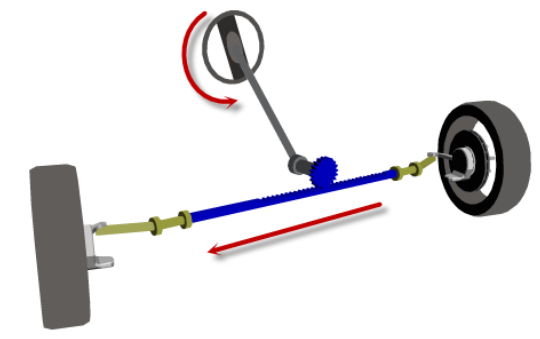
**CAUTION:** Accidental air bag deployment can cause serious injury or death.

After the air bag is removed, a steering wheel puller is needed to remove the steering wheel. As you can see, steering column service can be complicated, so it is critical to consult the vehicle service manual before attempting repairs.

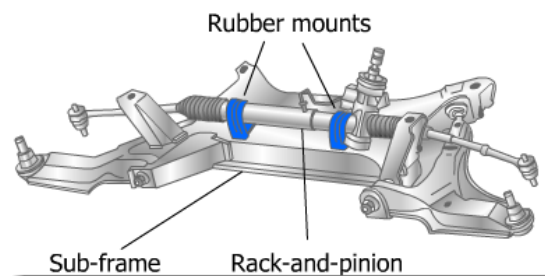


### *Rack-and-Pinion Steering System*

At the heart of the rack-and-pinion system is the steering gear. As noted in the introduction, the pinion transmits rotary motion to the rack, which converts this movement into linear, side-to-side motion. Below, you can see the fundamental operation of a rack-and-pinion.

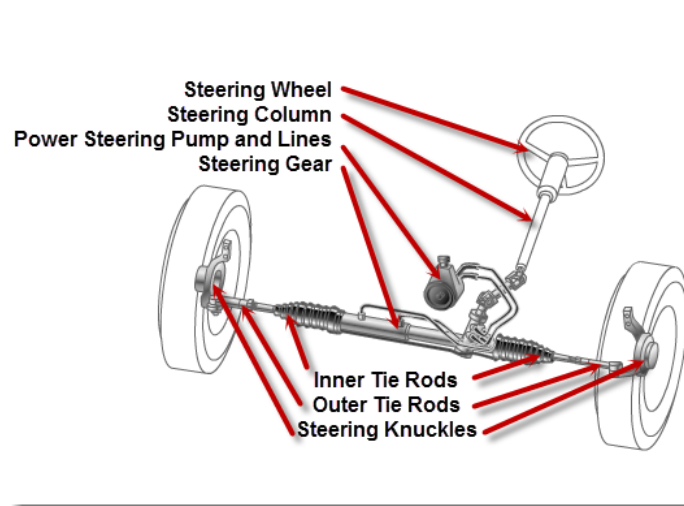


The rack is mounted to the sub-frame (or frame) with rubber bushings to help reduce shock. Inner and outer tie rod assemblies connect the rack to the steering knuckles.



### Rack-and-pinion System Components

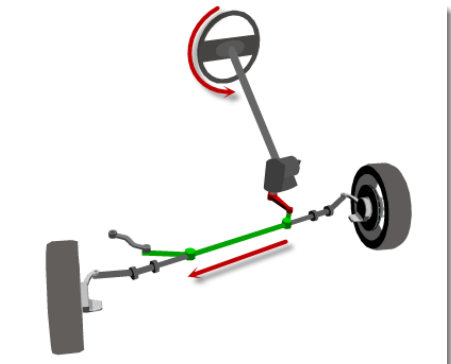
Rack-and-pinion systems can be either manual or power assisted. Power assisted units function similar to manual units, except a double-acting hydraulic power piston is integrated into the rack. A valve on the pinion gear shaft controls fluid flow. A belt-driven pump, similar to one used on a conventional power steering system, provides hydraulic power to the system. Below are the components of a rack-and-pinion system.



### Conventional Steering Systems

Now that you understand rack-and-pinion steering and some of the basic components that are common to both systems, conventional steering systems should not be difficult.

We noted in the introduction that conventional steering systems are also called “parallelogram” or “trapezium” systems for the shape of the linkage set. Below, you can see the fundamental operation of the steering linkage.



### Conventional Steering System Components

Conventional steering systems use a **recirculating ball steering gear** to transmit rotary motion from the steering wheel into linear motion at the steering arm (**pitman arm**). Although this motion is mostly side-to-side, the pitman arm does travel through an arc. The steering gear is bolted to the frame, and the linkage is supported on the other side of the vehicle by an **idler arm**, also bolted to the frame.

The pitman and idler arms are connected to the rest of the steering linkage through a **center link**. Conventional systems can be either manual or power assisted, but most are power assisted on modern vehicles. The power steering control components are normally within the steering gear housing as part of an **integral unit**. Below are the components of a conventional steering system.

**Conventional Steering Gear Box**



**Idler Arm**



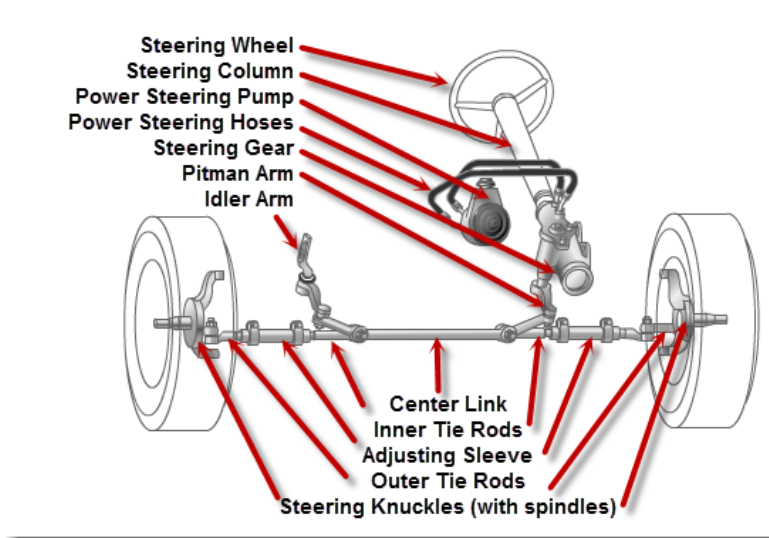
**Tie Rod End**



**Pitman Arm Side View**



**Pitman Arm Top View**

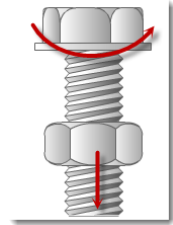




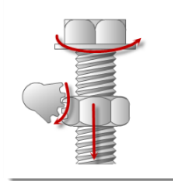
### Recirculating Ball Steering Gear

With a recirculating ball type steering gear, the input shaft (connected to the steering column shaft) is called a **worm shaft**, because at its end is a **worm gear**. You may be familiar with common worm gears that resemble a threaded shaft and provide a lot of gear reduction to the driven member.

Suppose you threaded a nut halfway down a bolt and then held the bolt by its head with the other end against a table. If you turned the bolt head while you held the nut to prevent its turning, the nut would have to walk up or down on the bolt. You would also have to turn the bolt head many times to move the nut up or down only a little. The same principle is used in a conventional steering gear. The worm gear provides gear reduction to reduce steering effort.

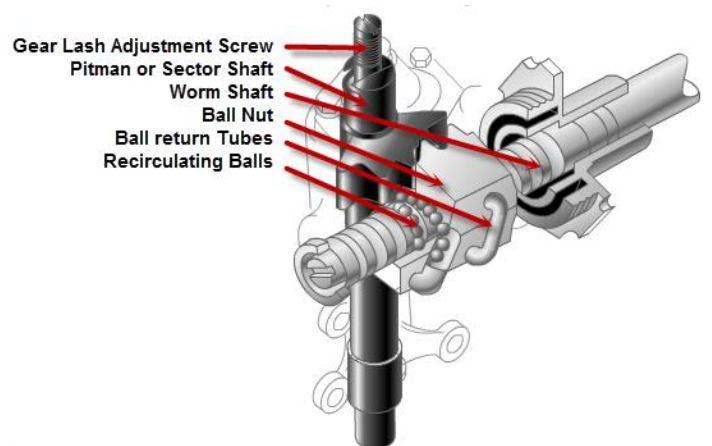


In the case of a steering gear, the nut has several teeth protruding from where one of the flats would be. These teeth run in the same direction as the movement of the nut on the shaft, so they drive another gear in the same direction. The teeth engage with teeth on the **sector gear** (output) which transmits this movement through the **sector shaft** (or **pitman shaft**) to the pitman arm.



In an actual steering gear, the nut the worm gear meshes with is called a **ball nut**. Since the worm shaft cannot move endwise when rotated, the ball nut is forced to move up or down the worm shaft.

Rather than resembling a threaded shaft, like a common worm gear, the steering worm gear has channels that house recirculating steel balls. The ball nut has corresponding channels for the balls to ride in. When the worm shaft is turned, the balls act upon the channels in the ball nut, causing the ball nut to screw up or down on the worm shaft as a rolling thread. The balls rotate and recirculate in their channels, returning through ball return tubes or guides.

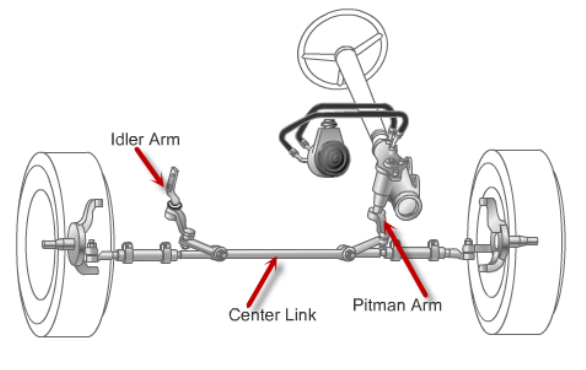


Using recirculating balls creates less friction and provides smoother and easier steering with less wear than would be possible with a common, threaded worm gear arrangement. The gearbox is lubricated with power steering fluid, if so equipped, and gear oil is normally used on manual units.

Note the adjustment screw at the top of the steering gear image above. This is for sector gear lash (clearance) adjustment. Adjustment is not usually necessary in normal service. Refer to the vehicle service manual for specs and adjustment procedure if adjustment is needed. **Insufficient clearance will damage the steering gear.** The cause of looseness in the steering will usually be found elsewhere.

### Conventional Linkage Components

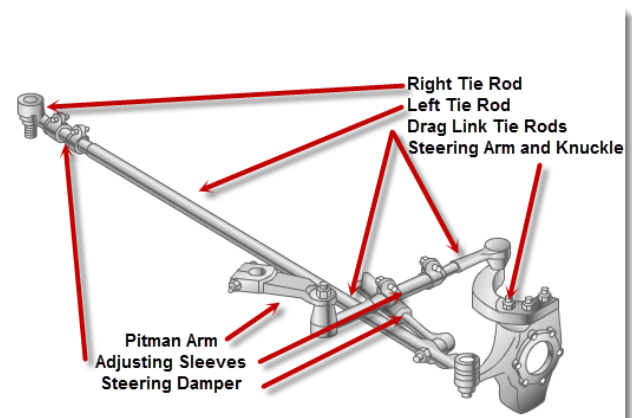
We have previously discussed tie rods in detail. The remaining linkage components that make up the conventional system are the pitman arm, center link, and idler arm.



Other types of linkage systems have been used also. Straight axle trucks and some four-wheel-drive steering linkage designs use one long tie rod assembly that connects to both of the steering knuckles, or variations on this arrangement. **Cross steer linkage** and **Haltenberger linkage** systems may be found on light and medium duty trucks.

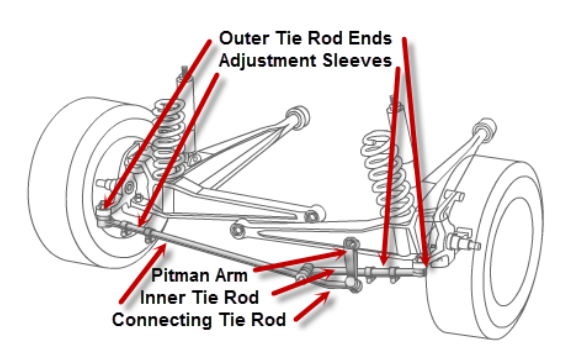
### Cross Steer Linkage

This design has two tie rods and an adjusting sleeve connecting the wheels. The left steering arm is connected to the steering gear with another tie rod assembly, sometimes called a drag link. The adjustment sleeve on this assembly is used to center the steering wheel during a wheel alignment. Note that the pitman arm attaches to the steering gear with a pinch bolt in this application. Many light truck and four-wheel-drive applications use another part shown here, a **steering damper**. Click on the steering damper for details.



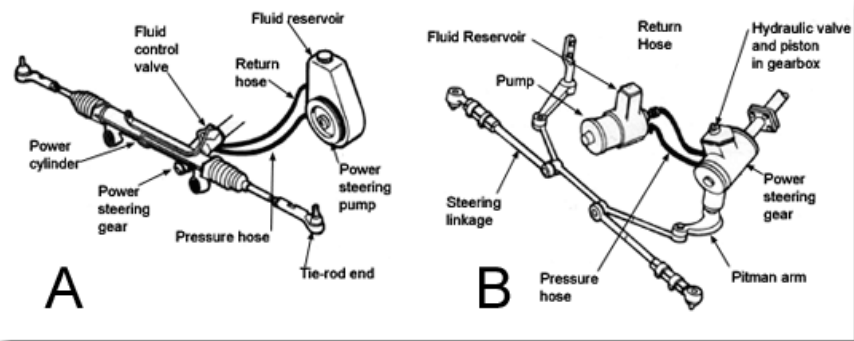
### Haltenberger Linkage

This linkage is used on twin axle four-wheel-drive suspensions and twin I beam suspensions like the one seen here. No idler arm is used; instead, a long right connecting rod is attached to the pitman arm, and the left inner tie rod end is attached to the connecting rod. We will see this suspension again when we get to the suspension section of the course.



### Types of Power Steering

There are two main types of power steering systems: power rack-and-pinion steering, and conventional recirculating ball steering gears with a hydraulic control system built into an integral power steering gearbox.



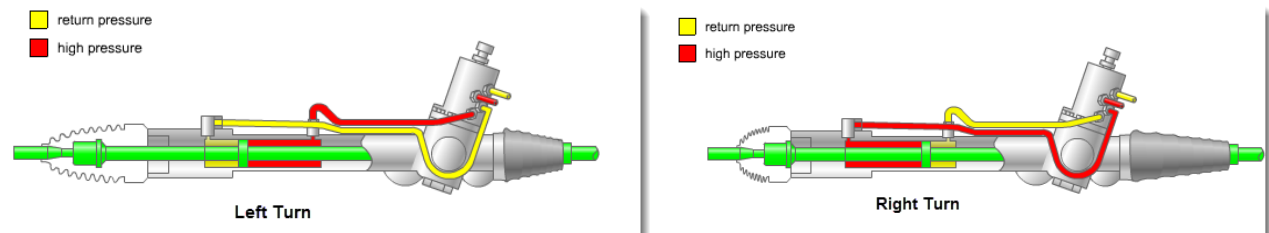
### Power Rack-and-Pinion Steering Systems

Power rack-and-pinion steering systems include the following:

- Power cylinder – a hydraulic cylinder inside the rack or gear housing
- Power piston – a double-acting, hydraulic piston in the power cylinder that acts upon the rack
- Control valve mechanism – located in the steering gear; senses and controls power assist
- Hydraulic lines – steel tubing from the control valve to the power cylinder that carries the power steering fluid

Most power rack-and-pinion units have a small tube that runs along the housing and connects to each bellows boot. This tube allows the air pressure in the bellows boots to equalize from one side to the other during turns.

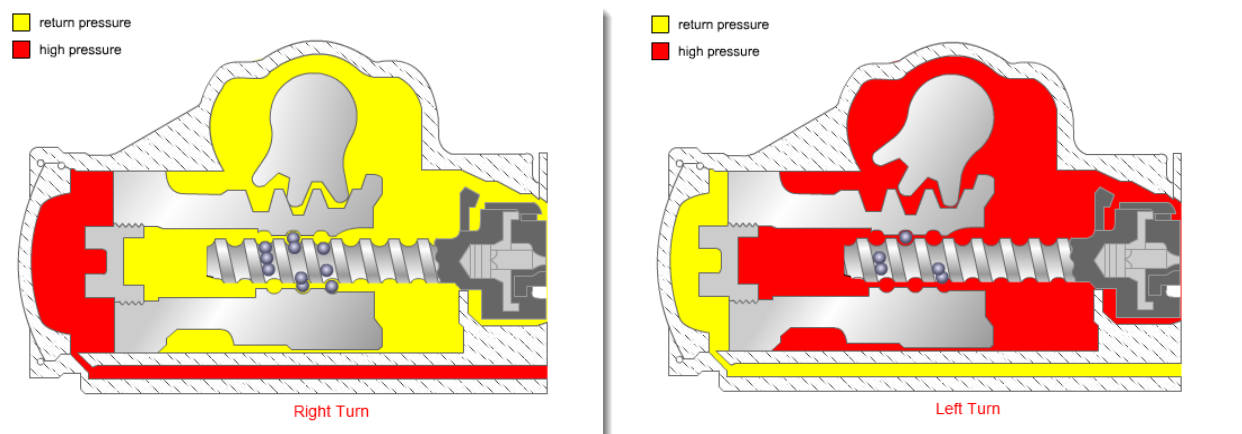
The power cylinder and piston are precisely machined and sealed with rubber O-rings. In operation, fluid is directed to a chamber of the power cylinder on either side of the rack. This fluid creates pressure to move the piston and thus the rack to the left or right. To sense and control assist, two types of control valves are used: either rotary control valves, or a spool control valve. Rotary control valves use a torsion bar attached to the input shaft to make the control valve move, aligning oil passages to the proper chamber. On spool valve units, the spool valve detects the thrust action of the input shaft caused by attempting to turn the steering wheel, and directs fluid to the proper chamber of the power cylinder.



### Integral Power Steering Systems

Integral power steering systems are commonly used with linkage-type steering. The steering gearbox contains a conventional worm-and-sector gear. The hydraulic power piston and directional control valve are mounted inside the gearbox housing. As with power rack-and-pinion units, the valve may be a spool valve or a rotary valve with a torsion bar.

When the steering wheel is in the straight-ahead position, the valve maintains equal pressure on both sides of the power piston. Oil flows back to the pump reservoir. During a turn, the control valve routes oil to one side of the power piston, which pushes it in the desired direction to provide assist. The oil on the non-pressurized side of the piston is forced back through the control valve and to the pump reservoir.



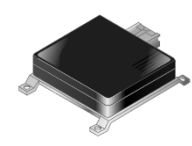
### Steering System Advancements, Innovations, and Variations

As electronic controls on vehicles continue to become more sophisticated, some manufacturers have applied this technology and other innovations in the steering systems of some models. These advancements can improve fuel economy by conserving horsepower, space, and weight, and can also improve maneuverability. In addition, efforts to improve handling and turning radius have resulted in four-wheel steering systems of several types.

### Variable Assist (Speed Sensitive) Power Steering

Efforts to improve fuel economy by conserving horsepower have led to the development of computer-controlled hydraulic and/or electric steering systems. Varying the amount of assist according to vehicle speed helps conserve power while improving road feel at high speed, where less assist is desirable.

With some hydraulic systems, fluid output from the pump is controlled; others control the fluid pressure at the steering gear. Variable assist systems use signals pertaining to vehicle speed, engine RPM, and other parameters from the Vehicle Control Module and/or other modules to determine and control the correct fluid pressure, and thus the amount of power assist provided.

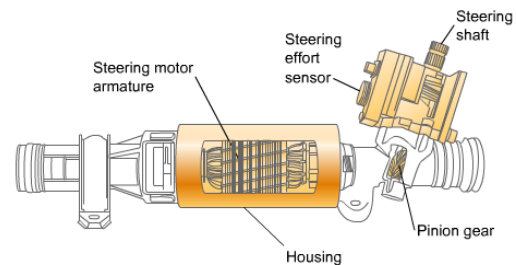


*This variable assist control module is located under the footwell kick panel on the driver's side.*

### Electric Power Steering

Computer-controlled electric power rack steering systems are also being used on some vehicles. These systems use a small electric motor within the housing to assist in moving the rack. Some electrical power rack systems include a recirculating ball steering gear. Computer-controlled electric systems typically use inputs from the antilock brake wheel speed sensors, steering angle and steering effort sensors, and other inputs to provide the proper amount of steering assist.

### **Computer-Controlled Electric Assist Rack-and-Pinion**



### Four-Wheel Steering

Four-wheel steering systems have been in production for several years on a variety of models. There are several different types of four-wheel steering systems. Generally, at low speeds, the rear wheels turn in the opposite direction from the front wheels, reducing the turning radius for tighter turning and easier parking. At high speeds, the rear wheels turn in the same direction as the front wheels, providing for improved handling and stability.

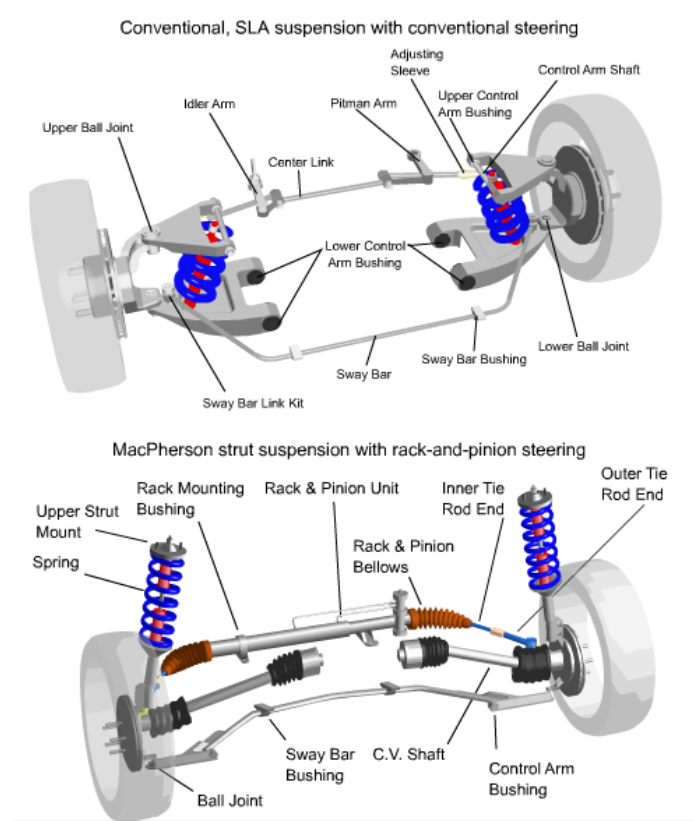
Simple hydraulic systems permit four-wheel steer only at high speeds (over 30 mph) and in the same direction, while electronic four-wheel steering systems can provide sophisticated rear steering using a computer to determine rear steering angles. These systems permit same-direction steering during a gentle turn, and then as the steering wheel is turned more sharply, the rear wheels straighten and then begin to turn in the opposite direction from the front. A steering control module uses inputs from several sensors to determine the correct steering angles. Early, mechanical four-wheel steering systems function similarly, but use a shaft connected from the front gearbox to a rear gearbox through a planetary gearset to achieve the proper rear steering mode.

Rear steering is subtle: same-direction steering is limited to about 1.5° and opposite-direction steering has a maximum of about 6° to 12° depending on the system and vehicle speed. Same-direction rear steering begins to diminish after the steering wheel is turned through 120° and at 240°, the rear wheels are straight. Turning the steering wheel farther causes the rear wheels to begin turning in the opposite direction.

## Chapter 2: Steering and Suspension Systems and Operation

### Suspension System Main Components

In the introduction, we briefly discussed the most common types of suspension systems used on cars and light trucks. In the sections on steering, we discussed ball-and-socket joints and steering linkage components. Now, we'll discuss the rest of the components to complete our picture of steering and suspension systems, and examine the different types of suspensions in greater detail.



### Vehicle and Service Information

An important step before working on a vehicle is to review service information. Identify all fluid types and capacities, note service precautions, and review TSBs related to the vehicle's drive train system. When completing the repair order, ask the owner for the vehicle's service history. The information is useful to safely perform diagnosis procedures and servicing the drive train components.

21st Century cars all have one or more airbags (SRS) to protect their occupants. While these systems do a good job of protecting the people riding in the vehicle, they pose a threat to technicians. A technician must be careful when performing service, as the accidental deployment of an airbag by a technician while performing service in the deployment area has caused serious injuries and even death. Even if the technician is not hurt by the deployment, the cost to repair one or more airbags will be very expensive.

The first step is to identify how many airbags are installed in the vehicle and each bag's location. Next, using service information, locate the procedure to disarm the airbags on the vehicle being serviced. Following the service, carefully perform the steps to safely disarm the airbags. With the airbag system disarmed, carefully perform the vehicle service required. Next perform the service test procedures required to ensure that it is safe to enable the airbags. With the test successfully completed, perform the procedure to enable the air bags.

## Springs

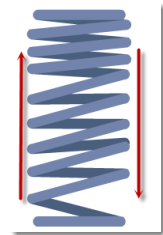
All suspension systems have some type of springs to support the weight of the car and absorb the up and down (jounce and rebound) motion of the wheels, rather than allowing this motion to be transmitted to the frame and body. There are three types of steel springs found on automobiles: **coil springs**, **leaf springs**, and **torsion bars**. Springs can also be made of composite materials. Some vehicles use air springs, which consist of a rubber cylinder pressurized by an electric compressor. Air springs can be effectively used for automatic leveling systems.

The **spring rate** refers to the stiffness, or tension, of a spring, and is based on the amount of weight required to bend it. Spring rate can vary among applications. For example, a vehicle with a towing package may have springs with a higher spring rate than a similar model with standard equipment.

**Sprung weight** is the weight of the vehicle components that are supported by the springs, such as the frame, body, and engine. **Unsprung weight** is the weight of the parts that are not supported by the springs, such as the tires, wheels, wheel bearings, steering knuckles, and axle housing. Vehicle engineers and designers try to minimize unsprung weight to improve ride and handling.

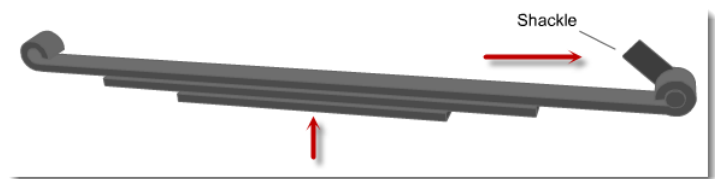
### Coil Springs

Coils springs are very common on suspension systems. A coil spring is simply a rod of spring steel (specially hardened steel) rolled into a coil. Coil springs can be made to have a variable rate by either tapering the width of the rod, or by varying the spacing of the coils. The coils that are of narrower width or closer together are the first to be compressed; the other coils come into play as more load is placed on the spring. Fatigued (weak) coil springs must be replaced with new units.



### Leaf Springs

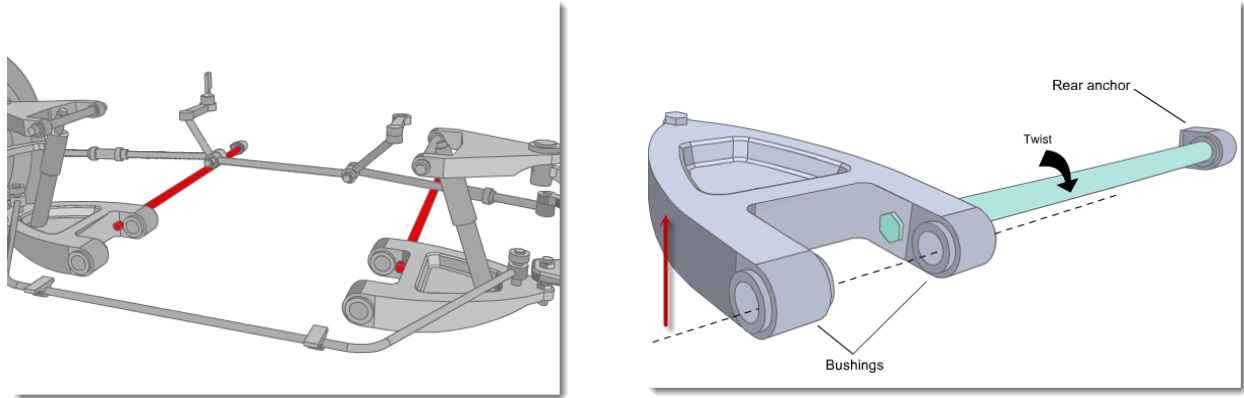
Leaf springs have been used on suspension systems since the horse-and-buggy days. A leaf spring is a long flat strip of spring steel forged into an arch. It is attached to the frame through a shackle assembly that permits changes in the effective length of the spring as it is compressed. To carry heavier loads, additional leaves can be stacked below the master leaf. This also provides a variable spring rate. Some suspensions use transverse leaf springs that are mounted perpendicular to the frame. One spring supports both sides of the suspension. When leaf springs become fatigued, they can be re-arched in a frame shop.



### Torsion Bars

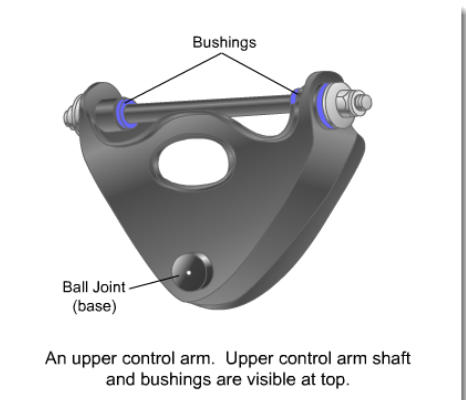
A torsion bar is a long straight rod of spring steel. One end of the bar is attached to the frame, and the other end is attached to the inboard side of the lower control arm. During jounce, the bar twists to absorb the movement of the control arm. During rebound, the bar returns to its normal loaded shape. Often, torsion bars are used because of space considerations. They are found mostly on light trucks and some SUVs. The tension of the torsion bar can be adjusted by turning a bolt or nut near the end of the bar, which allows the vehicle height to be restored without replacing the springs. Adjustments to torsion bars will affect alignment angles.

### Torsion Bar Suspension



### Control Arms

Control arms provide up-and-down pivot points for the suspension. The outer end of a control arm contains a ball joint that attaches to the steering knuckle; the inboard end contains a rubber bushing or bushings. A bolt or shaft through the eye of the bushing connects the arm to the frame.

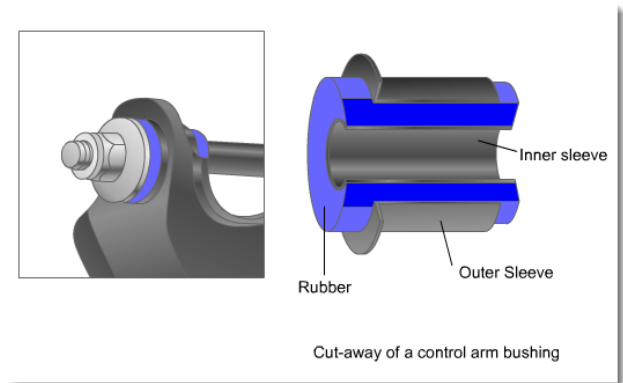


### Bushings

Bushings are common in suspension systems. Rubber bushings are used to separate parts while permitting the movement necessary for the suspension to function. Rubber cushions the parts and reduces vibration and noise to the body.



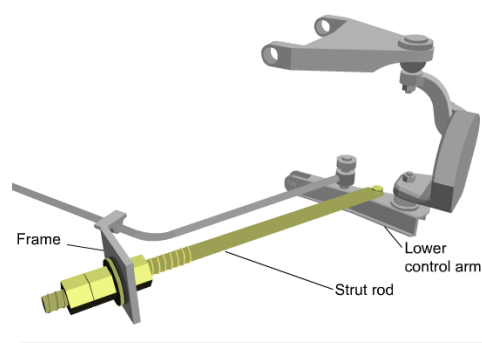
Control arm bushings have a metal inner and outer sleeve with rubber in between. The bushing is usually pressed into a hole in the control arm. The outer sleeve moves with the control arm, while the inner sleeve remains stationary with the frame. The rubber twists to allow the arm to move up and down. Bushings can also be found on strut rods, sway bars, shock absorbers, MacPherson strut upper mounts, leaf spring eyes and shackles, and other components.



### Strut Rods

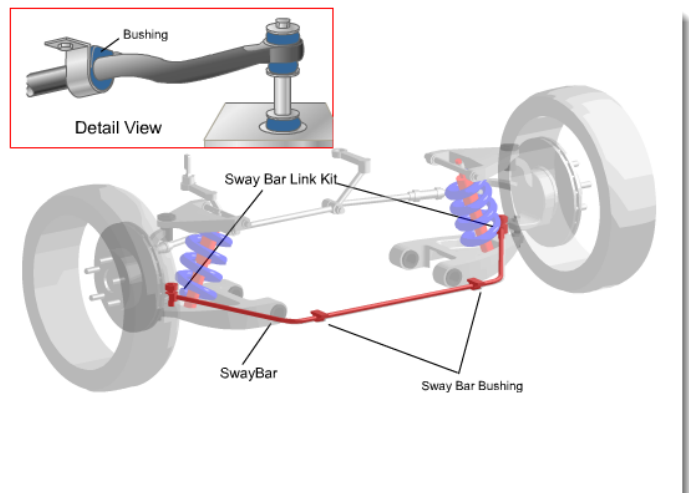
On suspension systems that use a lightweight lower control arm with a single anchor point at the frame, a strut rod is used to provide stability. The strut rod is rigidly bolted to the outer end of the control arm, and attached to the front of the frame through a bushing or a pair of bushings. A nut or nuts threaded onto the rod holds the rod in place. The strut rod prevents the control arm from moving fore and aft. Some strut rods are adjustable and others are not.

### Strut Rod Suspension



### Sway Bar (Stabilizer Bar)

A spring steel sway bar, or anti-roll bar, can be found on the front or rear of many suspension systems. The front sway bar connects to both of the lower control arms, usually through **sway bar links**, each link having a set of four bushings. It is secured to the frame with brackets and one-piece bushings. The bar prevents excessive body lean, or roll, by resisting the centrifugal forces that tend to make the inside of the body rise and the outside of the body drop during cornering. The resistance is provided through a twisting action of the bar.



*The sway bar reduces body roll in turns.*

### Shock Absorbers

The job of shock absorbers is to dampen spring oscillations (repetitive compression and extension cycles). Without shock absorbers, a vehicle would continue to bounce up and down long after striking an irregularity in the road. Shock absorber action helps maintain proper contact between the tires and the road; it reduces body roll when cornering, and dipping of the front end when braking. One end of the shock absorber is attached to the suspension and the other end is attached to the frame or body.



A shock absorber, or shock, is a hydraulic device. Fundamentally, the shock consists of oil-filled chambers in a cylinder with a piston attached to a rod. The piston has calibrated orifices with valves to control the rate of oil flow from one chamber to another, and thus the rate of piston movement within the cylinder. The shock absorber uses resistance to the movement of the oil to dampen spring action. Though the principle is simple, modern shocks have an extensive system of valving and oil control strategies, and there are many different designs and types of shock absorbers.

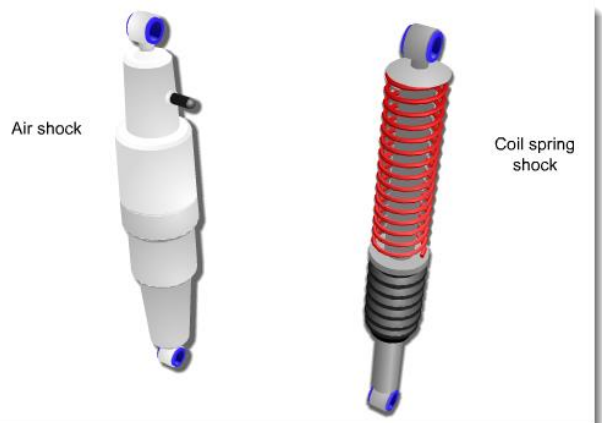
A shock absorber's resistance is sensitive to piston velocity. The faster the piston is forced through the oil, the greater the resistance to its movement. While shocks control both up and down movement, the resistance during compression is designed to be generally much lower than the resistance during rebound.

Many shock absorbers are **gas charged**. These oil filled shocks also contain a pressurized gas to prevent aeration of the oil on rough roads. If air bubbles form around the piston, the shock's performance is reduced. Placing the oil under pressure keeps the air that is naturally bound up in the oil in solution. Shocks that are not gas charged may suffer from foaming under severe conditions.

### Shock Absorbers



There are aftermarket devices that use the shock absorbers as a means to increase load carrying capacity or adjust the height of a vehicle. **Air shocks** use a rubber bladder in the shock to distribute some of the vehicle load to the shock mounts. The shocks are charged with air from a compressor. **Coil spring shocks** have a small coil spring mounted around a conventional shock. A disadvantage of these systems is that the shock mounts are not designed to carry the vehicle's weight. Putting too much stress on the shock mounts may cause them to break.



## Ball Joints

**Ball Joint Top View**

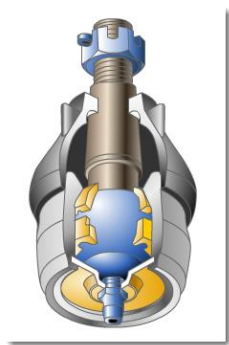


**Ball Joint Bottom View**



Depending on the suspension design, a ball joint can function in one of two ways: either as a load carrier, or as a follower ball joint. On suspensions with two control arms (SLA), the ball joint in the control arm that has the spring mounted on it is the load carrier. This is most often the lower ball joint. On MacPherson strut suspensions, the ball joint is a follower. The load is carried by the body through a bearing at the upper strut mount. Follower ball joints provide the necessary pivot points and keep parts in their proper position. Whether a ball joint is a load carrier or a follower is an important distinction, because it will determine where to jack the suspension properly for inspection. In addition, the testing methods and specs can be quite different. We will return to this in the section on suspension service.

**Ball Joint Cutaway**

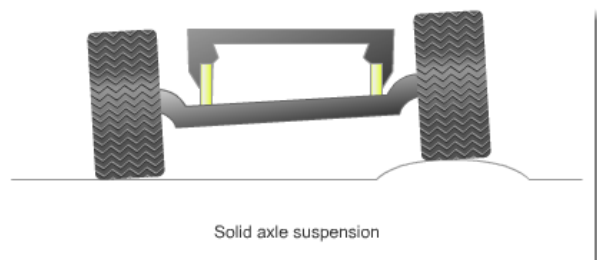
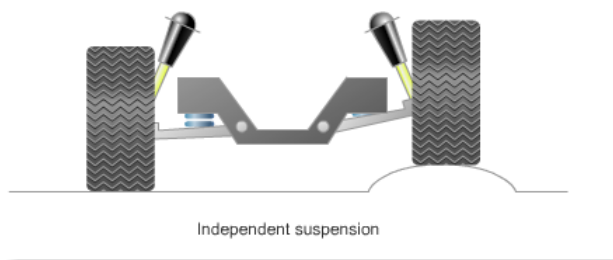


## Suspension Systems

### Independent and Non-Independent Suspensions

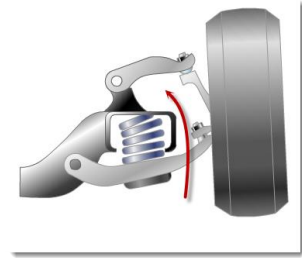
Suspension systems can be either independent or non-independent. On an independent suspension, one wheel can move up and down with minimal effect on the other wheels. On non-independent suspensions, the deflection of the suspension at one wheel affects the other wheel. This can reduce handling and ride quality. Independent suspension is desirable and widely used on modern vehicles, though some still use a non-independent rear suspension.

MacPherson strut and SLA suspensions are independent. A non-independent suspension has a **solid** or **straight axle**. Straight axles are strong and can carry heavy loads. For this reason, they are used on the rear of many light trucks and SUVs. Some four-wheel-drive vehicles have a solid front axle housing, and some medium-duty trucks have a straight front axle called an **I-beam**. I-beams are often connected to the steering knuckles using steel pins similar to a hinge, called **king pins**.



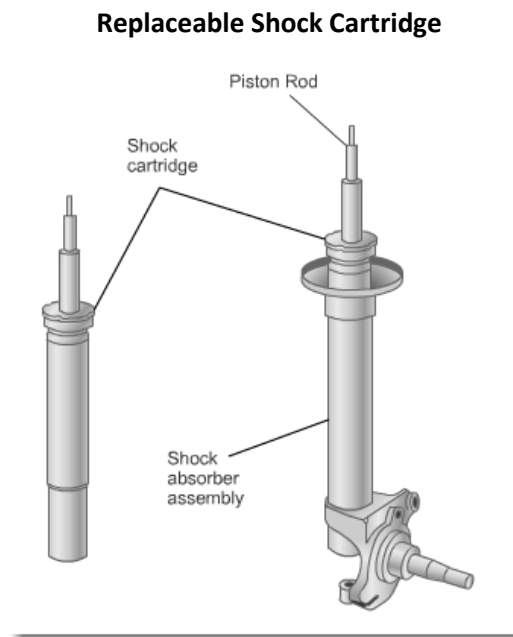
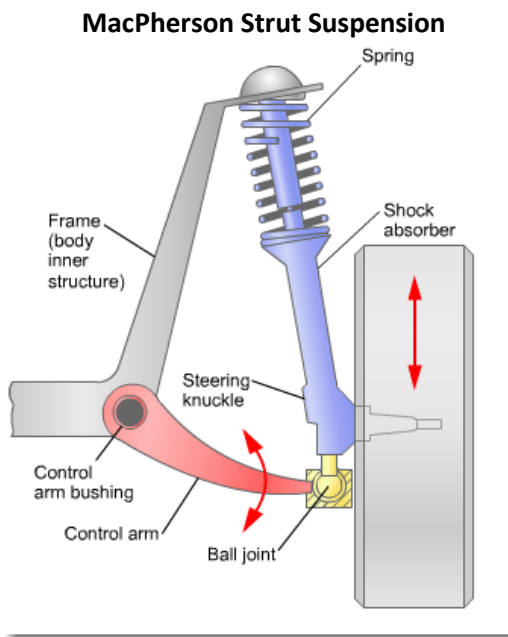
### Short/Long Arm (SLA) Suspension Design

Early independent front suspensions used two control arms of equal length. This caused the bottom of the wheel to move in and out as the suspension jounced and rebounded, resulting in tire scuffing and wear. The SLA design reduced this problem and provided better ride quality and improved directional stability. The shorter upper arm allows the track width to remain nearly constant at the road surface.



### MacPherson Strut Suspension

We have noted that the MacPherson strut suspension combines a coil spring and a shock absorber into a single unit. The shock absorber can often be replaced with a new cartridge when it wears out. This is the most common front suspension on passenger cars.

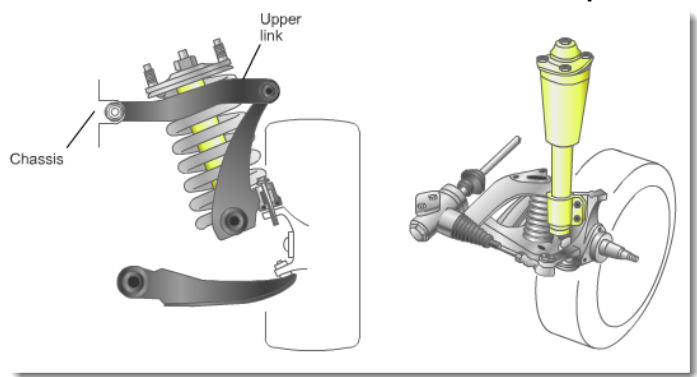


### Other Suspension Types

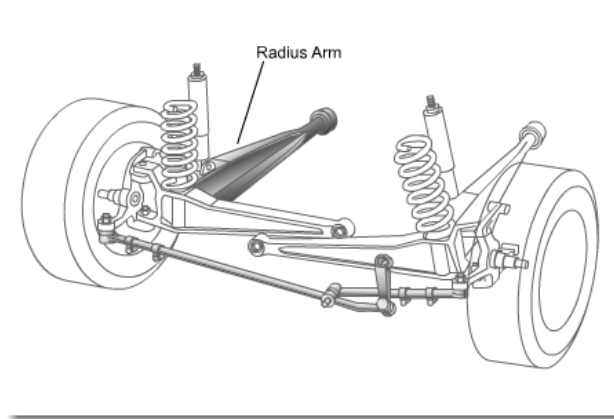
There are many suspension variations.

**Multi-link** suspensions are a variation on the MacPherson strut type, and are popular on both front and rear of smaller, performance-oriented cars. This design uses a small upper arm, or link, attached to the chassis to add stability. Another MacPherson strut variation is the **modified MacPherson strut**, which has the coil spring mounted on the lower control arm. This arrangement has been used on front and rear independent suspensions.

### **Multi-Link and Modified MacPherson Strut Suspensions**



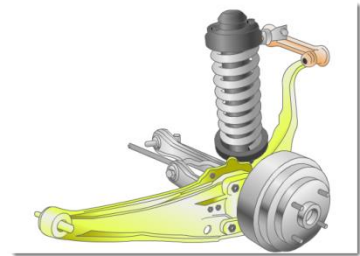
A twin axle, or **twin I-beam** front suspension was very popular on some lines of light trucks from 1965 until 1996, and many are still in service. This suspension is still used on some commercial and medium duty lines. On this suspension, each I-beam is attached to the frame on the opposite side from the wheel. A **radius arm**, similar to a strut rod, is attached to the outer end of each I-beam and extends rearward where it is attached to the frame through bushings.



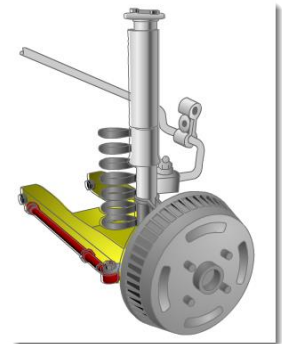
### Rear Suspensions

There are numerous rear suspension designs, many of which are variations on the SLA, MacPherson strut, multi-link, or modified strut designs. On light trucks, a solid axle with leaf springs is common. Some front-wheel-drive rear suspensions use a track bar or track rod to prevent lateral or side-to-side movement of the rear axle.

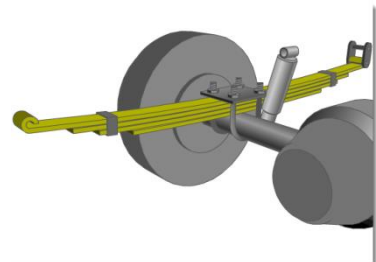
Multi-link rear suspension. This design has two lower control arms.



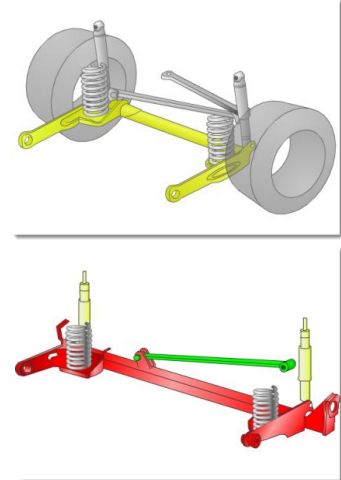
Modified MacPherson strut rear suspension. Note the tie rod end bolted to the control arm, used to adjust rear toe.



Solid axle rear suspension with leaf springs.



Solid axle “trailing arm” rear suspension for a front-wheel-drive model. Note the track bar directly above the axle.



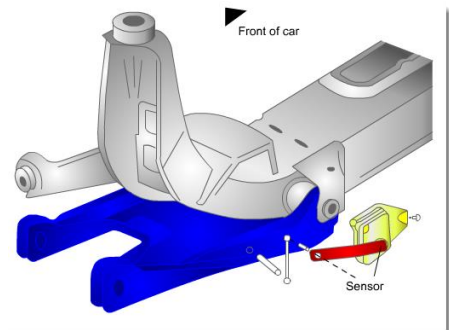
### **Other Suspension-Related Systems**

#### Suspension Leveling Systems

Some vehicles have the capability to adjust their suspensions to maintain the proper attitude (ride height) of the vehicle regardless of how they are loaded. They use air shocks or air springs and an onboard compressor to adjust the suspension’s height and rate.

Early leveling systems were operated with a manual switch. Later systems are automatic and rely on height sensors to determine the vehicle’s attitude. The compressor is switched on, or air is bled out accordingly. System designs and operations vary.

*A height sensor mounted on the frame. The actuating arm moves up or down with the suspension, varying a voltage signal at the electrical connection.*



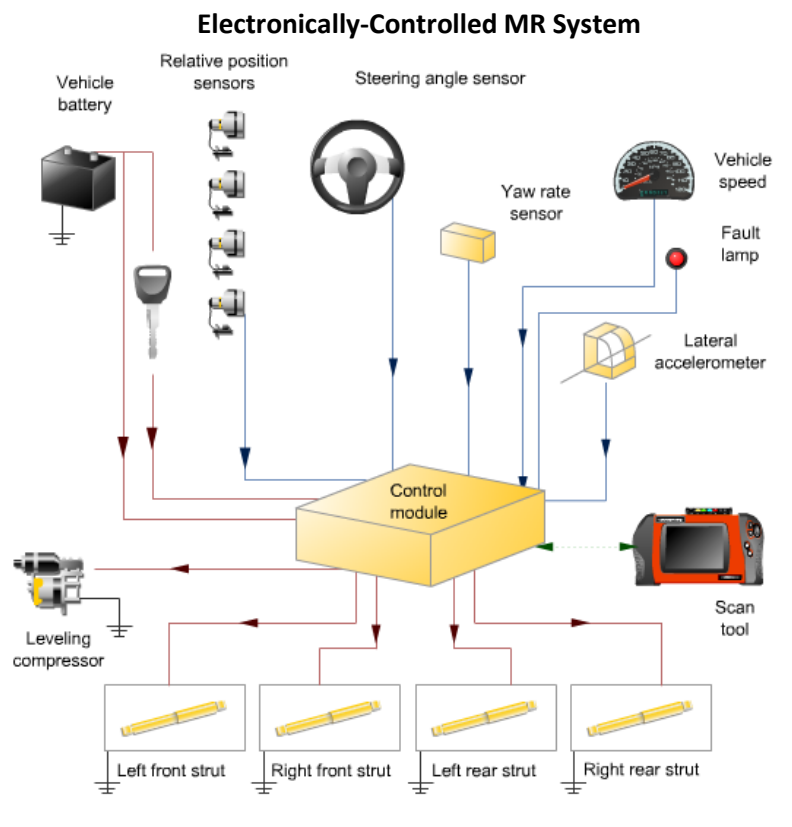
#### Electronically Controlled Suspension Systems

The increase in computer controls has brought many advancements and a high level of sophistication to modern automotive systems, and suspension systems are no exception. Suspensions are being produced that can change vehicle loading and ride characteristics very quickly, either automatically or on demand. These systems vary a great deal among manufacturers and model lines.

Some luxury or high performance models have electronically controlled shock absorbers. These systems vary the shock valving according to vehicle conditions, as determined by a control module with inputs from a variety of sensors. The control module activates motors or solenoids that change the size of the valve orifices. The module may use inputs from numerous sensors, including:

- Height sensors located on the frame near the wheels
- Vehicle speed sensor
- Steering sensor – detects steering wheel rotational angle and speed
- Brake and door sensors
- Throttle position sensor

One type of electronically controlled shock absorber system uses a magneto-rheological fluid (MR) in the shocks, instead of changing the valving. This fluid is a synthetic oil that contains suspended iron particles. The shocks or struts contain a winding that, when energized, acts upon the particles, giving the fluid a thicker consistency for more damping action. The damping characteristics can be changed variably and instantaneously.



### Active Suspension Systems

A few luxury and performance vehicles have active suspension systems. This type of system uses hydraulic cylinders (rams) in place of conventional springs and shock absorbers. The height and ride characteristics are actively computer controlled. Sensors on each ram send signals to the computer, which can extend or retract the rams by varying the fluid pressure. Other sensor inputs may also be used. Pressure is provided by a hydraulic pump driven by the engine. The system can react within milliseconds to changes in driving conditions, such as hard braking or cornering, bumps and dips.

When a wheel encounters a bump, sensors signal the computer, which immediately releases pressure from a control valve. It can release pressure instantly or more slowly, depending on the road surface. When the bump is passed, the computer increases the pressure in the ram, so the tire follows the surface of the road.

### Active Suspension



## Unit 2: STEERING AND SUSPENSION SERVICE

### Chapter 1: Steering System Service

In this section, we will discuss service of the steering system components related to power steering, steering gears, and other parts of the system. We will address linkage and ball-and-socket components in another section, when we discuss suspension systems in depth. These parts (ball joints, tie rods, idler arms, etc.) are normally checked during a complete suspension and steering inspection, prior to a wheel alignment or for chassis troubleshooting, and so we will deal with them together at that time.

All of the steering and suspension system parts must be checked for looseness and wear, not only to ensure safety and proper handling, but also to confirm that the vehicle is capable of holding wheel alignment settings within specifications. This check is commonly performed on a drive-on alignment rack, where the vehicle can easily be raised and properly lifted to unload the suspension with a hoist-mounted jack.

### Drive-On Suspension and Alignment Rack



### Common Steering System Problems

The steering system components from the steering wheel to the output of the steering gear are generally reliable, with a few exceptions. Flex couplings to the steering shaft can fail (causing excessive free play) and power steering fluid circuits in some rack-and-pinion units are failure-prone (causing intermittent or uneven assist). Some common overall steering and suspension system problems include hard steering, noise, abnormal tire wear or vehicle handling, leaks (power steering), and excessive free play in the steering wheel for a variety of reasons.

### Hard Steering

Hard steering can be caused by a number of conditions. Some simple causes of hard steering are low tire pressure, low power steering fluid level, or a loose power steering belt. Incorrect wheel alignment, binding of the steering linkage or MacPherson strut upper mounts, or steering gear problems also can cause hard steering. Listen for noise while confirming a hard steering complaint, and begin with a check of the simple causes. Check the belt condition and fluid level. If the fluid level is low, inspect the system for leaks. If the problem persists, perform a complete steering and suspension inspection.



### Noise

There are several types of noises associated with steering system problems. Loose parts or dry ball sockets can cause a clunk or a pop when turning or going over bumps.

Noises may also be produced in the power steering system. If the fluid level is low, the pump may whine or "groan" when the wheel is turned, especially when turned all the way to the end of its travel against a stop. However, some noise is normal when the wheel is turned to a stop in this manner, as the excess fluid pressure is bypassed. This normal noise may be described as a hissing or whirring sound. A loose or worn out power steering belt can cause a loud squealing noise, especially when turning hard or against a stop. This may be accompanied by a jerky feel in the steering wheel. The belt condition and tension should be checked and adjusted if needed, to prevent glazing of the belt or damage to the pulley.

Other noises in steering system related parts may be caused by bad or dry wheel bearings. Front wheel bearings on rear-wheel drive vehicles may squeak or roar (bad rear wheel bearings on these vehicles may growl). On front-wheel drive cars, **constant velocity joints** (CV joints) on CV shafts or "half-shafts" may clunk or shudder. A bad CV joint will often make a telltale, rapid clicking sound when backing in reverse with the wheels turned sharply. Look for damaged or torn rubber CV boots on the CV joints, and grease leakage in the area. Many CV joints can be replaced; however, it may be more practical to replace the CV shaft. The replacement shaft will come assembled with two new joints and boots, ready to install. Compare the costs for the application - when you consider the labor to rebuild a CV joint, it may make more sense to replace the shaft.

### Abnormal Tire Wear or Vehicle Handling

Steering and suspension problems can cause rapid, abnormal tire wear and/or handling problems. Tires may wear unevenly or have a scalloped wear pattern. A wheel alignment may correct the problem. How to read wear patterns will be discussed in the section on wheel alignment.

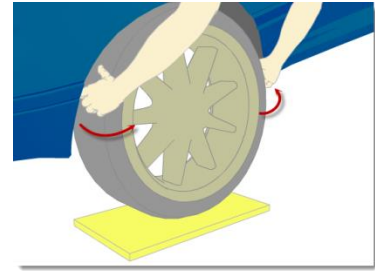
### Excessive Free Play

Too much free travel in the steering wheel can have several causes. Common causes of free play include worn ball joints, center link, idler arm, tie rod ends, and steering column flexible couplings. A worn or misadjusted steering gear also may cause excessive free play. These parts are checked during a complete suspension and steering inspection before a wheel alignment, but some of them can be effectively checked in a "**dry parkcheck**" with the weight of the vehicle on the wheels.

The dry park check will reveal obvious movement in the steering linkage and associated parts, but will not usually show movement in ball joints, control arm bushings, and other suspension parts. These parts must be checked with the suspension properly unloaded. However, a variation on this check is the most effective way to discover excessive movement in the inner tie rod ends on rack-and-pinion systems.

The best place to perform a dry park check is on an alignment rack, but it is possible to do it on the ground. To perform the check, have an assistant turn the steering wheel a small amount from side to side while you inspect the junction and pivot points of each steering and suspension component. Look closely for any independent movement. For inner and outer tie rod ends and center links, there should be no perceptible movement. We will return to this topic to discuss idler arms and ball joints later. For power steering-equipped vehicles, the engine must be running. A similar check can be performed with the vehicle lifted and the wheels hanging free. Have an assistant work the steering back and forth a small amount while you inspect the parts.

Inner tie rod ends on rack-and-pinion systems can be checked on an alignment rack before jacking the vehicle to unload the suspension. With the full weight of the vehicle on the wheels, remove the locking pins from the turn plates on the alignment rack. With the steering unlocked, grasp the front and rear of the tire and try to move it back and forth, as if it were being steered. Looseness in the inner tie rod end will be easy to feel before the rack begins to move. It takes much more effort to move the rack. You will be able to see the change in toe that the looseness causes. You can have an assistant confirm that the other wheel is not moving and that the movement is not in the outer tie rod end or wheel bearing.



### Power Steering Fluid Leaks

Leaks in the power steering system are a common problem. The system operates under high pressures, and rubber hoses can deteriorate, fittings may leak, and seals can fail. Procedures and diagnostic charts for checking leaks, suitable for printing, appear at the end of this section with the job sheet links.

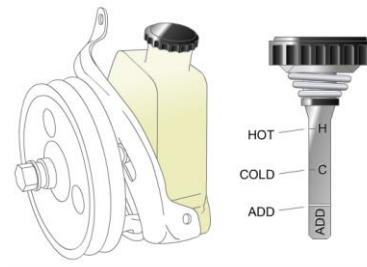
Look for “PD3. Diagnosing Power Steering Fluid Leaks” on the Steering Job Sheets page.

### Common Steering System Services

#### Fluid Level

Some power steering systems have a see-through reservoir with markings for the proper levels. Others may have a dipstick, often made as part of the reservoir cap.

*A power steering pump with the dipstick on the cap. Note that the slide bracket for belt tension adjustment is behind the pulley on this model.*



Levels are usually given for hot and cold, as the level will rise when hot. Be careful not to overfill the reservoir. Procedures for lubricant and fluid levels, suitable for printing, appear at the end of this section with the job sheet links. Look for “PD2. Manual and Power Steering Fluid Levels” on the Steering Job Sheets page.

### Lubrication

One of the most basic steering and suspension services is lubrication of the ball-and-socket joints and steering linkage, if these parts are not of the permanently sealed type. Often performed as part of a complete chassis lube, this important service should receive the attention it is due. It is extremely important to **wipe all grease and road grime away from the grease fittings (zerks)** prior to attaching the grease gun, and to wipe the tip of the grease gun. This prevents grit from being injected into the joint or damaging the one-way valve in the grease fitting.



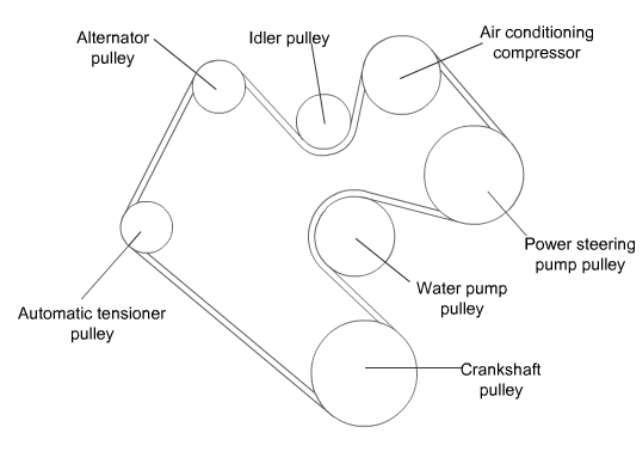
*Grease fittings, or zerks, contain a one-way valve with a spring and a check ball.*

Some joints have a grease relief port designed into the base of the protective rubber dust boot. Grease will begin to escape from the relief port when the joint is full. Many others do not have such a port. On these joints, the rubber boot will swell slightly when sufficiently greased. **Do not over-grease these joints, as this will rupture the boot and cause premature part failure.**

When lubricating the suspension, a film of grease should be applied to the steering stops on the steering knuckles and control arms. Chassis lubrication during maintenance also includes lubrication of other wear points. Check the vehicle service information to locate all of the lubrication points and proper lubricants.

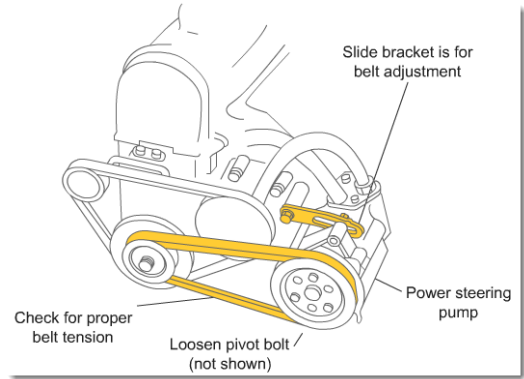
### Belt Tension Adjustment

The power steering belt should be checked for glazing (hard, shiny inner surface), cracking, fraying and proper alignment. The tension should be checked with a belt tension gauge and compared to specifications. Many serpentine belts use an automatic belt tensioner and do not require adjustment. V-belts and applications that do require adjustment may use either a screw-type adjustment or prying to set the proper tension. Excessive tension can damage the pump bearings.



*Serpentine Belt Routing Diagram – note the location of the automatic belt tensioner.*

On applications with a screw-type adjustment, make sure you have loosened all the required pivot and bracket fasteners to avoid stripping or bending the adjuster mechanism. If the tension is set by prying, loosen the fasteners, pry to the proper tension, and then tighten the slide bracket bolt. Use care when prying; do not pry against the reservoir or the side of the pump. Look for a 3/8ths or 1/2 inch square hole on the housing or a bracket. This hole is designed for a pull handle to be inserted for safe and easier prying.

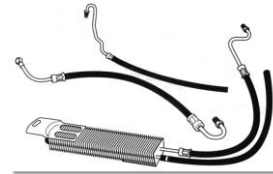


*This V-belt application requires prying to adjust belt tension.*

### Power Steering Hoses

Standard power steering systems have two hoses: a pressure hose and a return hose. The hoses are designed to be tough, since they are exposed to high pressure and temperature, but they may leak or fail. Check for leakage at the connections and the joints where the metal pipes are crimped to the rubber hoses. Look for swelling, abrasions, cracks, and feel for soft or spongy places that indicate internal deterioration.

When replacing hoses, also replace any O-rings, and torque the hose fittings to factory specs. Flush, refill, and bleed the system.



*Power Steering Hoses - note the oil cooler on the lower assembly.*

### Power Steering Pressure Test

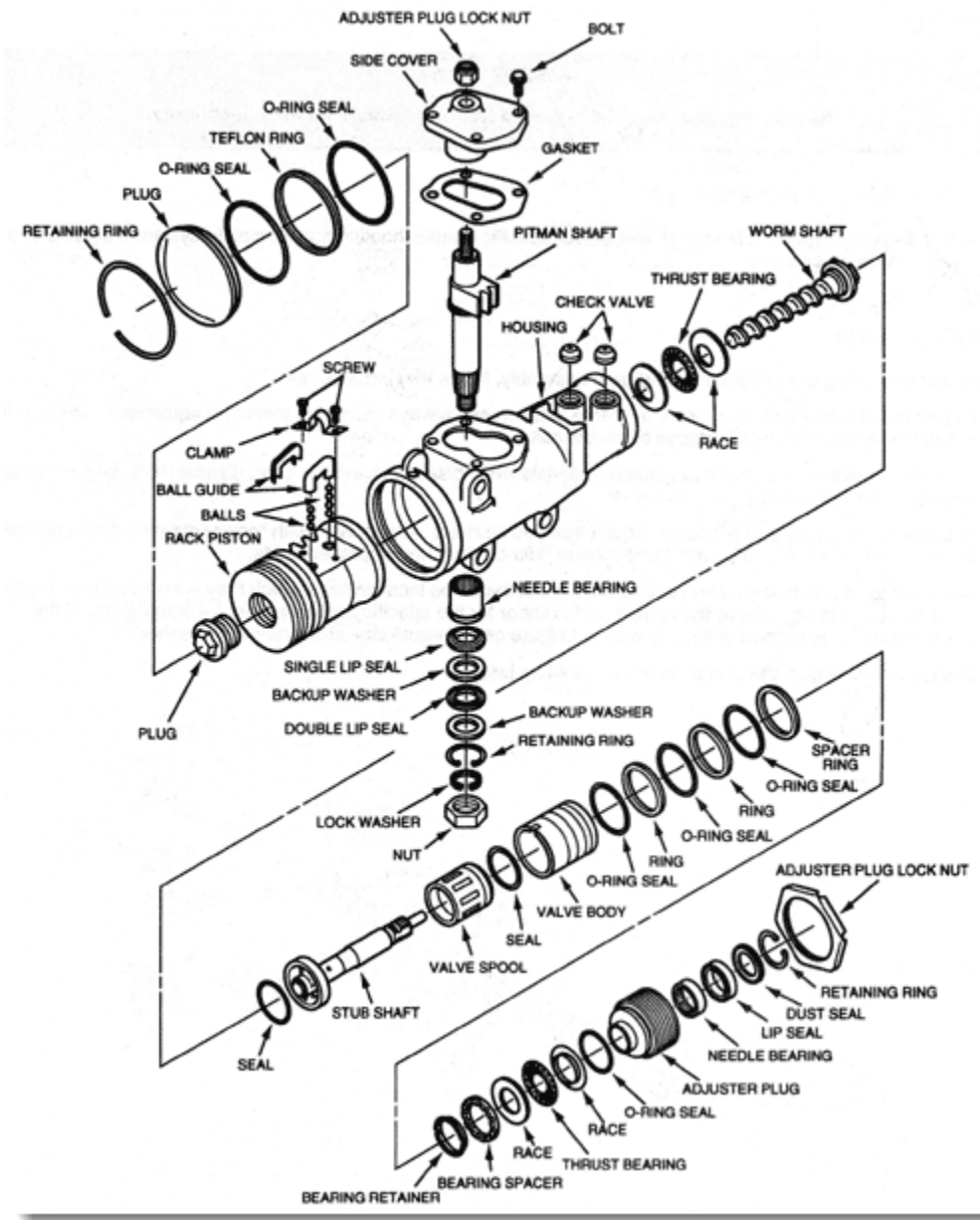
In some cases, it may be necessary to perform a power steering pressure test. This test checks the operation of the power steering pump, pressure relief valve, control valve, power piston, and hoses. A pressure gauge and shutoff valve is installed in line with the pressure hose for testing. Refer to the vehicle service manual for the procedure and specifications.

### Steering Gear Service

Earlier, we discussed that most steering gears, whether conventional or rack-and-pinion, provide an adjustment for gear lash or pinion tension, and that an adjustment was not normally required during the life of the vehicle. **These adjustments must be made with caution to avoid damage to the steering gear.** Refer to the vehicle service manual for specs and adjustment procedures if adjustment is needed.

**Conventional steering gears** will normally last the life of the vehicle. It is possible to rebuild both manual and power steering conventional gears; however, it may not be cost-effective. Refer to the vehicle service information for available kits and parts (seals, bushings, bearings, power valves, etc.), and the setup procedures and adjustments, and compare the cost of the parts and labor to that of a new or used unit.

### Integral Steering Gear



## *Rack-and-Pinion Service*

### Rack-And-Pinion Steering Assembly Inspection

#### Outer Tie Rod Ends

To inspect rack-and-pinion steering assembly outer tie rods ends, start by lifting the vehicle so that there is no weight on the wheels.

1. Use proper lifting equipment to raise the vehicle.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

2. Inspect the tie-rod assembly for wear or damage. Using your hands to move the each tie rod up and down, check for play in the ball sockets. Have an assistant turn the steering wheel lock to lock and check for play and alignment of the rod ball sockets. Inspect each ball socket boot for damage. Inspect the tie rod adjustment sleeves for corrosion, wear, or damage. Inspect tie rod adjustment sleeve clamps and bolts for corrosion, wear, or damage. Check the tie rod alignment (check for a bent tie rod).

#### Inner Tie Rod Sockets

Inner rack and pinion tie-rod sockets can be difficult to check because they are concealed inside either rubber or plastic boots. If the inner tie rod boot is soft and can be squeezed to the point where the technician can feel the inner tie rod end it will be possible to perform a quick test using the following steps:

1. Using proper lifting equipment raise the vehicle so that there is no weight on the vehicle's wheels and tires and the technician has access to the inner tie rod.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

2. While squeezing the boot, have an assistant turn the steering wheel back and forth one-quarter of a turn.
3. Have the assistant push and pull on the tires and turn them in and out one-quarter of a turn. If the tie-rod feels loose, replace it.

#### Boots

Some inner tie-rod boots are made of a hard plastic, which is impossible to squeeze. To inspect hard plastic rod boots, perform the following steps:

- Lock the steering wheel and use proper lifting equipment to raise the vehicle.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

- Remove the inner tie-rod boot clamps and slide the boot back to expose the rod.
- Turn the steering wheel back and forth while the wheels rest on the ground. Watch the sockets for movement. If movement is detected, replace the rod.

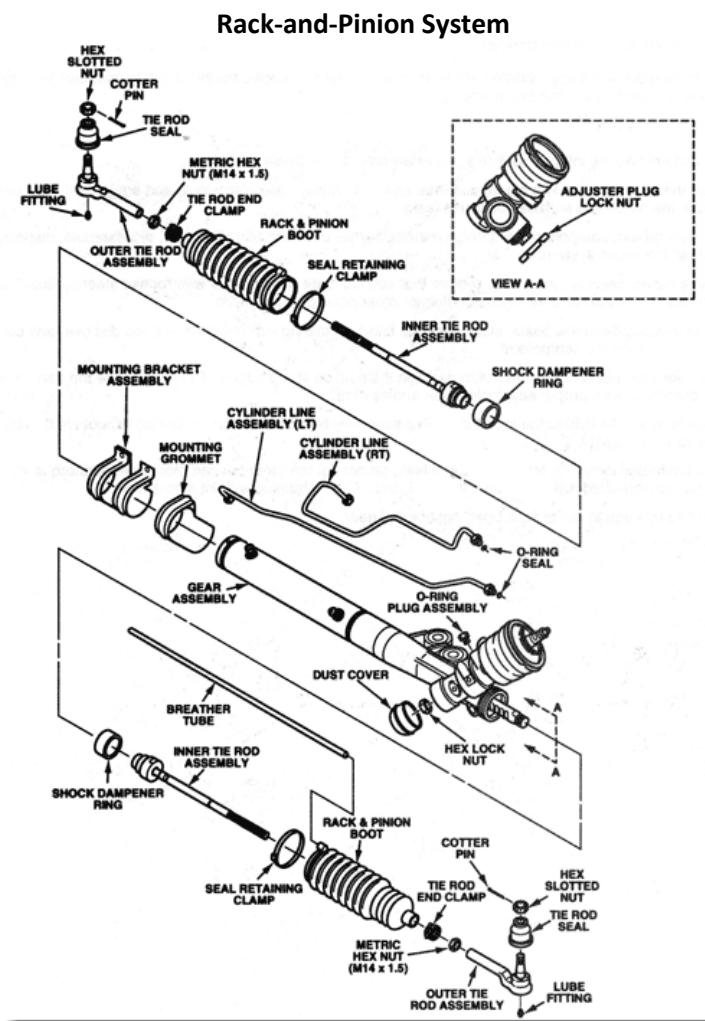
**Note:** Some rack-and-pinion designs have fluid in the inner tie rod boots that may spill out when the boot is removed. Loss of fluid when removing the boot will require that the system be refilled with the correct fluid following the reinstallation of the inner tie-rod boot.

### Replacing Rack-and-Pinion Steering Gears

**Rack-and-pinion steering gears** are often replaced with new or rebuilt units. Rebuilt rack units are typically available with inner tie rod ends installed. Although many rack-and-pinion units can be rebuilt in the shop, this is another area where it may be more practical to replace the unit. Again, refer to the vehicle service information for available kits, parts, and the setup procedures and adjustments, and compare the cost of the parts and labor to that of a new or rebuilt unit.

A common failure of power rack-and-pinion units occurs when grooves wear in the control valve housing, causing poor assist. The symptom usually happens on cold start-ups and disappears after several turns, and has been called "**morning sickness.**" Rebuilt units for models that are prone to this problem normally have a hardened sleeve pressed into the aluminum housing to prevent a recurrence of the problem.

When replacing a rack-and-pinion unit, refer to the vehicle service materials for the removal and replacement procedures and any special tools or materials needed.



### *Inspection and Service of Power Steering Pump Filters*

Some manufacturers install power steering system filters that must be inspected or replaced. The first step when working with power steering filters is to review service information to determine if the vehicle has one or more power steering filters and where they are located.

To service the power steering filter(s) use the following procedure:

1. Use service information procedures for inspecting, removing, and replacing the power steering filter(s).
2. Follow the service information to remove and inspect the power steering filter(s). If a filter is plugged or contains metal or rubber particles additional power steering components may need to be checked for condition.
3. Replace the power steering filter(s).
4. Refill and bleed the power steering system.
5. Test the power steering system operation and check for leaks.

#### **Notes:**

- It may be necessary to raise the vehicle to gain access to the power steering filter(s). Use proper lifting equipment to raise the vehicle and observe all safety precautions.
- Not all vehicles have power steering filters installed at the factory and those installed by technicians in the field may be difficult to locate.
- Some power steering filters are located in the high pressure hose and can only be replaced by replacing the complete hose and filter assembly.

### *Inspecting Electric Power-Assisted Steering Systems*

Electric power-assisted steering systems use electric motors and computer controls to reduce the effort required by the driver to steer the vehicle. Inspection of electric power-assisted systems is similar to hydraulic power-assisted steering from a mechanical stand point. Both systems use tie-rods, steering columns, and shafts. Electric power assisted systems do not have hydraulic components to inspect but do have additional electric/electronic components that require inspection.

To inspect an electric power-assisted steering system start by inspecting the mechanical components, including the following:

1. Inner and outer tie-rod ends
2. Rack and pinion mounts
3. Steering column components

When inspecting the electrical/electronic components the first step is to review service information to locate and identify the electric steering system components. Perform a visual inspection of each of the components for signs of damage or wear. Next, use service information to locate basic test and service safety procedures for the vehicle being inspected. Use the information to inspect the system's fuses, relays, control devices and electrical circuits. Most electric power-assisted steering systems rely on scan tools for diagnostic testing.



Hybrid vehicles have dangerous high-voltage circuits that are located alongside components and systems that sometimes require service. Many hybrid vehicles use electric power-assisted steering systems. Before beginning service on the electric power-assisted steering system, it is important to review service information and to locate and identify all of the high-voltage circuits that you may have to work with or around. All safety precautions must be identified and followed while working on the vehicle. Determine the locations of the high-voltage system components, including the high-voltage cables and service plug.

Power steering pressure switches are installed on many vehicles that do not use electric power-assisted steering systems. The purpose of the power steering pressure switch is to send a signal to the electronic engine controller when the pump is producing high pressure and adding to the engine load. The engine controller may then increase idler speed to prevent engine stall. The power steering pressure switch is commonly located on the power steering high pressure hydraulic line or sometimes on the power steering pump. Failure of the power steering pressure switch may result in the engine stalling when the steering wheel is moved at low engine speed.

#### Hybrid Vehicle High-Voltage Circuits



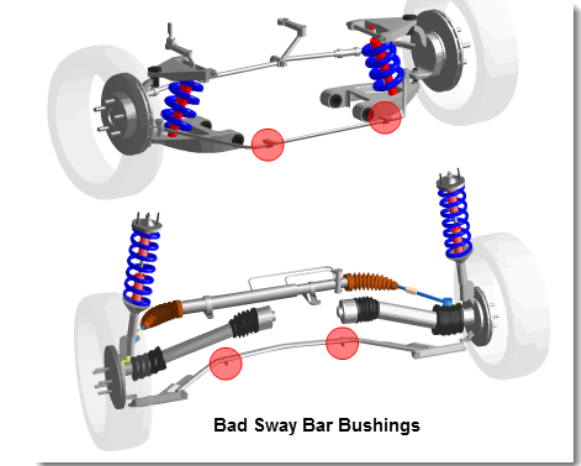
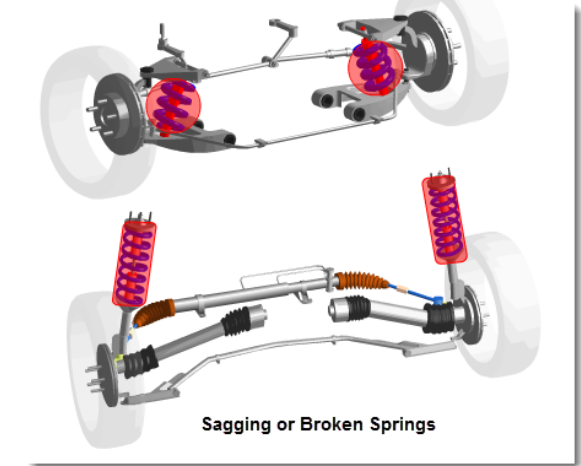
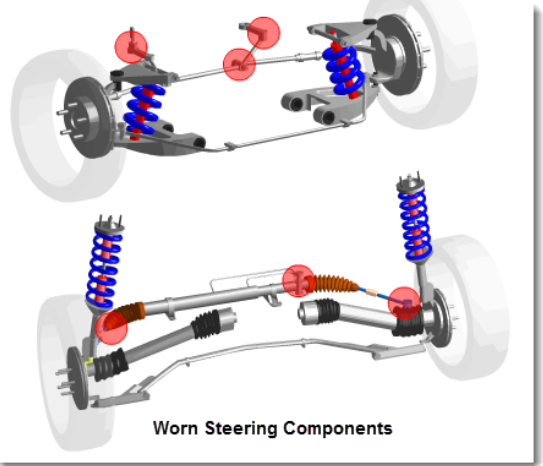
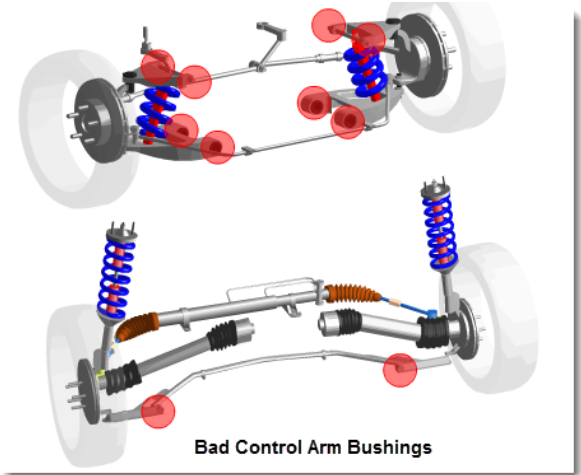
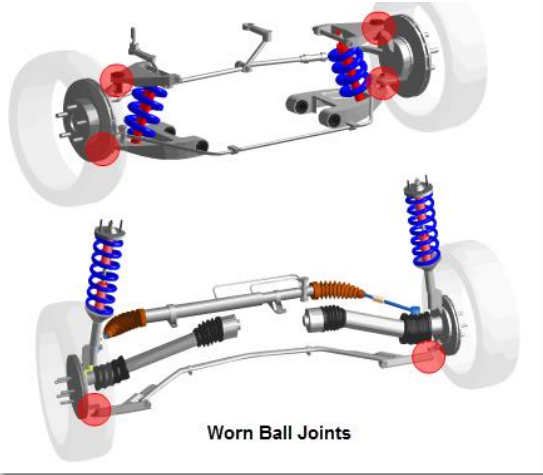
## Chapter 2: Suspension System Service

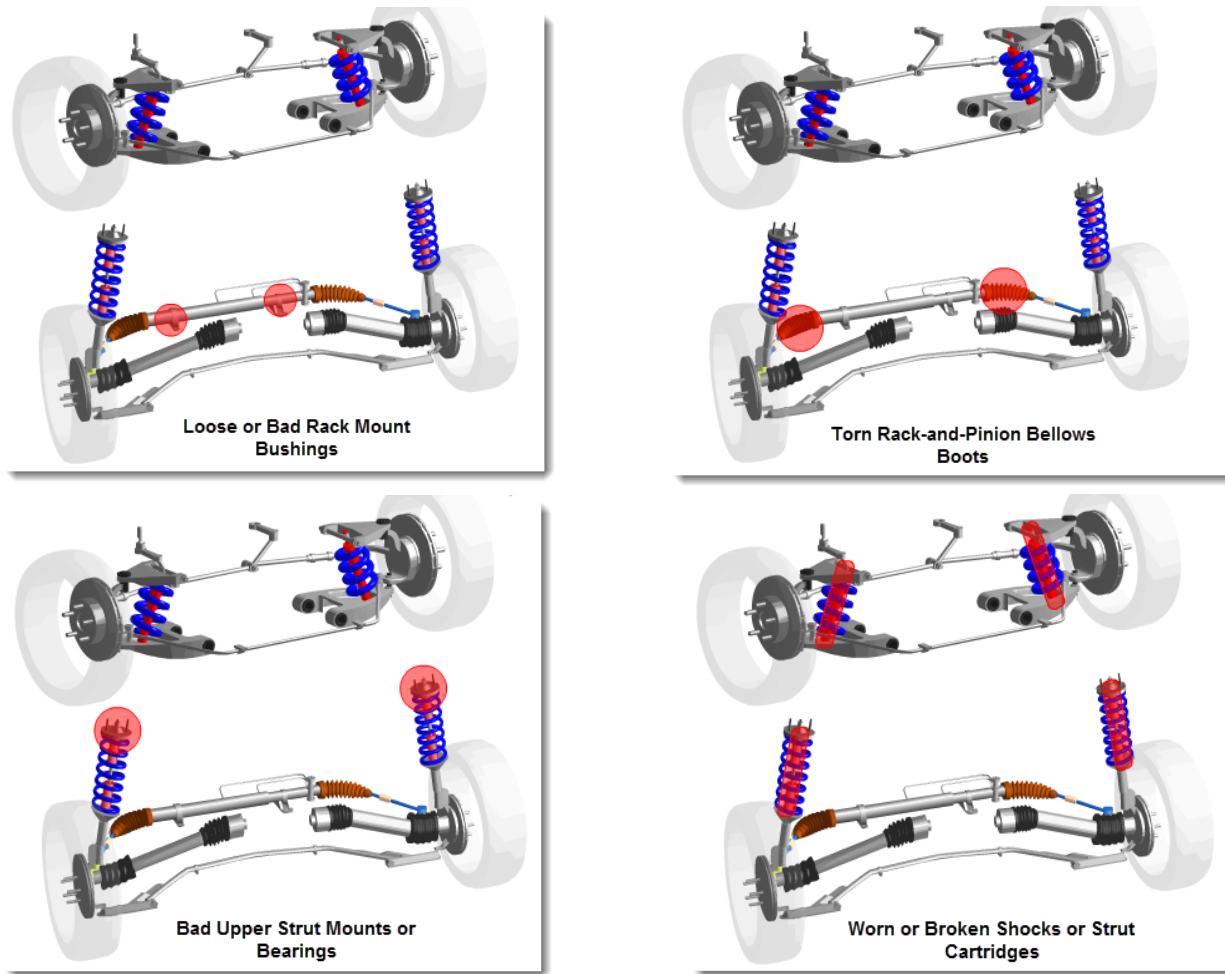
Suspension systems are designed to stand up to the abuse they receive under various driving conditions, but the tremendous “beating” they take can result in the need for minor and major repairs over time. Springs can fatigue and sag; ball joints, steering linkages, bushings, and shock absorbers can wear out and fail. The elements don’t help – water, salt, and other contaminants promote rust and corrosion that can also take a toll on these components.

### Common Suspension System Problems

Looseness is the enemy of steering and suspension parts. When wear causes looseness, the loose parts tend to hammer against each other, causing further wear and looseness. In extreme cases, parts can become bad enough to separate and cause a catastrophic failure, possibly resulting in an accident.

In the section on steering system service, we noted some common overall steering and suspension problems, including **noise, abnormal tire wear or vehicle handling**, and **excessive free play** in the steering wheel. In this section, we will examine these and other problems in detail.





### Shock Absorbers and MacPherson Strut Cartridges

Worn shock absorbers or MacPherson strut shocks will cause a vehicle to ride and handle poorly, especially on bad roads. The vehicle will have excessive body motion. Some shocks can still be effective after over 50,000 miles, while others might not make it to 20,000. They can develop internal or external oil leaks that reduce their damping effectiveness, or they can even break. Conventional shock absorbers' rubber **grommets** or mounting bushings are prone to fail, and shocks also can come loose from a mount. Shocks are replaced in pairs (front or rear). Sometimes shocks that are broken or non-functioning cause a **scalloped** wear pattern on tires. The tread will have cupped or dished areas.

### Scalloped Tire Wear



Most original equipment shocks and struts are designed to give a comfortable ride with a tight, new suspension. After 20 or 30 thousand miles, the suspension has settled considerably, and some people choose to replace the shocks to firm up the ride and handling.

### Checking Shocks and Struts

One quick way to tell if shocks or struts are badly worn or broken is with a “bounce test.” Push down hard several times on a corner of the body and then release it. The body should bounce about twice and then stop. If the body continues to bounce several times, the shock is bad. Repeat this on each corner. This is not the best way to evaluate shocks that might be marginal.

Shocks can be visually inspected for external leakage. An oily residue running down the shock indicates a seal leak, and the shocks will need to be replaced. A slight wetness at the seal is normal. Also inspect the mounts and rubber bushings, and look for physical damage to the shock.

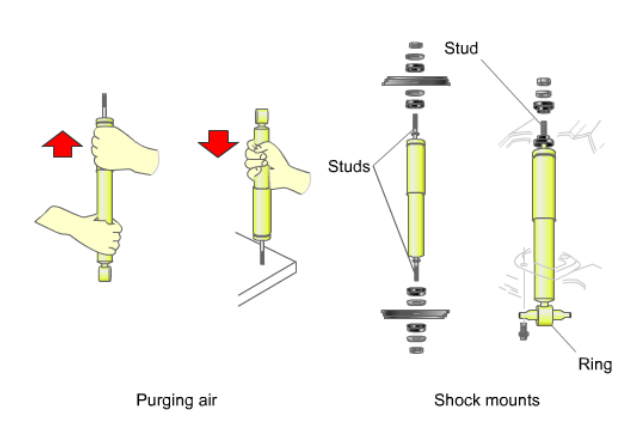
The best way to evaluate shocks and struts is to drive the vehicle over a variety of roads, especially a bad two-lane highway if possible. Excessive body sway, dip, wander, or “float” will be evident with poorly functioning shocks.

### Replacing Conventional Shock Absorbers

An air impact wrench greatly eases removal of most shock absorbers. An aerosol can of penetrating oil also comes in very handy for spraying rusty threads. A wheel alignment is not required after replacing conventional shock absorbers (although it is required after servicing MacPherson struts).

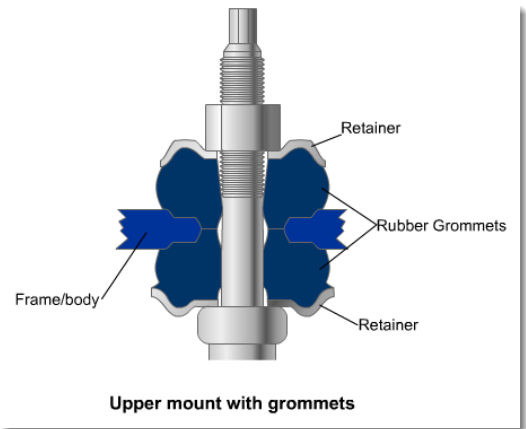
Shock absorbers that have been stored horizontally should be purged of air before installation. This is done by holding the shock vertically and extending the piston all the way out, then turning the shock over and collapsing it. Repeat this process until the shock extends and collapses smoothly, with no “skips.”

Gas shocks are shipped with a strap that keeps them compressed. When the strap is removed, the shock should fully extend on its own.



**Front Shocks** - The upper mount for many front shocks is a single threaded stud that attaches to the frame through two grommets with retaining washers and a nut. The stud is part of the piston rod. The bottom of the shock is usually connected to the lower control arm with bolts. The upper nut is usually removed with the vehicle on the ground. Rusty upper nuts and studs may require you to hold the top of the stud with a special wrench or vice grips while you back the nut off manually with an end wrench. Spray the stud liberally with penetrating oil and give it some time to soak. Some especially stubborn nuts may have to be cut off with an air chisel or other power tool. Once the nut is removed, you may lift the vehicle to access and remove the bottom mount. Reverse the procedure with the new shock. Shock absorbers that use this grommet arrangement are often over-torqued. The upper nut should be tightened only until the grommet bulges to the same diameter as the retaining washers.

**CAUTION:** Some vehicles must be raised on a hoist to access the upper shock mounts. Many shocks limit spring travel. An additional jack stand or lifting device must be used to support the suspension before the shock can be removed, in order to prevent sudden forceful movement of the axle or control arm, which could cause personal injury.



**Rear Shocks** – Other than the above caution, rear shock replacement is straightforward. Consult the vehicle and product service information for replacing shock absorbers.

**Air Shocks** – When installing air shocks, be sure to run the air lines clear of any possible pinch, heat, or rub points on the chassis. Air shocks are prone to leakage if overloaded to compensate for weak springs. Air shocks can be checked for leaks with a soapy water solution applied to lines and fittings.

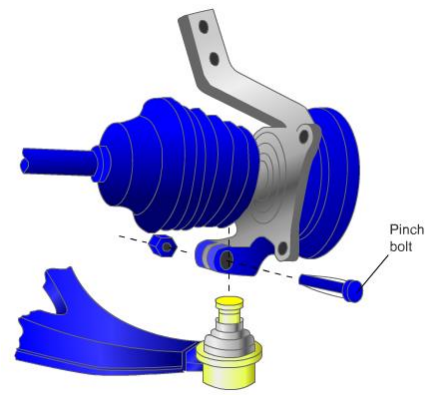
#### Replacing MacPherson Strut Shocks

To replace the shock absorber in a MacPherson strut, the entire strut assembly must first be removed from the vehicle. On some models, you must separate the ball joint from the steering knuckle in order to get enough clearance to remove the strut assembly. Removing the brake line from the caliper is required on some applications, which necessitates bleeding the brakes after the struts are serviced.

After the strut is removed, the housing is placed in a vice for disassembly and service. A spring compressor must be used to compress the coil spring before the upper nut can be removed. Once the spring is compressed, the nut can be safely removed. A large nut that seals the strut's shock is then removed, and after removing the piston and disposing of the old oil, a sealed replacement cartridge unit can be installed in the housing. The strut is then reassembled and installed on the vehicle. Unless bleeding the brakes is necessary, the vehicle is now ready for a wheel alignment.

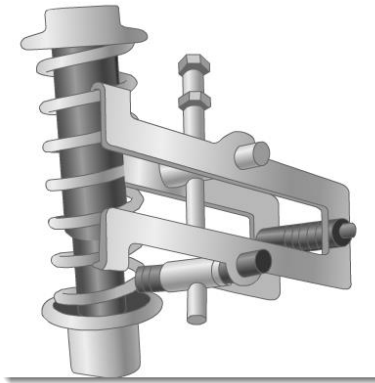


*Strut assembly bolted to the steering knuckle.*



*This ball joint is attached to the steering knuckle with a pinch bolt.*

### MacPherson Strut Spring Compressor

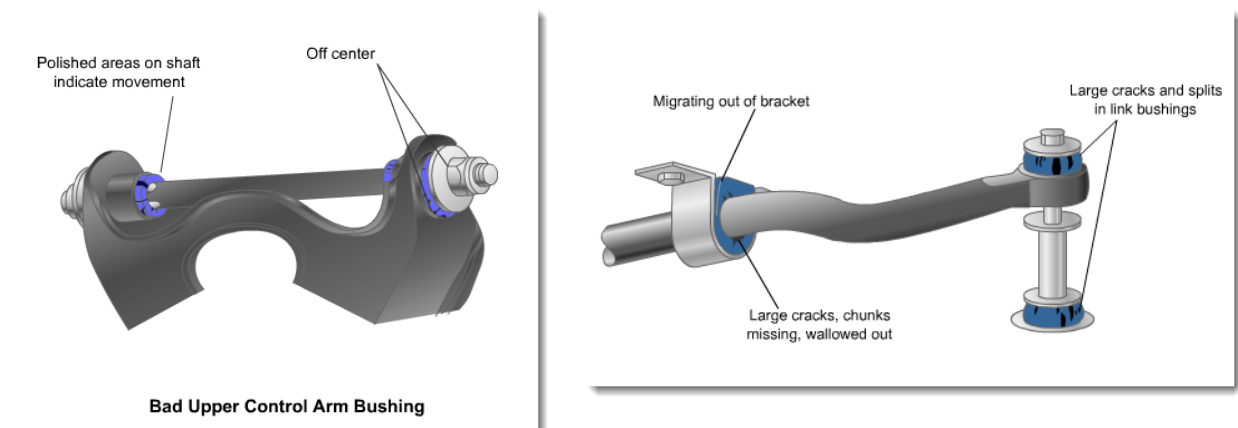


#### *Bushing Inspection and Service*

Failure of rubber bushings is a common noise-maker, as well as a cause of abnormal tire wear or vehicle handling, because of their affect on wheel alignment settings. While modern synthetic rubbers are very good, they have limitations. Oils, fluids, and road contaminants can attack the rubber. Excessive heat can deteriorate bushings near exhaust components. The rubber can deteriorate to the point where much or most of it falls out, allowing components to shift and cause problems. **Upper control arm bushing** failure can have a serious effect on tire wear and steering. It can cause a profound shimmy of what feels like “the whole front end” under certain conditions, as well as noise. **Strut rod bushing** failure can cause a loud clunk or knocking sound, as well as steering problems such as a sensation of shifting weight during stopping, starting, or cornering. It can also cause a pull to one side. **Sway bar link or frame bushing** failures only affect sway bar effectiveness, but they can also produce annoying rattling or popping noises.

#### Bushing Inspection

Bushings should be inspected for deterioration and splits in the rubber. Some surface cracking is acceptable, but the rubber should be in tact all the way around the bushing. With control arm bushings, look for missing chunks of rubber between the sleeves and for polished areas on shafts. With the vehicle properly lifted, rock the wheel in and out and feel for movement. Confirm visually.



*Sway bar bushing and link kit inspection.*

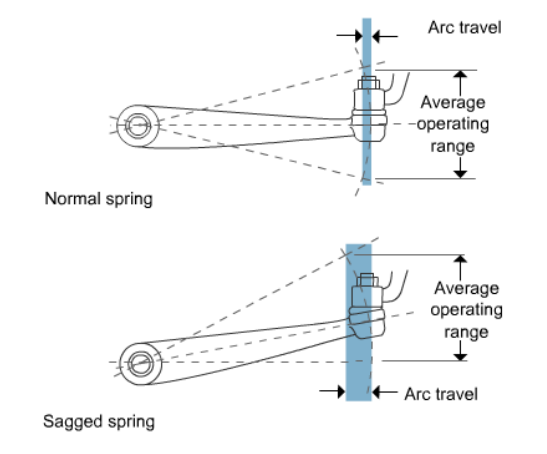
### Bushing Replacement

Some control arm bushings can be replaced with the arm still on the vehicle; others require removal of the arm. On a few applications, control arm bushings are threaded into the control arm, but most are press fitted. Press fitted bushings can be removed and installed with a bushing driver. Some may be removed with an air chisel, and some may be pressed into the arm with the retaining nut. This method can require periodic vibration of the control arm to coax the bushing into place. Care must be used in bushing replacement to avoid damage to the control arm. To properly position the bushing, the weight of the vehicle must be on the suspension before tightening the nut on most designs. Check the service information for the vehicle for the proper procedure.

Replacement of other types of suspension bushings is generally straightforward. Consult the service information.

### Vehicle Ride Height and Spring Service

A vehicle's suspension is designed to operate at a specified ride height, or curb height. Over time, springs can fatigue, causing the suspension to sag below the proper ride height. This can cause the vehicle to bottom out excessively, and it adversely affects the wheel alignment geometry and vehicle handling characteristics. On SLA suspensions in particular, this causes rapid tire wear. The control arms move outside their normal operating range during jounce and rebound, which increases tire scrub (lateral movement).



*This image shows increased tire scrub resulting from weak springs.*

### Inspection and Measurement

Broken or missing rubber **jounce bumpers** (strike-out bumpers) on the control arms, and corresponding shiny areas on the frame are good indicators that the springs are fatigued. Check the springs for misshapen or broken coils.

The vehicle ride height must be checked prior to a wheel alignment. Service information will provide the measurement points and specifications for the vehicle. Wheels and tires must be of the proper size and inflated to the recommended pressure, and a full fuel tank (or equivalent weight) is usually specified. The vehicle interior and trunk or bed should be cleared of excess weight.

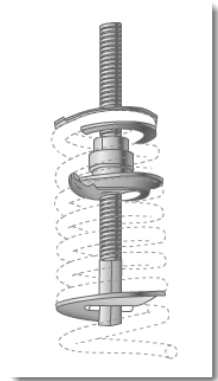
### Coil Spring Replacement

Rear coil spring replacement is often a simple matter, but front coil spring replacement can be more involved. Procedures vary with different manufacturers and models, and some call for special tools. Refer to service information for the vehicle.

An internal spring compressor may be needed when removing and replacing front coil springs. The springs are under compression, even when the vehicle is lifted by the frame. After removing the shock, the replacement procedure may involve breaking ball joint tapers (lower, upper, or both), removing a ball joint, and removing other components such as sway bar links. The lower control arm can then be pried downward, and the spring pried out from its place.

**CAUTION:** Compressed springs have tremendous stored energy. To avoid injury, make sure a spring compressor or other spring control device is in place, or the control arm is supported, before disconnecting any spring-loaded components. Handle compressed springs with care.

### Coil Spring Compressor

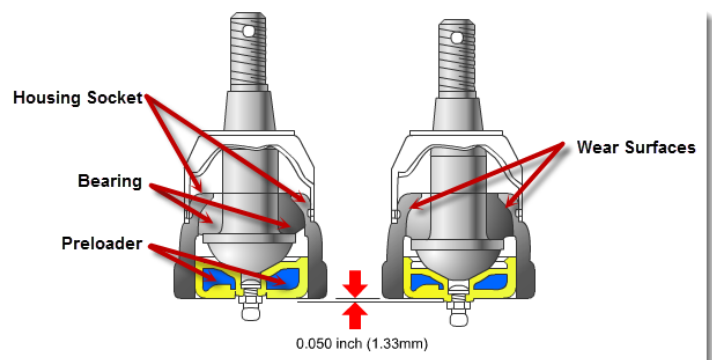
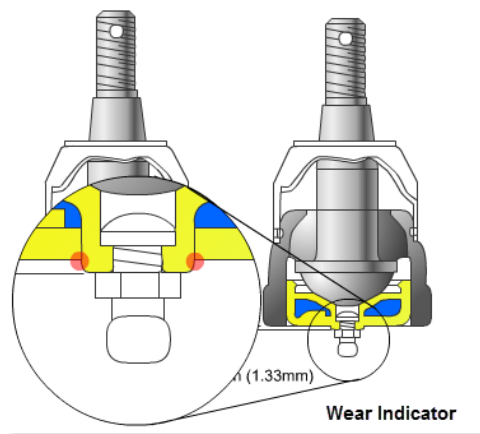


### Ball Joint Wear, Inspection, and Service

Ball joints normally have a long service life, but they can fail due to a loss of lubricant, or from contamination if the seal (boot) fails. A worn ball joint allows looseness in the suspension between a control arm and the steering knuckle. This looseness causes poor handling and misalignment, and it doesn't take much looseness to cause problems.

#### Inspecting Ball Joints

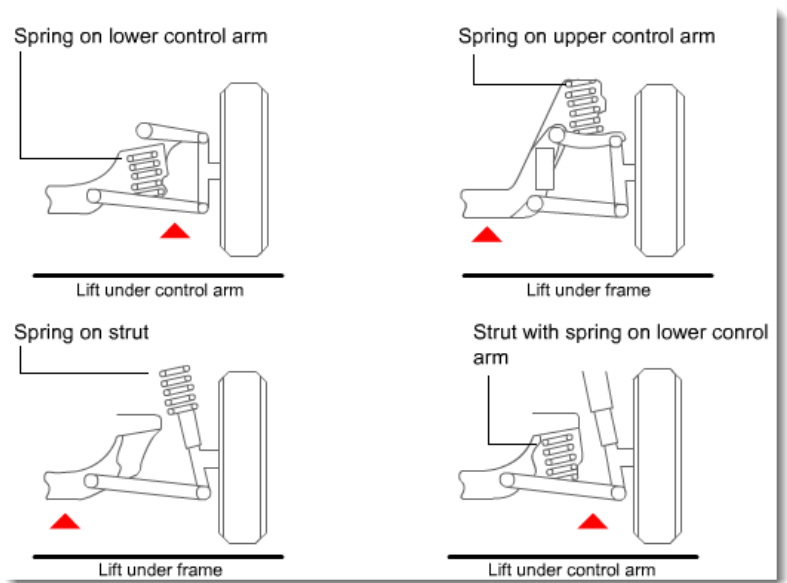
Some manufacturers make ball joint inspection easy by providing **wear indicators** on their ball joints. These are checked with the full vehicle weight on the suspension. On the most common type, the grease fitting is threaded into a round boss that protrudes from the base of the ball joint. As the joint wears, the boss recedes into the joint. When the shoulder of the boss is flush with the base of the ball joint, the joint should be replaced. A small screwdriver may be used to scrape away any debris and help determine the position of the boss. The service information will identify wear indicator ball joints and how to read them.



Manufacturers provide specifications for allowable movement in ball joints. The vertical (up-and-down) spec is listed as **axial movement**, and the horizontal (side-to-side spec), if provided, is listed as **radial movement**. Typically, load-carrying ball joints have an axial movement limit specification of around 0.060 of an inch, though some may allow up to 0.200 of an inch. The spec for many follower ball joints is “no perceptible movement.”



To check for ball joint and other component movement, the suspension must be unloaded by jacking it at the proper lift points. Recall that if the spring is mounted on the lower ball joint, then the joint is a load carrier, and that on a standard MacPherson strut suspension, the ball joint is a follower. If the lower ball joint is a load carrier, lift under the lower control, as near as possible to the ball joint. Below the spring seat is usually a good place. If the lower ball joint is a follower, lift by the frame. Study the diagram of lift points.



*This image shows lifting points for unloading different types of suspensions.*

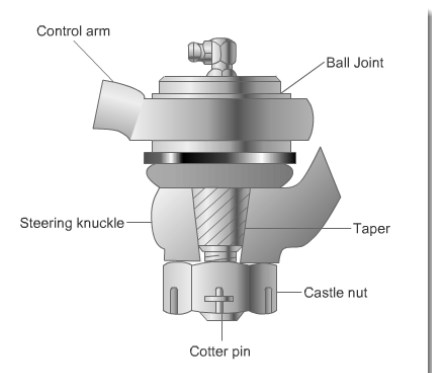
With the suspension properly lifted, a long steel pry bar is used to wiggle the tire up and down and side to side, while observing the amount of movement in the upper and lower ball joints. Compare the amount of movement to the specs. A **dial indicator** mounted to the control arm with the plunger placed on the steering knuckle can be used to measure small amounts of movement.

### Replacing Ball Joints

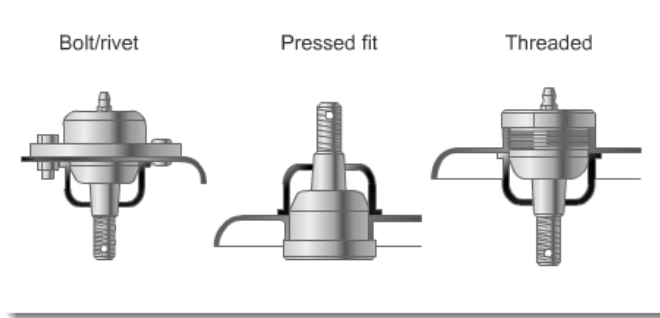
Ball joints are replaced in pairs (both upper or both lower). They are attached to the control arm using a press fit, rivets, bolts, or threads. Similar to tie rod end tapers, a tapered ball stud fits into a mating tapered hole in the steering knuckle, and a castellated nut or locknut draws the stud into a tight fit. A special tool or a large hammer can be used to “break” the taper.

To break the taper with a hammer, remove the cotter pin and back the nut off several turns. Position the vehicle so that the ball joint is loaded by the spring. Then use the hammer to sharply strike the steering knuckle on the outside of the taper. The taper will pop loose and the knuckle will rest against the nut. The suspension can then be unloaded so that the nut and ball joint can be removed.

### **Ball Joint Taper**

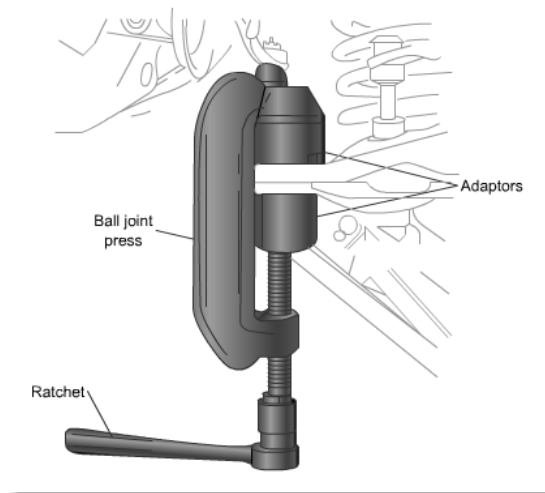


### Ball Joint Retention Methods



If the ball joints are pressed into the control arm, a **ball joint press** is used to press in the new joint. Care must be used to align the ball joint in the hole properly to avoid damage to the control arm. If the ball joints are held in with rivets, the rivets are removed and replaced with hardened nuts and bolts. Threaded ball joints are simply threaded in place and torqued to specs. Use the supplied lock nut or a **new cotter pin** to secure the nut.

### Ball Joint Press



### Steering Linkage Wear, Inspection, and Service

With the suspension unloaded for a complete steering and suspension inspection, all steering linkage parts should be checked for looseness. As with other components we've discussed, looseness in any of these parts can cause steering wheel play, poor handling, and tire wear. The vehicle will not hold a wheel alignment. The linkage check is similar to the dry park check discussed in the section on steering service, but more thorough. Loose parts must be replaced and then a wheel alignment must be performed.

#### Idler Arm Inspection

The idler arm is a common wear item. To check it for looseness, grasp the center link as near to the idler arm as possible and try to move it up and down. Note the amount of movement at the end of the arm. Compare the amount of movement with the specifications. A typical spec might be a limit of 1/4 of an inch. This type of movement will cause a toe change. Note that the spec might pertain to safety limits rather than tire wear concerns.

Recall that some idler arms have a pivot point at the center link. Check this point for movement as described under "Center Link Inspection" below.

### Center Link Inspection

The most common wear point for most center links is at the pitman arm. To check the center link, place your hands, palms out, against the inside of each front tire. Alternate between pushing one tire outward and then the other, creating a rocking motion, while looking for movement at the pitman arm. Compare to the specs. In general, there should be no perceptible independent movement. Recall that on some designs, the wear points are in the pitman arm and idler arm, so check this type accordingly.

### Tie Rod End Inspection

Conventional tie rod ends can be checked by grasping them near the ball socket and squeezing the tie rod into the connecting part, or attempting to push the tie rod towards and then away from the connecting part. Tie rod ends with looseness should be replaced. Some designs are spring loaded, and it is possible to overcome the spring tension, but the spring should provide firm resistance. Don't confuse the spring movement for looseness in the ball and socket.

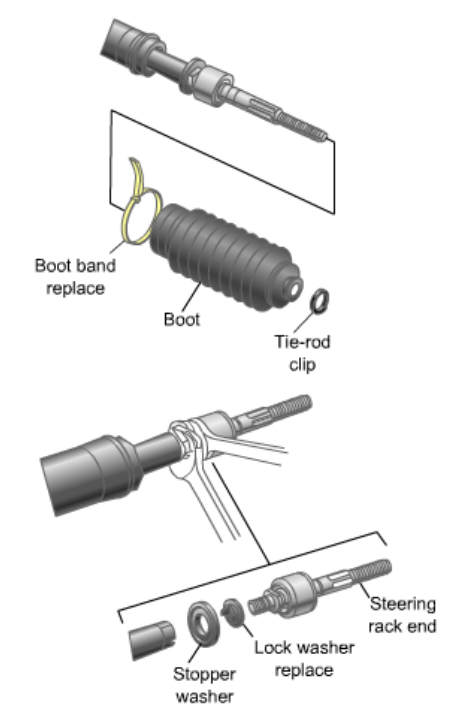
Inner tie rod ends on rack-and-pinions may be checked by grasping them and attempting to move them in and out. An effective method for checking them was covered in the section on steering service under Excessive Free Play.

### Steering Linkage Service

As with tie rod ends and ball joints, many idler arms have a taper connection, which must be broken to remove the idler arm. The tapers on steering linkage components are easier to break than those on ball joints. The tapers can be broken with the suspension unloaded. Either a hammer method similar to that described under **Replacing Ball Joints**, or a taper breaking tool can be used. A taper breaking tool can destroy the part, so the hammer method should be used when breaking the taper to replace a different part (if the part is to be reused). Leave the nut on the stud to help protect against a glancing hammer blow that could damage the threads.

When replacing tie rod ends, measure or mark the tie rod length before disassembly. This will allow you to obtain an approximate toe setting for reassembly, making alignment much easier.

Inner tie rod ends on rack-and-pinions are usually threaded onto the rack. Various methods are used to lock the tie rod end. Consult the vehicle service information.



*Two wrenches are needed to loosen this inner tie rod end from the rack.*

### *The Complete Steering and Suspension Inspection*

We have noted that all of the steering and suspension components must be checked prior to a wheel alignment. This is when most steering and suspension problems will come to light. The customer may not realize that they have steering or suspension problems, or they may expect that a wheel alignment will "cure" their steering or suspension concerns.

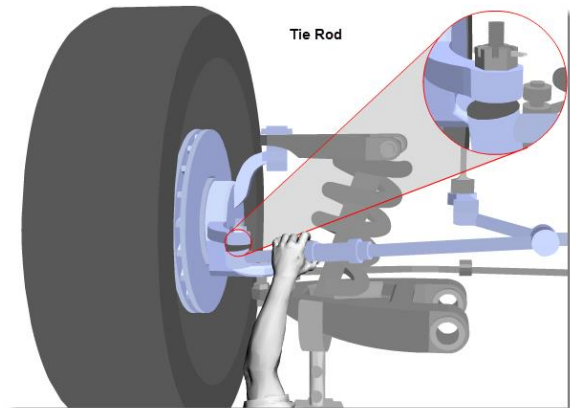
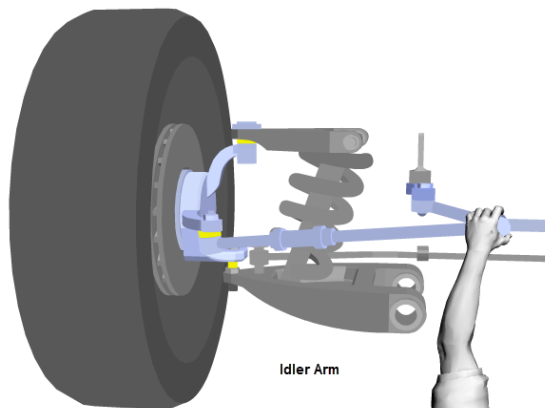
A complete steering and suspension inspection should begin with a test drive, if possible. Anything unusual about the steering and suspension systems should be noted, such as any noises or handling problems. The vehicle should then be placed on an alignment rack, the parking brake set, and the hood raised for the inspection. At this time, you should check:

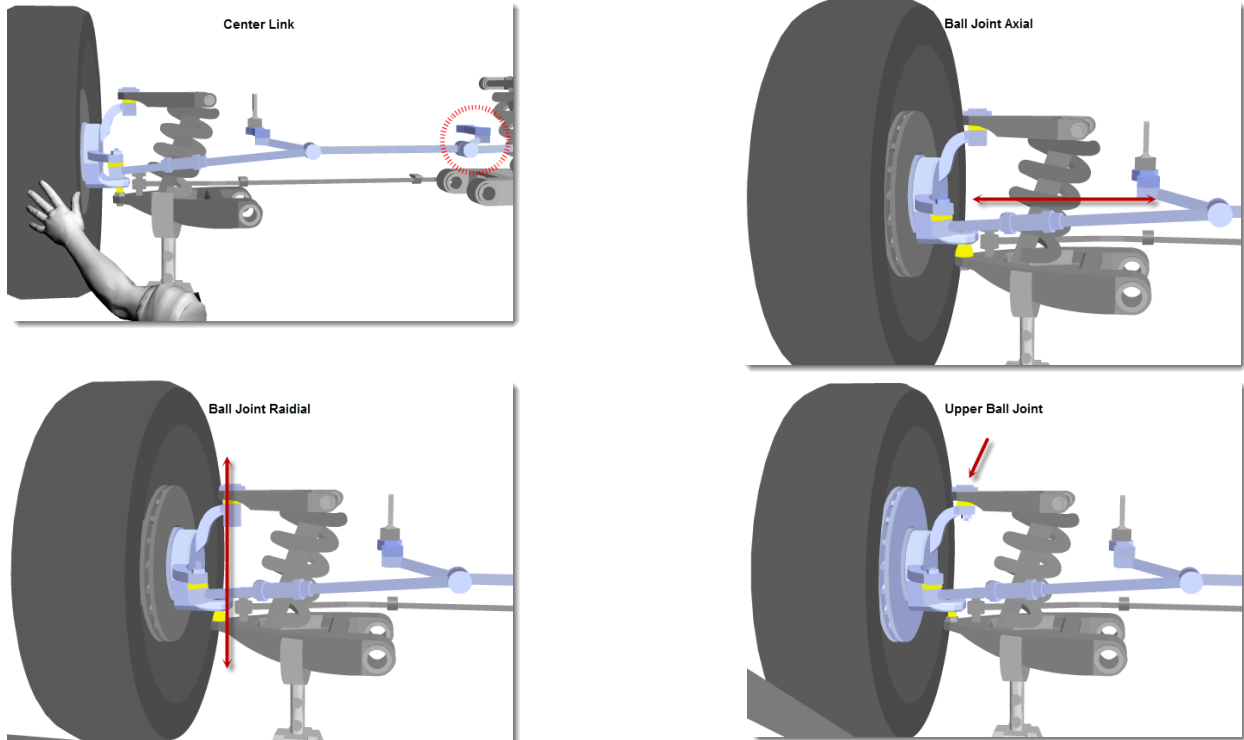
- Tires and wheels for proper size, tires for inflation and uniform construction (same type)
- Vehicle ride height
- Under the hood - upper control arm bushings, if applicable; upper strut mounts for binding or other problems, flexible steering links, shocks and mounts, power steering hoses, etc.

Next, turn the ignition key to unlock the steering, and then raise the vehicle. If the ball joints have wear indicators, check them now. Then, use the hoist-mounted jack to unload the suspension. You can then check all of the steering and suspension components as we have described.



Now, we will demonstrate checking parts on a typical SLA suspension. The vehicle has been raised under both lower control arms. Inspection procedures are similar for other suspensions, as outlined; just remember to properly unload the suspension and look for looseness in the parts. View the animations located in this section of the MLR Steering and Suspension course at <http://www.todaysclass.com>.





### Inspect Rear Suspension System Lateral Link and Control Arms

#### *Procedure for inspecting the control arms and track rod*

1. Inspect the control arms for the following:
  - Bent or broken lower and upper control arms
  - Deteriorated or worn bushings (bolts should be centered in the bushings)
2. Inspect the track rod for the following:
  - Deteriorated or worn bushings
  - Damaged or worn mounting brackets
  - Bends or twists in the rod

#### *Removing and installing the lower control arm*

1. Procedure for removing the lower control arm
  - Use proper lifting equipment to raise the vehicle.
  - Remove the bracket bolts that attach the control arm to the axle housing.
  - Remove the bracket bolts that attach the control arm to the body.
  - Remove the lower control arm.
2. Procedure for installing the lower control arm
  - To install the lower control arm, reverse the removal procedure.
  - Tighten all fasteners to the specified torque.

### *Removing and installing the upper control arm*

1. Procedure for removing the upper control arm (rear-wheel-drive axle):
  - Use proper lifting equipment to raise the vehicle. Support the vehicle with safety stands placed under the axle housing.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

- Place a support under the differential pinion nose.
  - Remove the front and rear arm attaching bolts and then remove the arm.
2. Procedure for installing the upper control arm (rear-wheel-drive axle)
    - To install the upper control arm, reverse the removal procedure.
    - Tighten all fasteners to the specified torque.

### Control arm bushing replacement

**Note:** The bushings in many control arms can be replaced while the arm is removed from the vehicle. Some bushings cannot be serviced. If nonserviceable bushings are defective, the entire control arm must be replaced.

1. Using a press and suitable adapters, press out the bushing. Be certain to support the inner portion of the arm to prevent it from being crushed.
2. If the bushings are located on the axle end of the upper arm, press them into a flange on the axle housing instead of the arm.

Once you have identified and corrected any steering and suspension problems, you may proceed to perform a wheel alignment, the subject of our next section.

## **Unit 3: WHEEL ALIGNMENT**

### **Chapter 1: Wheel Alignment Service**

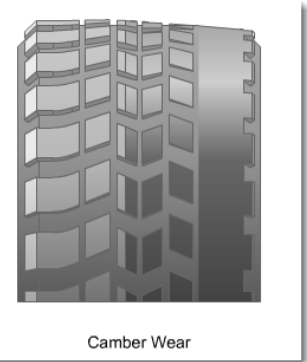
At the beginning of the section on wheel alignment principles, we discussed the purposes of wheel alignment. Aside from vehicle handling and steering concerns, long tire life with even wear is one of the primary goals and reasons for routinely checking and correcting wheel alignment.

#### *Reading Tire Wear*

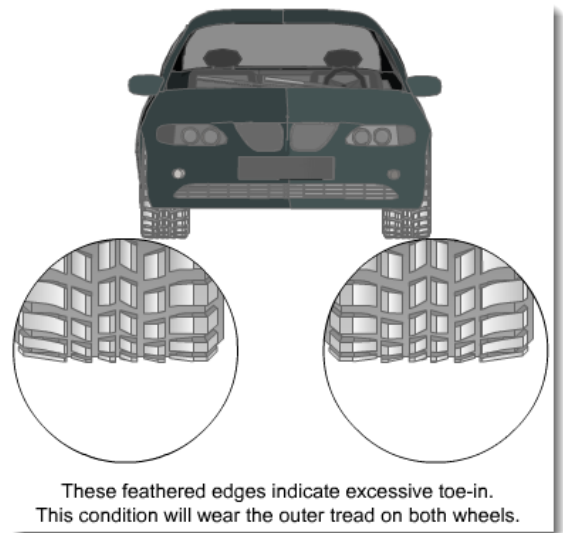
Examining the tires closely will provide an indication of the vehicle's wheel alignment condition and prepare you for what problems to expect. If the tires provided long life and are worn evenly across the tread, chances are good that the alignment requires little or no correction. On the other hand, misalignment or other problems can produce characteristic wear patterns on the tires, and recognizing them will help you identify the problem. Examining the tires in this manner is called **reading the tires**.

Wear on the Inside or the Outside

More wear on the inside or outside of the tread can be an indication of incorrect camber or toe, or both. Negative camber will wear the inside tread on wheels that are out-of-spec. Toe-out will also wear the inside tread, but the wear will be similar on **both** front wheels. Excessive positive camber or toe-in will show up as wear on the outer tread in the same manner. In general, camber wear tends to be located more on the edge of the tread, or the shoulder of the tire, but this is not always the case; other combinations or conditions can appear similar.

Feathered Edges

This type of wear pattern is caused by excessive front toe-in or toe-out. With feathered edge wear, one side of each tread rib is raised and “sharp,” while the other side of the rib is lower and rounded. You can feel these edges by running your hand across the tread from one side to the other. Your hand will catch on the raised edges, but slide smoothly going the other way. If your hand catches while moving out and slides smoothly as you move it in, toe-in is indicated. Check also for accompanying uneven inside or outside wear on both front tires. A feathered wear pattern usually indicates toe that is far beyond specs.

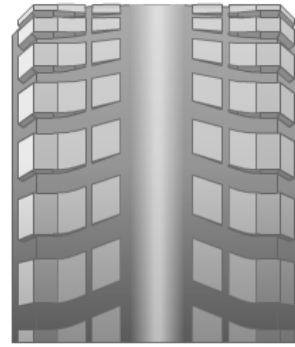
Wear on Both Edges or To the Center Ribs

Wear to both the inner and the outer edges of a tire can indicate underinflation. **Underinflation is the most common cause of rapid tire wear.** An underinflated tire flexes too much at the sidewalls and has poor road contact at the center of the tread. This can also cause overheating, tread cracking, and sudden tire failure. Wear on both edges can also be caused by hard cornering.

Wear to the center ribs can indicate overinflation. This pattern became less common when radial tires largely replaced bias ply tires, but with today’s wider wheels and lower profile tires, it is making a comeback.



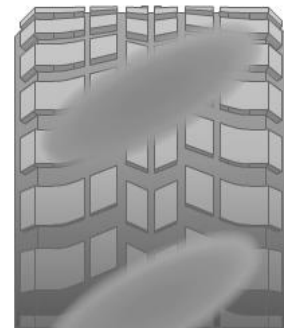
Underinflation or hard cornering



Overinflation

### Diagonal Wear Pattern

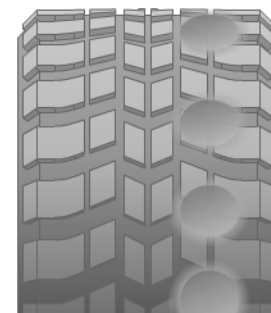
Occasionally, a diagonal wear pattern appears on the rear tires of front-wheel-drive vehicles. This is an indication that the toe is out-of-specs. Because of all of the turning the front wheels do, front toe wear is distributed evenly around the circumference of the tire. Since the rear wheels carry less weight and do not turn, excessive toe makes the tire tend to drag and then roll, setting up this pattern, which causes noise and vibration.



Rear toe wear

### Erratic Wear

Erratic tire wear can have several causes, though it is seldom caused by alignment settings. We have discussed that broken or non-functioning shocks can cause a scalloped wear pattern on tires. Failed suspension parts can cause this type of wear also, and other irregularities such as bald spots can be caused by an unbalanced wheel, or a wheel or tire defect.



Scalloped or cupped

### *Relationship of Angles and Adjustment Sequence*

The alignment angles are interrelated, and changes to one angle may cause change to another. For this reason, a specific sequence is followed when setting the alignment, so that once an angle has been properly set, it does not usually have to be set a second time. However, if the changes are large, resetting a previous angle may be required, so always check the other angles after making changes to one.



The sequence may vary among some equipment or vehicle manufacturers, but the standard sequence is this:

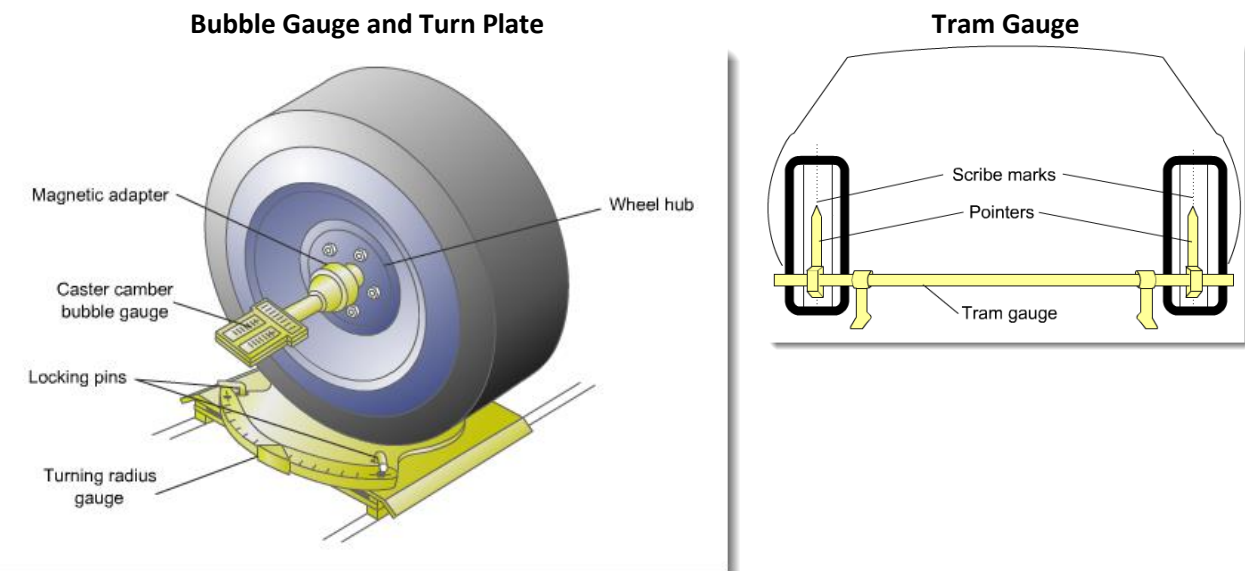
- Rear camber
- Rear toe
- Front caster
- Front camber
- Front toe

**Note:** On many designs, caster and front camber must be adjusted together.

In most cases, the SAI, included angle, and turning radius are checked if the other angles cannot be brought into specs, bent parts are suspected, or when troubleshooting a specific problem.

### *Wheel Alignment Equipment*

The design and complexity of wheel alignment equipment varies greatly, ranging from simple gauges to complex computerized machines. A level surface must be used in any case. The simplest equipment consists of small mechanical **bubble gauges** that are attached to the wheels or hubs to measure caster and camber. A **turn plate**, or **radius gauge**, is placed under each wheel to be aligned. Resting on ball bearings, the turn plate is marked in degrees and used in measuring the caster and turning radius angles. The turn plates allow the suspension to remain in a relaxed position with easy turning of the wheels. A **tram gauge** can be used for toe measurements. The tram gauge is a shaft with two pointers. The pointers slide on a gauge marked in inches or millimeters. The distance between the fronts of the tires is measured and compared to the distance between the rears of the tires.



### Computerized Alignment System

A satisfactory alignment can be performed with simple equipment; however, modern, sophisticated equipment is more accurate, easier to use, and much faster. It will make some measurements automatically, and can measure angles such as SAI and the IA (included angle) that some simple equipment cannot.

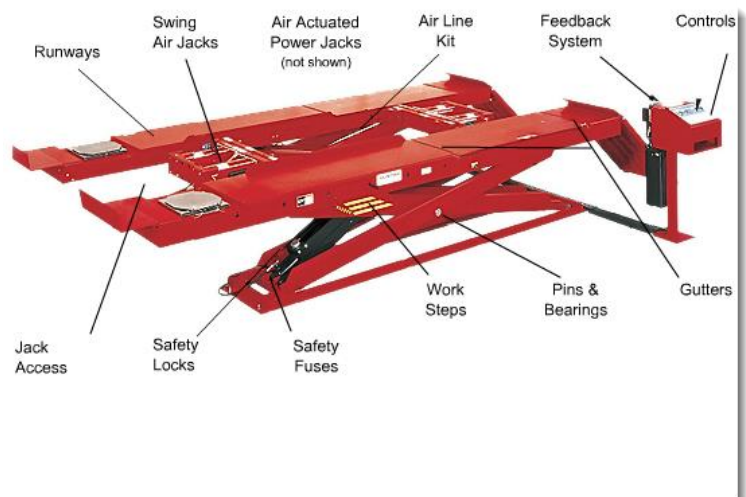
A professional alignment system consists of a drive-on rack with turn plates for the front wheels, slip plates for the rear wheels, alignment heads (or targets in some cases) that mount to the wheels, and some type of console with a display. The console usually consists of a dedicated computer, a monitor, a keyboard, and a printer. The computer software can contain a great deal of information, such as instructions for using the equipment, vehicle specs, adjustment methods, diagrams, photos, and other helpful reference materials. The software is often stored on CD-ROMs. These materials can be displayed on the monitor or printed. The monitor also displays screen prompts during the alignment process, and displays current "live" measured values. For measuring the angles, modern equipment may use infrared light beams, laser beams, video cameras, attitude and proximity sensors, or other means.



*This computerized alignment system uses four digital video cameras. Two are mounted on each side of the vertical beam. (Image courtesy of Hunter Engineering)*

### Alignment Rack

*Alignment racks are designed to provide a level surface with convenient lifting capabilities. A popular type of rack is shown here. (Images courtesy of Hunter Engineering)*



### Alignment Heads

Alignment sensors, or heads, do the measuring on most modern equipment. They are mounted to the wheels with adapter clamps. After the heads are mounted and the safety cable is connected to the wheel's valve stem, each head must be set to compensate for **lateral runout**.

This step compensates for differences in wheels and bracket placements. The simple procedure may be a mechanical adjustment or a mathematical calculation performed by the computer. Follow equipment instructions for the procedure. Some heads are magnetic and mount to the wheel hub. The wheel hub is a machined surface and lateral runout is assumed to be negligible.

### **Alignment Sensor and Clamp Adapter**



*(Courtesy of Hunter Engineering)*

### Types of Alignments

There are three types of wheel alignments: **centerline alignment**, **thrust alignment**, and **four-wheel alignment**.

#### Centerline Alignment

A centerline alignment is a two-wheel or “front end” alignment, and heads are mounted only on the front wheels. This type of alignment references the vehicle centerline for straightening the front wheels and centering the steering wheel when adjusting front toe. Measurements to the frame or body are used to determine the centerline. This type of alignment can be performed on rear-wheel-drive vehicles, and was standard for many years. If the thrust angle is off, the result can be a crooked steering wheel after the alignment.

#### Thrust Alignment

A thrust alignment is similar to a four-wheel alignment, because heads are mounted on all four wheels. Instead of referencing the vehicle centerline, this type of alignment references the rear wheels to the front wheels and measures the thrust angle. This information is used for straightening the front wheels and centering the steering wheel. The only difference between a thrust alignment and a four-wheel alignment is that a thrust alignment is performed on vehicles that have no method of correcting the rear wheels. Referencing the rear wheels takes the guesswork out of straightening the front wheels and centering the steering wheel.

#### Four-Wheel Alignment

A four-wheel alignment is performed on vehicles with adjustments for all four wheels. With a four-wheel alignment, all wheels are measured and corrected, resulting in a thrust angle at or near zero and a centered steering wheel. Two-wheel alignment equipment can be used to perform a four-wheel alignment by backing the vehicle onto the rack first and referencing and setting the rear wheels to the vehicle centerline. The vehicle is then turned around and the front wheels are referenced and corrected to the vehicle centerline.

### *Alignment Preparations and Setup (Four-Wheel and Thrust Alignments)*

Due to the wide variety of alignment equipment available and the differences in their operation, you must refer to the operating instructions for your equipment. However, there are some general similarities in the setup and usage of most wheel alignment equipment.

- Before driving a vehicle onto the alignment rack, be sure the locking pins are in place in the turn plates and slip plates. After you position the vehicle on the rack, set the brake and block the rear wheels. Turn the ignition key to the “unlocked” position.
- Perform a complete steering and suspension inspection as outlined in the Suspension Service section. Raise the vehicle and then jack the front suspension for inspection, then jack and inspect the rear.
- After the vehicle passes inspection, extend the leveling legs on the rack and lower the vehicle onto them (if equipped), or lower the rack into position for mounting the heads and engage the leveling locks.
- Start the alignment program on the console. Most computerized machines will prompt you as to the type of alignment to be performed, vehicle make, model, year, (or Vehicle Identification Number) and sometimes other vehicle information. The computer will retrieve the vehicle data, offer various display options, and prompt you to mount and compensate the sensors (heads).
- Place the transmission in neutral, release the parking brake, mount the heads, and then compensate them. If rotating the wheel is part of the compensation process, be sure the heads that are mounted on drive wheels are free to rotate (not locked to the wheel brackets), because rotating one drive wheel can cause the other wheel to rotate as well. After compensating the heads, place the transmission in park or gear and reset the parking brake.
- Remove the locking pins from the turn plates and slip plates, and then lower the rear wheels. Next, lower the front wheels onto their plates. With the rear wheels blocked, place the transmission in neutral and release the parking brake. Jounce the rear and front suspensions several times to settle them. Place the transmission in park and reset the parking brake.

**Note:** You may have to use wheel blocks on the front or rear and set and release the parking brake several times during the course of an alignment. Be sure the vehicle is never free to roll while on the alignment rack.

- Level the heads. You are now ready to begin taking measurements.

### *Measuring Wheel Alignment*

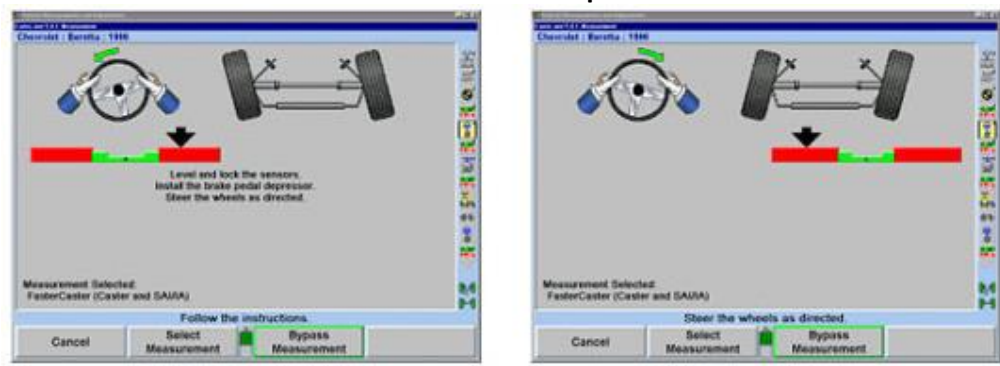
Despite differences in the equipment used to check wheel alignment, the basic principles and geometry of wheel alignment remain the same. With your equipment's operating instructions and an understanding of how alignment measurements are made, you will be able to perform a precision alignment regardless of the type of equipment being used.

### Measuring Caster

To measure caster, each front wheel must be turned through an arc to take the readings. This is known as a "caster sweep." The caster angle is actually determined by measuring the difference in camber from one position to the other. A brake pedal depressor tool is used to prevent the wheels from rotating. To measure caster with bubble gauges, turn one of the wheels in or out 20 degrees on the radius gauge. Turn the adjustment knob on the caster gauge to center the bubble on zero. Then, turn the wheel the other direction through a 40-degree arc, stopping at the other 20-degree mark. The degree mark next to the bubble on the caster scale indicates the caster for that wheel. Repeat the process for the other wheel.

To measure caster with computerized equipment, the sweep for both wheels is done at the same time, often by turning the steering wheel. The monitor prompts the user to turn in one direction and then the other. The display shows a graphic of the wheel positions so the user can see where to stop and hold the wheels while the computer takes the reading. The screen then prompts the user to return the wheels to the straight ahead position, and then the measurements for caster (as well as the other angles) will be displayed. The caster measurement is usually not a "live" reading (continuous in real time); if the caster or camber is adjusted, another caster sweep will have to be made.

### Caster Sweep



*(Courtesy of Hunter Engineering)*

### Measuring Camber

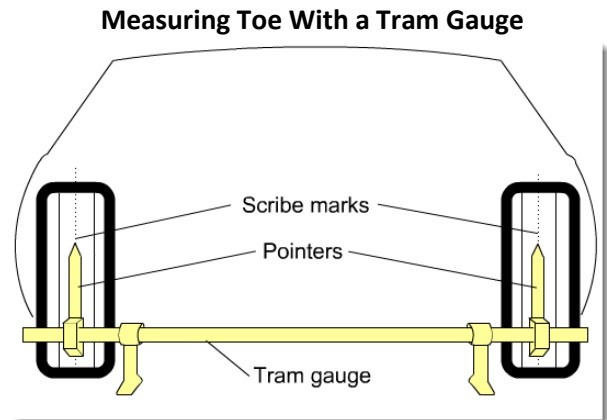
Obtaining the camber measurement is simple. The camber reading is taken with the wheels pointing straight ahead. With a bubble gauge, read the camber value where the bubble appears on the camber scale at each wheel. With computerized equipment, the camber value is displayed live on the screen.



*Camber and other angles are displayed on the screen. (Courtesy of Hunter Engineering)*

### Measuring Toe

To measure toe with a tram gauge, the tires must first be marked for reference (after the vehicle passes inspection is a good time). With the wheels off the ground, apply a chalk line around the center rib of each tire. Then, while spinning each tire, use a scribing tool to mark a fine line within the chalk line. This will give you a precise reference point for measuring. With the wheels on the turn plates, use the tram gauge to measure the distance between the scribe marks at the fronts of the tires and at the rears of the tires at spindle height. The difference in distance is twice the actual toe.



**Note:** When adjusting rear toe using a tram gauge, extra steps must be taken to ensure that the vehicle centerline (thrust) is correct.

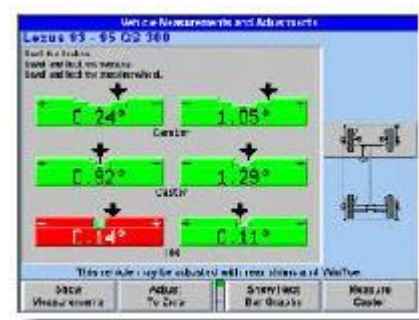
Electronic equipment can use a variety of methods to measure toe. Optical devices, such as lasers or infrared projectors are common. The heads project towards each other: rear to front, front to rear, and front to front. With computerized equipment, the heads communicate to the computer the relative positions of each wheel. The computer takes the information from the heads and calculates the individual toe for each wheel, total toe per axle, thrust angle, and other parameters. The measurements are displayed on the monitor.



*The component on the left of this sensor projects a toe signal across to the sensor on the opposite wheel. It receives a similar signal in return, and the left rear sensor projects a signal forward to this sensor. (Courtesy of Hunter Engineering)*

### Monitor Display

The format for the monitor display will vary among manufacturers, and some offer a variety of graphic displays that can be selected according to user preferences. Typically, the values displayed for the angles are color coded, with those that are within specs displayed in green and those that are outside specs in red. The graphic may show the amount and direction of adjustment required, and the live readings will indicate when the adjustment is within specs and at the preferred setting.



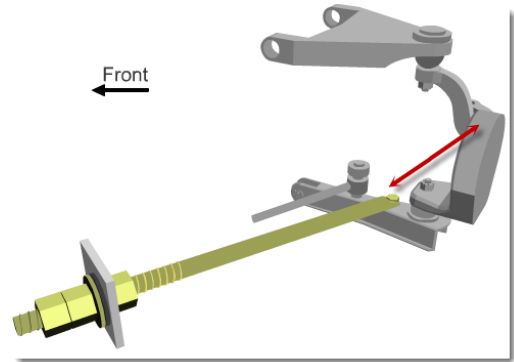
*Color-coded display. The reading on the lower left is out-of-spec. (Courtesy of Hunter Engineering)*

### Adjustment Methods

Many methods of adjusting alignment angles are used. We will discuss some of the most popular ones here. Other methods may be used. Always consult the service information if you are unsure of the method of adjustment.

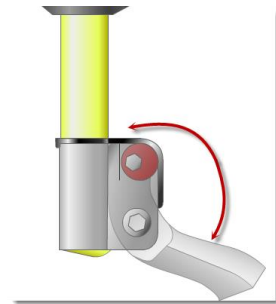
#### Adjusting Caster

One popular method for adjusting caster on MacPherson strut systems and on SLA suspensions with the spring on the upper control arm is by lengthening or shortening the strut rod. This moves the lower control arm fore or aft. Caster is increased by shortening the rod and decreased by lengthening it. A jam nut is tightened against the retaining nut to secure the setting. However, on many vehicles, caster and front camber must be adjusted together.



#### Adjusting Camber

Some MacPherson strut systems use an **eccentric cam** at the lower attaching bolts on the strut to adjust camber. On each strut, one strut mounting hole is slotted. The eccentric cam lobe acts against bosses on the strut housing, moving the spindle assembly in or out when the bolt head is turned. Other vehicles use a similar method to set camber, but do not have the eccentric cam. On these models, the wheels must be jacked to unload the suspension, and the wheel held in the proper position while the lower strut mounts are tightened.

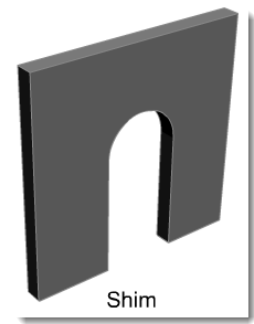


On other MacPherson strut designs, camber can be adjusted by loosening the upper strut mounting nuts and sliding the strut in or out. This type may or may not also include a caster adjustment at this location.

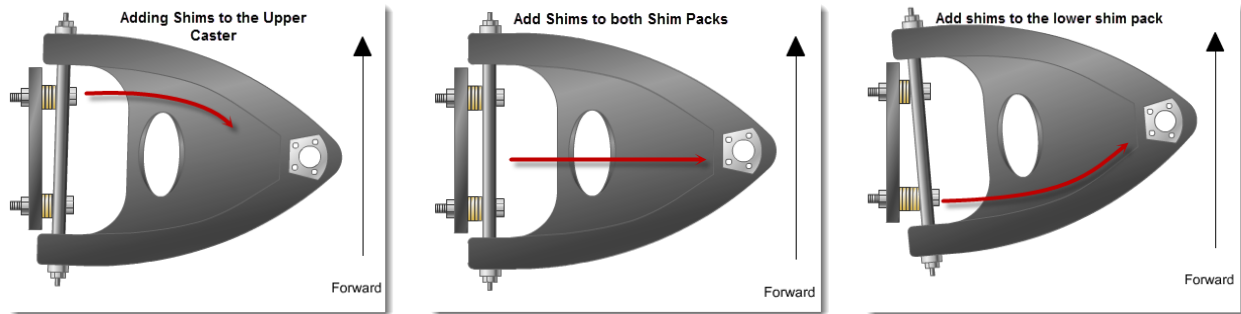
#### Adjusting Caster and Camber Together

We have noted that on many vehicles, caster and front camber must be adjusted together. Many SLA suspensions use **shims** between the upper control arm shaft and the frame. Others use eccentrics to position the front and rear of the control arm shaft. Slots in the frame have also been used for adjusting caster and camber.

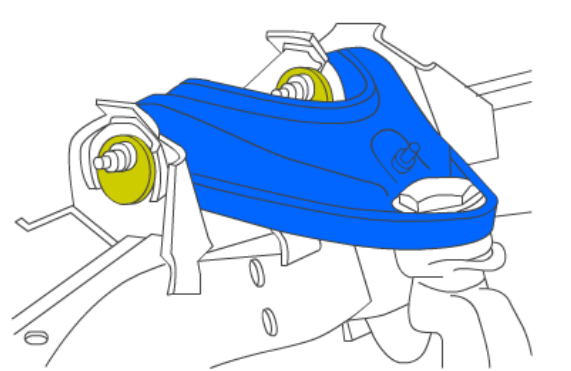
On vehicles that use shims, the shims are added or removed to affect changes in caster and camber. If the control arm shaft is on the inboard side of the frame, removing shims will increase camber, and if the shaft is on the outboard side of the frame (as with many light trucks) removing shims will decrease camber. With shims, changes can be made to either the caster or camber with little affect on the other angle. To change camber, shims are added or removed equally from the front and rear shim packs. To change caster, shims are moved from the front shim pack to the rear or from the rear to the front. Shims of various thicknesses can be used to make fine adjustments.



Suppose you are aligning a light truck, and you want to increase both the caster and the camber on the left front wheel by 0.5 degrees. Adding a 1/16 inch shim to the front shim pack might give you the desired changes. Suppose on the other wheel the camber is good, but you want to reduce the caster by 0.5 degrees. Moving a 1/32 inch shim from the front to the rear might give you the desired change. Actual changes will vary by make and model.

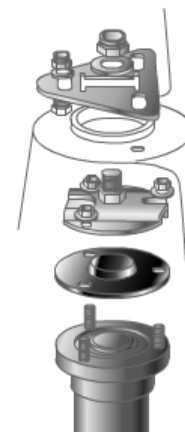


A similar strategy is used with vehicles that have eccentrics at the upper control arms, but the movement is obtained by rotating the cam. With practice, you can loosen the nuts enough to permit the desired movement of the cams without allowing them to move too far, or in the wrong direction under the weight of the vehicle. In some cases, you may have to unload the suspension to make the desired adjustments.



Upper control arm eccentrics

Some vehicles use an eccentric or an offset bushing at the ball joint to change caster, camber, or both, and some MacPherson strut systems permit changes to caster and camber at the upper strut mount. In addition to the method of loosening the upper mounting nuts and sliding the strut inward, outward, forward or back, on some strut systems the upper nuts are removed to drop the strut down. The upper mount is then rotated into another position and reinstalled. This type is an “either/or” adjustment with a limited range of settings.



Upper strut mount with slots for adjusting caster and camber



### Adjusting Toe

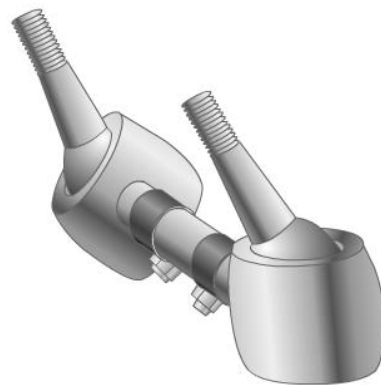
There are several methods used to adjust rear toe on front-wheel-drive vehicles, including tie rods, eccentrics, and shims. On vehicles that use shims, one shim placed between the back of the spindle and the axle is used to correct both camber and toe. Most vehicle manufacturers whose products may require rear shims specify the use of full contact shims, rather than "half" shims. Calculating which shim thickness and the correct orientation for the shim is simplified by using the computer alignment software, some of which will display templates and directions.

#### Selecting a Rear Shim



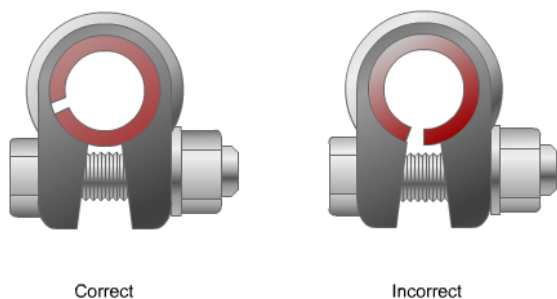
We have previously discussed that front toe is adjusted by lengthening or shortening the tie rod assemblies. A steering wheel holder is used to lock the steering wheel in place during adjustments. There are a few points to bear in mind when adjusting toe. With conventional linkage systems, it is possible to tighten the tie rod sleeves in such a way as to bind the tie rod ends.

The tie rod assembly is designed to pivot to allow for movement of the suspension. Before tightening a tie rod sleeve, ensure that both ball studs are either centered or pointing in the same direction in their sockets. When properly aligned, the assembly can rock forward and backward. On turnbuckle type sleeves, do not allow the gap in the sleeve clamp to align with the gap in the sleeve. The tie rod adjustment on most rack-and-pinion systems is secured with a jam nut.

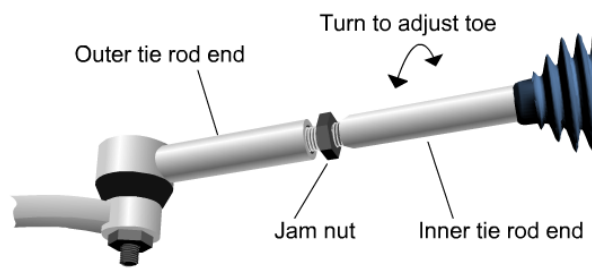


Tightening the tie rod assembly in this position will bind the tie rod ends.

#### Tie Rod Sleeve Gap



#### Rack-and-Pinion Tie Rod Assembly



Special tools are available for turning rusty or stubborn tie rod sleeves. The tool grips the edge of the sleeve's gap without squeezing the sleeve. Rack-and-pinion tie rods are solid and sometimes machined with flats for easier turning. A pipe wrench can be used to turn stubborn round tie rods.

#### Tie Rod Adjusting Tool



### Centering the Steering Wheel

When a vehicle is properly aligned, the steering wheel is centered while driving straight ahead. If the steering wheel is not centered, it can be corrected by adjusting the front toe. Use the alignment equipment to ensure that the thrust angle is correct and the front toe is evenly split, and then look at the steering wheel. It should point straight ahead. If it does not, straighten it and lock it in place with the steering wheel holder. Now, the equipment will indicate a great deal of toe-in on one front wheel and toe-out on the other. Adjust the tie rods for each side to bring them to the preferred setting for each wheel, and the steering wheel should now be centered when driving straight. On vehicles with power steering, start the engine and move the steering wheel back and forth a few times to center the steering before installing the steering wheel holder. Some manufacturers specify that the engine should be running while adjusting the toe.

If a centerline alignment shows a centered steering wheel on the rack, but produces a crooked steering wheel when driving straight, the thrust angle is off. To compensate for this and center the steering wheel, note the steering wheel position when driving straight and then set up the alignment equipment again. Turn the steering wheel an equal amount off center in the opposite direction, and install the steering wheel holder. The equipment will show a great deal of toe-in on one front wheel and toe-out on the other. Adjust the tie rods for each side to bring them to the preferred setting for each wheel, and the steering wheel should now be centered when driving straight.

### Alignment Tips and Strategies

#### If the Vehicle Pulls to One Side

We have noted that caster or camber that is out-of-spec, or too much spread in these angles can cause a pull. Several other conditions can also cause a pull.

- **Tires** - One of the most common causes of a pull to one side is actually the tires. Radial tires can set up a wear pattern in which the belts shift, squirm, or separate, causing a pull. Rotating the front tires from one side to the other and test driving the car can confirm if the tires are the cause. If the pull subsides or the vehicle pulls the other way, the tires are causing the pull. Low air pressure in one front tire, or tires of different sizes can also cause a pull.
- **Brakes** - If the pull worsens or occurs only during braking, the cause may be a sticking brake caliper or a restricted line.
- **Power steering** - Occasionally, a sticking or misadjusted spool valve or a restricted line can cause a pull. A pressure test may be necessary to confirm this.
- **Torque steer** - This condition can occur on front wheel drive vehicles with transverse engines and CV shafts of different lengths. It is characterized by a pull to one side when accelerating, and sometimes a pull in the other direction when decelerating. This condition can also be caused by front drive axles being at different heights, due to a loose or damaged sub-frame or other problem.
- **Bump steer** - If tie rods are at unequal heights, a vehicle may momentarily pull to one side when going over bumps. This may be caused by a bad or improperly installed idler arm.



- Some drivers may confuse an off-center steering wheel with a pull. Confirm the complaint with a test drive.

### Vibration

Chassis vibrations, especially at road speeds, are usually caused by out-of-balance wheel assemblies, or tire defects such as out-of-round. High frequency vibrations of this type can also be caused by driveline faults, such as a bent or out-of-balance drive shaft, or CV or universal joints that are worn or damaged. Brake rotors and drums that have thrown a balance weight can also cause a vibration. One thing that **does not** normally cause this type of vibration is wheel alignment settings.

In addition to the causes of shimmy previously discussed (such as bad or missing control arm bushings), a low-speed shimmy or "wobble" can be caused by a tire with broken or separated belts.

### Preferred Specs

Vehicle manufacturers provide a range of settings that are acceptable for each of the wheel alignment angles on their products. The preferred setting is in the middle of this range, or it may be specified, such as, "Front toe: 0.0 inch plus/minus 0.06 (1/16th)." We have noted that the preferred setting is a "best average" that assumes various operating conditions. The preferred specification may not always be the best setting on a particular vehicle. For example, a rear-wheel-drive vehicle that is seldom driven on the highway may get better tire wear with the front toe set at less than the preferred spec. An especially heavy driver may need less camber on the left front than called for. It's up to the alignment technician to read the tires and consider any other factors to determine the operating conditions of the vehicle and set the alignment angles accordingly.

## Unit 4: WHEELS AND TIRES

### Chapter 1: Wheel and Tire Design

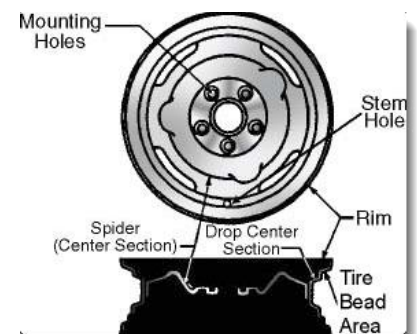
#### *Basic Wheel Construction*

Wheels are made from stamped steel or cast or forged aluminum or alloys.

A wheel consists of the following basic parts:

- Holes for the mounting wheel lugs
- Rim
- Hole for a valve stem
- Dropped center section
- Bead section

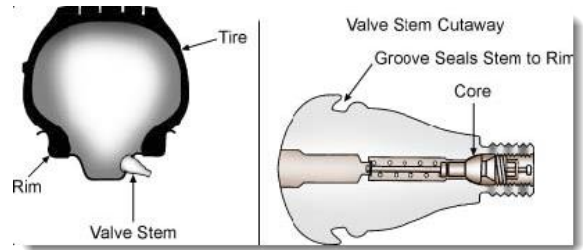
The wheel usually has between four and six mounting holes that connect the wheel to the wheel hub of the vehicle.



Wheel sizes are designated by the diameter of the wheel from bead to bead and also by the width of the wheel between the rim flanges. Common wheel diameters for passenger vehicles are 12 in, 13 in, 15 in, and 16 in.

### Many wheels have safety rims

The rims have a safety ridge near the lip of the wheel ridge that helps keep the tire from entering the inner depressed part of the wheel. This lip helps to prevent the bead from unseating if the vehicle corners hard or if the tire goes flat while the vehicle is moving.

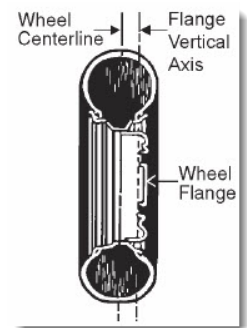


The inner depressed area allows for tire bead clearance; a tire machine is then used to stretch the other bead over the wheel ridge.

### Valve Stems

Valve stems are mounted into a wheel. This enables the addition or removal of air from the tire. If the valve stems are made from rubber, they snap into the hole. Other valve stems are made from metal that are held in place with a nut.

The valve core is located within the stem, allowing air to enter when inflating. A small return spring keeps a tight seal around the valve core.



### Wheel Offset

Factory-installed wheels are designed with proper clearance for brake and suspension components. Wheels are also designed to distribute the vehicle load evenly on the wheel bearings.

### Types of Wheel Designs

#### *Stamped steel wheels*

One type of automotive wheel design is made from stamped steel. The wheel consists of two pieces: the center and the rim.

The center section is riveted or spot welded to the rim (the outer portion). The mounting holes are tapered to match the tapered wheel nuts (lug nuts). The tapering helps to center the wheel on the wheel studs.

These wheels are commonly dressed out with a hubcap.

#### *Cast and forged wheels*

Many wheels today use lighter materials than steel such as aluminum and aluminum alloys due to the fact that lighter vehicles have better fuel efficiency.

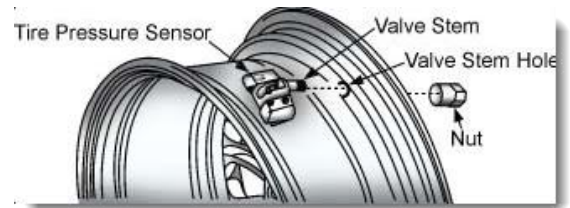
- Aluminum wheels usually have a high-quality finish, so the hubcaps are not normally used.
- The term "mag wheels" is commonly given to wheels made from magnesium or other alloys.

### ***Wheels with Tire Pressure Sensors***

In an effort to reduce accidents due to underinflated tires, the National Highway Traffic Safety Administration has issued legislation requiring all new passenger vehicles to be equipped with tire pressure monitoring systems.

Many tire pressure monitoring systems use battery-operated sensors that send radio signals to a receiver module. The basic operation of the system is as follows:

1. A tire pressure sensor, mounted on the rim and in the valve stem hole of all four wheels on the vehicle and the spare, senses tire pressure and temperature.
2. The sensors send the data about each tire to a receiver module. If the tire pressure goes below or above a certain level that is programmed in the system, the module sends a signal to a display on the dashboard to warn the driver.



#### **Basic components**

- Tire pressure sensors, which are composed of a transmitter, battery, valve stem with core and cap, mounting nut, and sealing grommet
- Electronic receiver module with dashboard console for digital display
- Special magnet tool for programming the tire pressure sensors

The following are the advantages of maintaining the proper tire pressure:

- Enhanced safety due to fewer tire blowouts and improved vehicle handling
- Better fuel economy
- Longer tire life

### ***Wheel Maintenance***

#### **Wheel offset**

When replacing a wheel or installing an aftermarket wheel, use a wheel that has the same offset (positive or negative) as the original.

Many aftermarket wheels have an offset that is different from the original factory wheel. A difference in the offset can affect wheel alignment, vehicle handling, and tire wear. A different offset could also affect weight distribution on the spindle and wheel bearings. This causes premature failure of these components.

#### **Wheel runout**

Always replace damaged wheels. Wheels can become damaged from accidents, age (rust), and hitting large potholes or curbs. Rims are measured for runout to determine if the wheel is out-of-round. Wheels can have lateral or radial runout. Lateral or radial runout is measured with a dial indicator. If the wheel runout exceeds the manufacturer's specifications, replace the wheel. Excessive wheel runout may cause the vehicle to shimmy or vibrate.

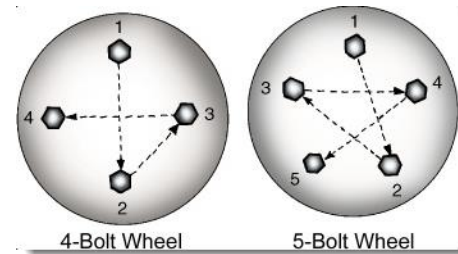
### Torque specifications

It is important to torque all wheels (steel or alloy) to the proper specifications for the following reasons:

- If the lug nuts are not tight enough, the wheel may fall off while it is driven.
- The lug nuts may vibrate loose. Once they are loose, the wheels can shear the studs off of the hub.
- If the lug nuts are too tight, the disc brake rotor may become distorted or warped.
- If the lug nuts are too tight, the driver may not be able to loosen the lug nuts with a hand lug wrench in an emergency.
- If the wheel studs or nuts become stripped, premature failure occurs.

**Note:** Lug nut torque specifications typically range from 80 ft-lb (foot-pounds) to 120 ft-lb, but always check the manufacturer's specifications.

Tighten the lug nuts in the correct sequence. Failure to do so could result in bending or warping the wheel, brake drum, or brake rotor.



When tightening the lug nuts, ensure that the taper of the lug nut is toward the wheel. Snug the lug nut up to the wheel and then tighten in the correct sequence and to the correct specifications with a torque wrench (manually) or with a torque stick (using pneumatic tools).

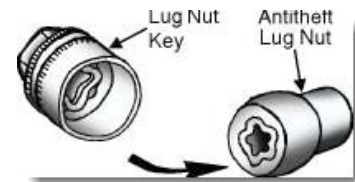
Torque sticks work in combination with a pneumatic (impact) wrench to install lug nuts. They are a set (usually four to eight pieces) of color-coded, long-shafted sockets. The shafts have a different diameter.

The thicker the shaft's diameter, the higher the torque provided. The manufacturer of the torque sticks provides an application chart for most vehicles.

### Antitheft lug nuts

**Antitheft lug nuts** are used on many cars today. Usually, one antitheft lug nut is used per wheel to prevent someone from stealing wheels and tires from a vehicle.

The manufacturer supplies a special lug nut key that loosens and tightens the antitheft lug nut.



## *Tire Design*

### Purpose and Basic Design of Tires

Automotive tires provide traction and absorb road shocks. They must perform well on a variety of road surfaces and in various driving conditions. Tires must provide traction on asphalt, concrete, gravel, and dirt. They must also function as effectively on wet or snow-covered roads as on dry roads.

Most of the tires used today are tubeless; however, some tube tires are still produced. In a tubeless tire, the tire and wheel retain air under pressure. A synthetic gum rubber liner is built into the tire to prevent air from leaking through the tire fabric.

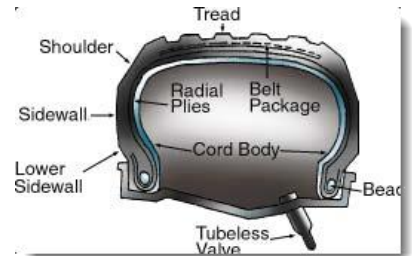
In tires using tubes, both the tire and an inner tube are mounted on a wheel. The tube is inflated and retains the air inside the tire. Tires with tubes are seldom used in today's cars and light trucks.

**Note:** Tire manufacturers use natural and synthetic rubber components in the construction of the tire.

### *Tire Construction*

The three basic types of cord body construction for passenger tires are bias, belted bias, and radial ply. All tire types have the following components: beads, cord body, tread, and sidewall.

**Beads** are bands of strong steel wire that fasten to the tire plies and are molded to the inner circumference of the tire. The beads hold the tire in position on the rim.



The **cord body** connects to the steel bead wires. The cord body consists of layers of rubber-impregnated fabric (plies). These layers are molded together in rubber to form the tire. The way the plies are assembled determines the design of the tire's construction (radial plies, belted bias, etc.). The number of plies determines the tire's load-carrying capacity.

The **tread** is the part of the tire that contacts the road. The tread rubber is molded directly to the cord body. Rubber is also molded to the cord body sidewalls. Manufacturers use varying tread designs and rubber compounds to comply to specific tire designs.

The **sidewall** connects the tread to the bead. The tire's sidewall is made from rubber compounds that absorb shocks and irregularities in the road. The flexibility in the sidewall gives the vehicle a smooth ride.

Tires are made from various compounds, as listed below:

- Fabric (steel, nylon, aramid fiber, fiberglass, polyester)

#### **Notes:**

- The sidewall rubber is not as thick as the rubber on the tread.
- The rubber compounds contain antioxidants that help prevent cracking from the sun's ultraviolet radiation.
- Rubber (natural and synthetic)
- Reinforcing chemicals (carbon black, silica, resins)
- Antidegradants (antioxidants)
- Adhesion promoters (cobalt salts, brass on wire, resins on fabrics)
- Curatives (cure accelerators, activators, sulfur)
- Processing aids (oils, tackifiers, peptizers, softeners)

### Cord Body Construction

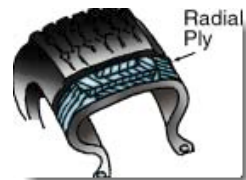
**Bias ply tires** consist of two or more plies placed one on top of another. The cords run in a crisscross (bias) pattern from bead to bead. Plies are constructed of rayon, nylon, polyester, etc.



**Belted bias tires** are constructed like bias ply tires, but they have two or more layers of tread-reinforcing plies or belts that wrap around the circumference of the tire under the tread. These belts do not extend to the sidewalls. They are positioned under the tread area only. The belts are usually constructed of fiberglass, rayon, or steel, and they allow for better wear and handling and increased puncture resistance.



In **radial ply tires**, the plies of the cord body run in straight lines parallel to each other and perpendicular to the beads. The plies are at right angles to the tire tread. Two or more belts, made of either fabric or steel, lay on top of the cord body under the tread section.



Radial ply tires are used on a majority of today's passenger cars. They offer better traction, increased tread life, and a softer ride at medium and high speeds. They also create less rolling resistance, a measurement of how much friction a tire produces as it rolls on the road. Lower rolling resistance allows for better fuel economy.

**Note:** Do not use both radial and bias ply tires on the same vehicle because these two types of tires have different handling characteristics.

### Specialty Tires: Compact Spares

A temporary-use spare is a type of compact spare tire that is most commonly supplied with passenger cars today. The compact spare tire takes up less space in the vehicle's trunk or luggage compartment than a full-size spare tire.

Temporary-use spares are designated with a T in the alphanumeric size. Inflation on temporary spares is usually about 60 psi, but the top speed is rated at only about 50 mph.

A space-saver spare is another type of spare tire that is supplied with the vehicle.



This type of tire is inflated with a special air compressor that comes with the vehicle. Normal inflation is about 35 psi. While inflating the tire, ensure that there are no folds in the sidewall of the tire.

A lightweight-skin spare is an additional type of spare tire that is included in the vehicle. This type of tire is a bias ply tire with a reduced tread depth. The estimated tread life is only about 2,000 miles.



**CAUTION:** Do not substitute compact spare tires for normal tires. They are not rated for the speed or distance of normal (passenger) tires. Use them only for emergencies. Drive the vehicle only a short distance and at reduced speeds until reaching a service facility.

### Other Specialty Tires

Some tire manufacturers are designing and producing **run-flat tires**. These tires, also called **extended mobility tires** (EMTs), eliminate the need for a spare and safety stands.

Run-flat tires have stiffer sidewalls that support the vehicle even if the tire loses its air pressure.

Automotive manufacturers that install these tires as normal tires usually install a tire pressure monitoring system on the vehicle. This system alerts the driver if a tire has lost or is losing pressure.

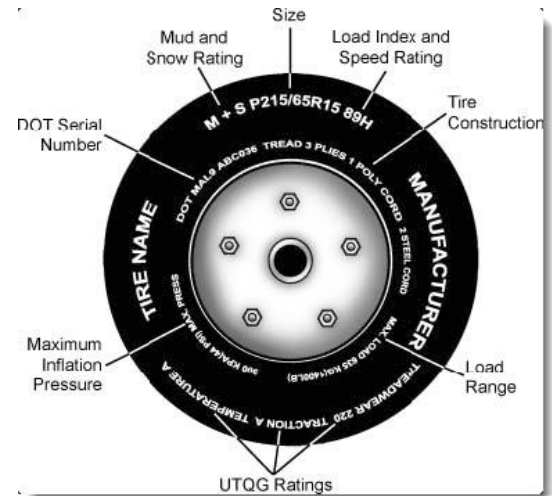
The driver can safely operate the vehicle on run-flat tires for about 125 miles with no air pressure to reach a service facility.

Another type of specialty tires is **self-sealing tires**. These have a special sealant lining on the inside of the tire that seals small punctures with diameters up to 3/16 in.

### Grades and Ratings

The **Uniform Tire Quality Grading Standards**, developed by the National Highway Traffic Safety Administration, are quality standards used for passenger car tires. These standards provide the criteria to rate tires in the categories of tread wear, traction, and ability to dissipate heat.

**Note:** A tire's rating in these various categories is molded into the tire's sidewall during its construction. The following graphic shows some of the information found on tires.



In the category of **tread wear** (length of tread life), each tire is assigned a grade number (e.g., 90, 100, etc.). The tread life increases as the number increases. For example, a tire with a grade of 180 should wear twice as long as one with a grade of 90.

The letters A, B, and C are used to rate a tire's ability to provide traction on wet roads. A tire with an A rating offers the best traction under wet conditions, whereas C offers minimum traction under wet conditions.

The letters A, B, and C are also used to indicate the tire's ability to dissipate or resist heat. A tire with a rating of A has the greatest ability to dissipate or resist heat, whereas a tire rated C has the least ability to resist heat.

### Speed Rating

A tire's speed rating indicates the maximum speed at which a tire can operate safely. Speed ratings are not valid if the tire is damaged, under- or overinflated, or overloaded. Letters are used to designate the maximum speed rating of the tire, as listed below.

- S 112 mph
- T 118 mph
- U 124 mph
- H 130 mph
- V 149 mph
- Z +149 mph

### Load Range

- A tire's **load range** is given to identify the maximum weight each tire size can carry.
- The P-metric system indicates load range in kilograms and pounds. The alphanumeric system indicates load range with letters.
- For cars and light trucks, the letters that designate a common load range are B, C, D, and E. Cars usually have a load range of B, whereas light trucks have tires with load ranges of C, D, or E.
- Some manufacturers use other designations: SL (standard load) and XL (extra load).

### Ply Rating

A tire's **ply rating** is a general indication of its load-carrying capacity.

The ply rating is molded into the tire's sidewall. Note that the rating number is not necessarily the same as the number of actual plies. For example, a tire with a two-ply sidewall may actually have a four-ply rating. A tire would receive this rating if it had the carrying capacity of four plies.

The following table represents common ratings that usually, but not always, correlate with each other. The maximum pressure (max press) listed below is measured in pounds per square inch (psi).

Common Comparisons for Car and Light Truck Radial Tires		
Load Range	Ply Rating	PSI Max Press
B	4	35
C	6	50
D	8	65
E	10	80

### Load Index and All-Season Tires

#### *Load index*

Some manufacturers use a new marking system to designate **load index**. These two- to three-digit numbers usually precede a speed-rating letter. The higher the load index number, the greater the load that the tire can carry. For example, a tire sidewall may have a marking of 90H. The 90 stands for the load index; the H stands for the speed rating.

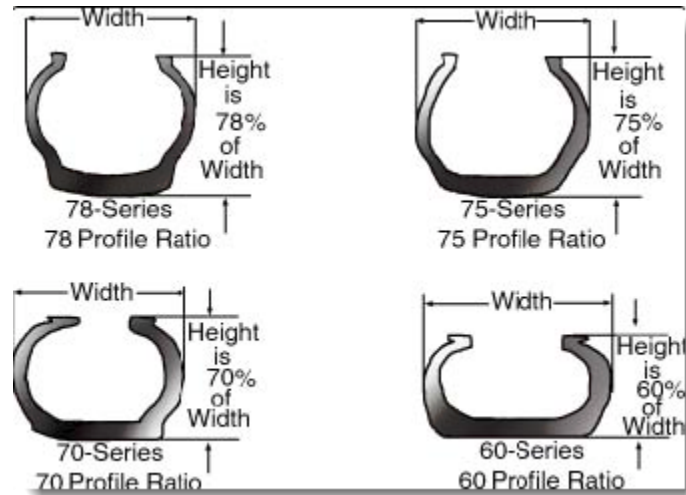
### All-season tires

Some tire manufacturers use the letters M and S to identify that the tire performs as required in mud or snow. Tires with this designation are commonly called **all-season tires**.

### Sizing

In order to understand tire sizing, it is first important to understand **aspect ratio**, which is the relationship of a tire's height to its width. Another term for aspect ratio is **profile**, or series. For example, a 70-series tire is 70% as tall as it is wide. The most common series are 60, 70, 75, and 80.

A combination of U.S. and metric units is used to designate most tires today. A common tire size is P225/60R16. Below is an explanation of the alphanumeric designations.



The first letter indicates the tire type.

- P = passenger car (as shown in the above example)
- T = temporary
- C = commercial
- LT = light truck

The next three digits indicate the section width in millimeters. In the example above, 225 = 225 millimeters. Section width is the measurement from the outer sidewall to the inner sidewall at the widest part of the tire when the tire is mounted and inflated.

The next two digits indicate the aspect ratio: section height/ section width. In the example above, the section height is 60% of the section width.

The next letter indicates the construction type.

- R = radial (as shown in the example cited)
- B = belted bias
- D = diagonal (bias)

The next digit indicates the rim diameter in inches. In the example cited, 16 in.

Alphanumeric sizing was once the accepted standard by which tires were sized. However, metric sizing eventually replaced this system. A typical alphanumeric size is FR70-15. Below is an explanation of what the letters and numbers mean.

- F = size range
- R = radial ply construction
- 70 = aspect ratio
- 15 = rim diameter in inches

### **Tire Placard**

Most vehicles have a placard that is permanently located on the vehicle. It is usually on the driver's door jamb. A placard example is shown below.

The driver and service technician should refer to the tire placard for tire information (e.g., inflation pressure, maximum vehicle load, and tire size).

GVWR		MFD BY		03/99	
2200KG(4850LB)		GAWR FRT		GAWR RR	
		1134XG(2500LB)		1225KG(2700LB)	
THIS VEHICLE CONFORMS TO ALL APPLICABLE U.S. FEDERAL MOTOR VEHICLE SAFETY AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.					
1GNCT18W4XK187526 TYPE: M.P.V.					
MODEL: T10516 PAYLOAD = 348KG(768LB)					
TPBS	TIRE SIZE	SPEED RTG	RIM	COLD TIRE PRESSURE	
FRT	P235/70R15	S	15X7J	220KPA(32PSI)	
RR	P235/70R15	S	15X7J	220KPA(32PSI)	
SPA	P235/70R15	S	15X7J	240KPA(35PSI)	
SEE OWNER'S MANUAL FOR MORE INFORMATION.					

### DOT/MOT number

Tires have a number designated by the DOT (U.S. Department of Transportation) or MOT (Canada Ministry of Transportation).

This number identifies where and when the tire was manufactured and identifies the tires for warranties and recalls.

### Tire Performance Criteria (TPC) specification

The TPC specification, molded on the sidewall, serves as a rating and identifier for original equipment tires on GM vehicles.

This specification ensures that the tire has met the size and performance standards (noise, handling, rolling resistance, traction, endurance, etc.) for the specific vehicle.

## **Chapter 2: Wheel and Tire Service**

### **Inflating and Inspecting Tires**

#### Inflating Tires

Tires should be inflated to the factory-recommended pressure. The recommended tire pressure for a vehicle's original equipment is found on the tire placard, which is usually located on the driver's door jamb. If the original tires have been replaced, use the tire manufacturer's specification.

Tire pressure should be checked while the tires are cool (at 50°F to 70°F). The tires are usually sufficiently cool after the car has been immobile for about 3 hours or if the car has been driven less than 1 mile.

**Note:** A tire reduces in air pressure about 1 pound per square inch (psi) for every 10° drop in temperature. In addition, a tire increases in air pressure about 1 psi for every 10° increase in temperature. When tires become hot because of driving, their pressure may increase as much as 6 psi.

Test the inflation pressure with a pencil-type tire gauge at least once a month or before a long trip. Also check the spare tire.

Procedure for checking tire pressure:

- Remove the cap from the valve stem.
- Press the tire gauge on the stem to obtain the pressure reading.
- Compare the reading to the pressure recommended by the vehicle manufacturer.
  - If the pressure is high, press the metal stem in the center of the valve to release air from the tire and recheck the pressure with the tire gauge. Repeat this step until the correct pressure is reached.
  - If the pressure is low, add air and recheck the pressure with the tire gauge. Repeat this step until the correct pressure is reached.
- Reinstall the valve stem caps.
- If stem extensions are used, make sure they are in place.

**CAUTION:** If stem caps and valves are not in place, dirt and moisture may enter the valve core, causing leaks.

Procedure for checking tire wear and condition

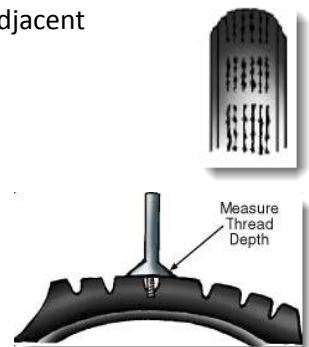
1. Use proper lifting equipment to raise the vehicle.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

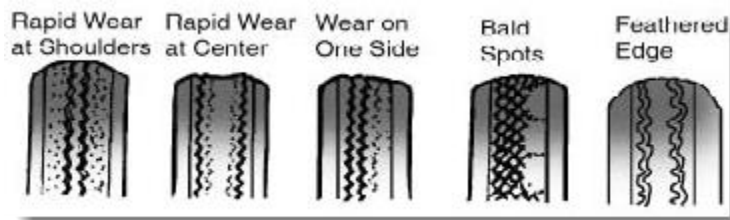
**Note:** Most tires have built-in tread wear indicators that appear as 1/2-in-wide bands when the tread is worn to 1/16 in.

2. Check the tread wear indicators. If the indicators appear in two or more adjacent grooves at three or more locations around the tire, replace the tire.

3. Use a tread depth gauge to measure the tire wear. This gauge usually indicates increments of 1/32 (1/16 in = 2/32 in).



4. Inspect the tires for exposed tread fabric. Replace any tire that has worn through the tread.
5. Inspect the tires for lumps or knots caused by broken or damaged tire plies. Replace tires that have lumps or knots.
6. Inspect tires for deep cuts, especially cuts that expose the fabric. Replace tires that have deep cuts.
7. Inspect tires for flat spots on the tread surface. The cause of flat spots is hard brake applications at high speeds or defective tire construction. Replace tires that have flat spots.
8. Inspect tires for foreign objects (nails, screws, etc.) that have penetrated the tire. If any of these objects are found, repair or replace the tire.
9. Inspect the tires for missing valve stem caps. If the stem caps are missing, replace them.
10. Inspect the tires for signs of tread separation. Separations resemble blisters on the tire's tread or sidewall.
11. Inspect the tires for broken or bent wheels. If there is damage, replace the wheel. To ensure the wheel is straight, manually spin each wheel-and-tire assembly and watch for excessive runout (wobble).
12. Inspect the tires for abnormal wear caused by overinflation, underinflation, lack of rotation, or incorrect wheel alignment.



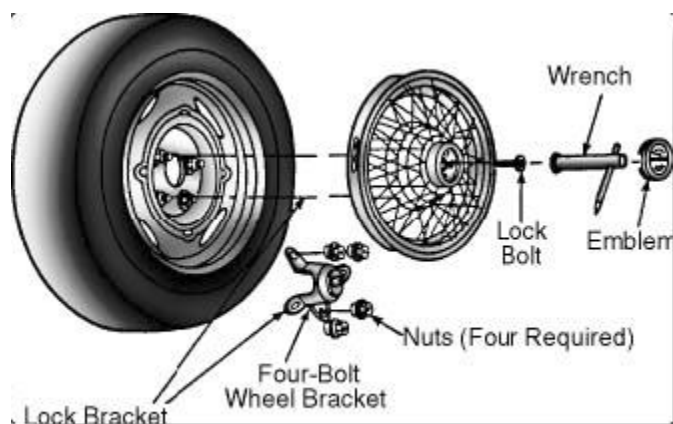
- Underinflation, lack of rotation, or hard cornering causes wear on the shoulders.
- Overinflation or hard acceleration causes wear in the center.
- Incorrect wheel alignment (camber) causes wear on one side.
- Bald spots occur when the tire is out of balance.
- Feathered edges result from incorrect wheel alignment (toe).

#### Procedure for removing the wheel-and-tire assembly

- Using a suitable prying tool, carefully pry off the wheel cover.

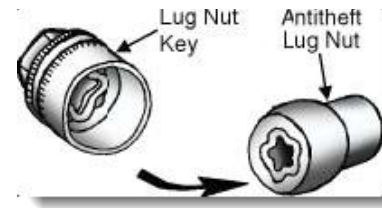
**Note:** If the wheel is equipped with a locking-type wheel cover, remove the trim cover from the lock bolt. Next, use a special wheel bolt wrench to remove the lock bolt.

**CAUTION:** Handle the wheel covers carefully to avoid injury and to avoid damaging the covers. Many wheel covers have very sharp metal edges. Consult the owner's information if the wheel covers are difficult to remove.



- Loosen the lug nuts one turn. If using an electric or pneumatic impact tool, skip this step and go to step C below.

**Note:** Some vehicles are equipped with one antitheft lug nut on each wheel. Use a special socket or key to remove the antitheft lug nut.



- Raise the vehicle until the tires are off the floor and then secure the vehicle.

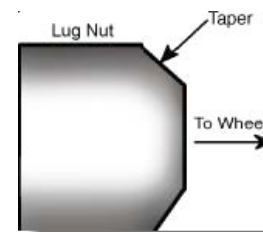
**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

- Remove the lug nuts and remove the wheel.

**CAUTION:** Torque sticks are designed for tightening lug nuts, not loosening them; using torque sticks to loosen lug nuts will damage the sticks. Use the correct size impact socket when using electric or pneumatic impact wrenches.

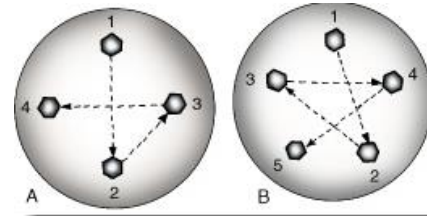
#### Procedure for installing the wheel-and-tire assembly

- Clean dirt and corrosion from the wheel hub mounting area and from the center pilot hole of the wheel.
- Place the wheel on the hub and install the lug nuts finger-tight.



**Note:** Make sure the tapered part of the lug nut goes toward the wheel.

- Using the proper wrench, tighten the nuts alternately to draw the wheel evenly against the hub. Shown below are the tightening sequences for (A) a four-bolt wheel and (B) a five-bolt wheel.
- If using an electric or pneumatic impact tool with torque sticks, tighten all lug nuts completely in an alternating pattern (or in a star pattern for five lug nuts).
- If tightening the lug nuts manually, lower the vehicle and finish tightening the lug nuts with a torque wrench to the manufacturer's specified torque rating.



**CAUTION:** To prevent rotor distortion, do not use an air wrench to replace lug nuts on hubs with disc brakes.

- Install the wheel cover.

**CAUTION:** To prevent damage to the wheel covers during installation, hit the cover only around the outer circumference with a soft-faced rubber mallet.

- If the wheel is equipped with a tire pressure monitoring system, perform the procedure to register the wheel with the system.

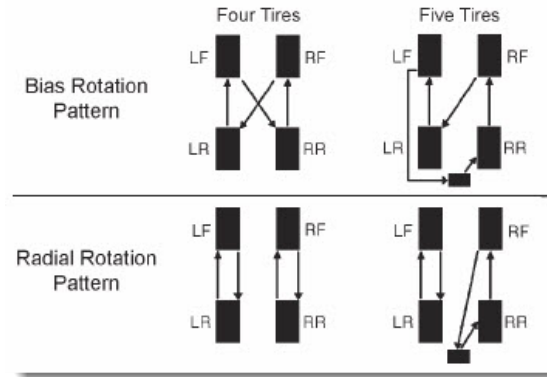
### Rotating the Tires

Rotating the tires, which involves moving the tires to a different location on the vehicle, lengthens the life of the tires. Because tires wear differently and at different rates, it is important to rotate them every 7,500 miles or at the intervals that the tire manufacturer specifies.

**CAUTION:** If abnormal tire wear is discovered during rotation, correct the cause before completing the rotation.

**Note:** If the spare tire is a full-size tire, include it in the rotation. Never include compact spare tires in the rotation.

Two popular types of tire rotation patterns are shown below.



### Procedures for rotating tires

**Note:** Tires can be rotated in various patterns; however, the rotation pattern must meet the tire manufacturer's recommendation. For example, some radial tires are unidirectional. This means that their rotation pattern resembles the bias rotation pattern more closely than a typical radial rotation pattern.

- Loosen the wheel-and-tire assemblies as described earlier in Section II.
- Raise and support the vehicle so that all four wheels are off the ground.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

- Rotate the wheel-and-tire assemblies in the chosen pattern.
- Inspect the condition of the tires during the rotation.
- Inspect the condition of the wheel studs and lug nuts. Replace any defective wheel studs or lug nuts according to the instructor's directions.

**CAUTION:** Some tires are directional. This means that they have a special tread designed to roll in only one direction. As a result, they should not be crossed from one side of the vehicle to the other. This type of tire normally has an arrow molded into the sidewall that indicates the direction of rotation.

**CAUTION:** Some wheels are directional. This means that they can rotate only in one direction. As a result, they should not be moved from one side of the vehicle to the other. The purpose of directional wheels is to help cool the brakes.

- Inflate all tires to the recommended pressure
- Install the wheel-and-tire assemblies as described in Section III.



**CAUTION:** To prevent rotor distortion, do not use an air wrench to replace lug nuts on hubs with disc brakes.

- If the wheels are equipped with a tire pressure monitoring system, perform the procedure to register the wheels with the system in their new location.

### *Mounting Tires and Repairing Punctures*

#### Procedure for Dismounting Tires

**CAUTION:** Dismount or mount tires only with a tire changing machine (also called a tire changer). Using tire irons or pry bars to mount or dismount tires can damage tire beads.

- Deflate the tire by removing the valve core with a valve core tool.
- Using wheel weight pliers, remove all wheel weights.
- Mount the wheel-and-tire assembly securely on a tire changer according to the instructions from the manufacturer of the tire changer.
- Break the beads loose from the rim according to the instructions from the manufacturer of the tire changer.
- To prevent bead damage and make removal easier, lubricate both beads with a tire rubber lubricant or a mild soapy water solution.



**Note:** Do not use a petroleum-based oil or silicone as a lubricant.

- Remove the tire beads according to the instructions from the manufacturer of the tire changer.

**CAUTION:** Failure to follow the tire changer's instructions carefully could result in serious personal injury.

**CAUTION:** To avoid bead damage, do not force the mounting tool or allow it to hang up on the tire beads.

#### Procedure for inspecting and mounting tires

- Clean the wheel. Both bead seats must be free of dirt and rust. Use a wire brush to clean the bead seats.
- Inspect the wheel for damage.

**Note:** Wheels that are cracked or obviously bent must be replaced. Wheels that are suspected of being bent or distorted should be tested for excessive runout.

- Inspect the valve stems according to the procedure outlined below.
  1. Bend the rubber valve stems from side to side and look for signs of deterioration or cracking.
  2. If the stems are defective, replace them.

**Note:** It is a good practice to replace the valve stems when mounting new tires.

3. Clean any rust or debris from the stem hole by using a wire brush from the inside of the wheel.

4. Apply a rubber lubricant or rubber sealer to the new stem and pull it through the hole. Use a special valve stem installer tool.
- Inspect the tire that requires mounting according to the following procedure.
    1. Inspect the condition of the tire beads. Discard tires that have badly torn or damaged beads.
    2. Inspect for punctures or damage to the tire tread or sidewall.
    3. Clean all foreign material from inside the tire.

- Lubricate both tire beads with a rubber lubricant or a mild soapy water solution.

**CAUTION:** Inadequate lubrication can damage beads or make installing and seating the beads difficult. Too much lubrication can cause the tire to slip on the rim.

**Note:** If the tire tread is directional, note the direction of the tread before mounting.

- Using the instructions provided by the manufacturer of the tire changer, mount the tire on the wheel.

**Note:** If the bead of the tire or wheel is pitted, add a liberal amount of tire bead sealer to both tire beads.

- Inflate and inspect the tire according to the procedure outlined below.
  1. Inflate the tire until both beads pop out on the rim.
    - a. Do not allow pressure to exceed 25 pounds per square inch (psi). Popping out the beads at pressures over 25 psi can damage the rim.
    - b. If the tire continues to inflate but does not pop, do not continue to add air. Deflate the tire. Break and relube the beads before continuing.

**CAUTION:** Keep fingers out and away from the bead seating area while popping up the beads.

2. After the beads have popped, continue to inflate the tire to 40 psi. Passenger car tires should never exceed 40 psi.

**Note:** This additional pressure helps to seat the beads properly on the rim.

3. Install the valve core and adjust the tire pressure to the recommended pressure.
4. Place some soapy water in the valve stem at the valve core. Bubbles in the water indicate leaks.

**Note:** Leaks around the valve core are fairly common. If leaks are discovered, loosen the valve core. Retighten and recheck the core. If it still leaks, replace the valve core and recheck for leakage.

5. Install the valve stem cap or valve stem extension.
6. Pour some soapy water around both tire beads. Bubbles in the water indicate leaks around the tire bead and wheel.

- Visually inspect the tire for uneven bead seating.

**Note:** The distance from the edge of the rim to the concentric rim-locating ring on the tire should be equal around the circumference of the tire. A tire that is not concentric with the rim cannot be balanced accurately and may have excessive runout. These conditions result in unacceptable performance.



**Note:** The concentric rim-locating ring is molded into the tire. The ring is visible just outside of the rim when the tire is mounted on the wheel.

- Check the distance from the edge of the rim on the wheel to the concentric rim locating ring on the tire.
- If the wheel and tire are not concentric, deflate the tire and break and reseal the beads.
- Rebalance the tire.

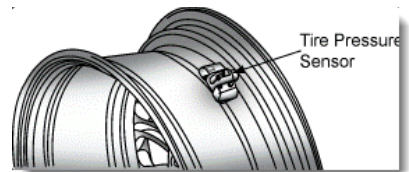
#### Procedure for dismounting a tire on a wheel equipped with a tire pressure sensor

**CAUTION:** Dismount or mount tires only with a tire changing machine (also called a tire changer). Using tire irons or pry bars to mount or dismount tires can damage tire beads.

- Deflate the tire by removing the valve core with a valve core tool. Retain the valve core for reinstallation.

**CAUTION:** The valve cores used for tire pressure sensors are specially made for the sensors. Replacing the valve cores with types that are not designed for the system may cause the sensors to corrode and malfunction.

- Using wheel weight pliers, remove all wheel weights.
- Procedures for dismounting a tire on a wheel with a tire pressure sensor vary. Use the vehicle manufacturer's instructions for dismounting the tire to ensure that the tire pressure sensor is not damaged.
- Mount the wheel-and-tire assembly securely on a tire changer according to the instructions from the manufacturer of the tire changer.
- Break the beads loose from the rim.
- To prevent bead damage and make removal easier, lubricate both beads with a tire rubber lubricant or a mild soapy water solution.



**Note:** Do not use a petroleum-based oil or silicone as a lubricant.

- Remove the tire beads according to the instructions from the manufacturer of the tire changer.

**CAUTION:** Failure to follow the tire changer's instructions carefully could result in serious personal injury.

**CAUTION:** To avoid bead damage, do not force the mounting tool or allow it to hang up on the tire beads.

[Procedures for inspecting and mounting a tire on a wheel equipped with a tire pressure sensor](#)

- Clean the wheel. Both bead seats must be free of dirt and rust. Use a wire brush to clean the bead seats.
- Inspect the wheel for damage.

**Note:** Wheels that are cracked or obviously bent must be replaced. Wheels that are suspected of being bent or distorted should be tested for excessive runout.

- Inspect the valve stem of the tire pressure sensor according to the procedure outlined below.
  1. Bend the rubber valve stems from side to side and look for signs of deterioration or cracking.
  2. In the tire pressure monitoring systems that are currently being installed by most manufacturers, the valve stem is part of the sensor. If the valve stem is damaged or defective, the tire pressure sensor will have to be replaced.

**CAUTION:** The valve stems used for tire pressure sensors are specially made for the sensors. Replacing the valve stems with types that are not designed for the system may cause the sensors to corrode and malfunction.

**CAUTION:** Do not use a rubber sealant to install the new stem because sealant can clog the pressure sensor.

**Note:** Some early tire pressure sensors are located in the center of the rim and do not use the valve stem as a part of the system. On those systems, the valve stems are serviced normally.

3. Before installing the valve stem, clean any rust or debris from the stem hole by using a wire brush from the inside of the wheel.
- Inspect the tire that requires mounting according to the following procedure.
    1. Inspect the condition of the tire beads. Discard tires that have badly torn or damaged beads.
    2. Inspect for punctures or damage to the tire tread or sidewall.
    3. Clean all foreign material from inside the tire.
  - Lubricate both tire beads with a rubber lubricant or a mild soapy water solution.

**CAUTION:** Inadequate lubrication can damage beads or make installing and seating the beads difficult. Too much lubrication can cause the tire to slip on the rim.

**Note:** If the tire tread is directional, note the direction of the tread before mounting.

- Procedures for mounting a tire on a wheel with a tire pressure sensor vary. Use the vehicle manufacturer's instructions for mounting the tire to ensure that the tire pressure sensor is not damaged.

- Mount the tire on the wheel.
- Inflate and inspect the tire according to the procedure outlined below.
  1. Inflate the tire until both beads pop out on the rim.
    - a. Do not allow pressure to exceed 25 pounds per square inch (psi). Popping out the beads at pressures over 25 psi can damage the rim.
    - b. If the tire continues to inflate but does not pop, do not continue to add air. Deflate the tire. Break and relube the beads before continuing.

**CAUTION:** Keep fingers out and away from the bead seating area while popping up the beads.

2. After the beads have popped, continue to inflate the tire to 40 psi. Passenger car tires should never exceed 40 psi.

**Note:** This additional pressure helps to seat the beads properly on the rim.

3. Install the valve core and adjust the tire pressure to the recommended pressure.

**CAUTION:** The valve cores used for tire pressure sensors are specially made for the sensors. Replacing the valve cores with types that are not designed for the system may cause the sensors to corrode and malfunction.

4. Install the valve stem cap or valve stem extension.

**CAUTION:** The valve caps used for tire pressure sensors are specially made for the sensors. Replacing the valve caps with types that are not designed for the system may cause the sensors to corrode and malfunction.

5. Pour some soapy water around both tire beads. Bubbles in water indicate leaks around the tire bead and wheel.

- Visually inspect the tire for uneven bead seating.

**Note:** The distance from the edge of the rim to the concentric rim-locating ring on the tire should be equal around the circumference of the tire. A tire that is not concentric with the rim cannot be balanced accurately and may have excessive runout. These conditions result in unacceptable performance.

**Note:** The concentric rim-locating ring is molded into the tire. The ring is visible just outside of the rim when the tire is mounted on the wheel.

1. Check the distance from the edge of the rim on the wheel to the concentric rim locating ring on the tire.
2. If the wheel and tire are not concentric, deflate the tire and break and reseal the beads.

- Rebalance the tire.

- Use a special tool to register the tire pressure sensor with the tire pressure monitoring system. See the next section for this procedure.

**Note:** All the tire pressure sensors on the vehicle may need to be registered, not just one. Consult the manufacturer's instructions.

Procedure for inspecting, diagnosing, and calibrating a tire pressure monitoring system

- Check the accuracy of the tire pressure monitoring system by performing the following steps on each wheel.
  1. Check the air pressure in the tire with an air gauge that is known to be accurate.
  2. If the gauge and system readings do not match within specifications, reregister the wheel with the system and perform step 1 again.
  3. If the gauge and system readings still do not match, replace the tire pressure sensor.

Procedure for replacing the tire pressure sensor.

1. Remove the wheel-and-tire assembly from the vehicle.
2. Dismount the tire from the wheel using the procedure outlined in Section III.

**Note:** The following steps for replacing the tire pressure sensor are general. Consult the appropriate service information for the procedure that applies to the specific vehicle.

3. Remove the nut that retains the sensor to the wheel and remove the sensor from the wheel.
  4. Replace the sealing grommet at the base of the valve stem.
  5. Clean the area where the grommet contacts the wheel, making sure the wheel surface is not damaged.
  6. Install the new pressure sensor on the wheel.
  7. Install the retaining nut and tighten it to the torque specified by the manufacturer.
- Mount the tire on the wheel using the procedure previously outlined.
  - Rebalance the tire.
  - Install the wheel-and-tire assembly on the vehicle.
  - Reregister the tire pressure sensors with the tire pressure monitoring system.

**Note:** The following steps for registering the tire pressure sensors are general. Consult the appropriate service information for the procedure that applies to the specific vehicle.

1. Place the magnet tool, which is supplied with the system, over the wheel's valve stem.
2. Access the correct menu in the computer module and register the wheel with the system at the proper location on the vehicle.
3. Move the magnet to each of the other wheels, including the spare, and register them in the same manner.
4. Exit the program after the module displays that the procedure is complete.
5. Use an accurate gauge to check the air pressure in each tire and ensure that the readings match those from the tire pressure monitoring system within specifications.

Procedures for repairing a tubeless tire with the patch-plug and patch methods

**Note:** Use step A through step F and then step G for the patch-plug method or step H for the patch method.

**CAUTION:** Plug repairs or aerosol sealants provide only temporary repair. To achieve permanent tire repairs, use one of the following procedures.

- If a tire is suspected of having a leak, inflate the tire to the maximum recommended pressure. Immerse the tire in a tank of water or apply a soapy water solution to all areas of the tire. In either case, bubbles will appear at the leak.

**Note:** In addition to the tire, the cause of leakage is sometimes from the valve stems, valve cores, and wheels.

- After locating the puncture, mark the hole with a tire crayon and then dismount the tire.
- Remove the foreign object that caused the puncture if the object is still in the tire.
- Dismount the tire and mount it in a tire-spreading tool.
- Inspect the tire for damaged beads. Discard the tires with badly torn beads.
- Inspect the tire for cuts, exposed cord, separations, etc., as previously described.

**Note:** It is possible to permanently repair punctures and nail holes that have a diameter up to 1/4 in and that are confined to the tread area. These repairs can be made only from inside the tire. Never repair tires worn below 1/16 in. The illustration below shows the normal repairable area of a tire.



**Note:** The following is the final step if using the patch-plug method.

Installing a patch-plug

1. Clean out the puncture with a tungsten carbide rod tool.



2. Buff the area with a tungsten carbide buffing wheel driven by a 3/8-in drill or pneumatic tool. Buff to achieve a finely grained bonding surface.



3. Do not burn the rubber with the buffing wheel. Do not buff until the cord body is exposed through the inner rubber lining.
4. Clean the buffing dust from the inside of the tire.

**Note:** Do not use a petroleum solvent to clean the buffed area. Petroleum may neutralize the chemicals in the patching cement.

5. Apply an even coat of patching cement to the puncture and the buffed area. Allow the cement to dry thoroughly.



6. Select a patch-plug that has a stem slightly larger than the puncture. Remove the protective backing from the patch-plug.

7. Coat the patch-plug with cement and insert it through the puncture. Use a special installation tool to pull the plug through the hole. Pull until the base of the patch presses against the tire.



8. Bond the patch firmly to the tire by rolling over the patch with a patch wheel. Keep the strokes close together to avoid trapping air under the patch.



9. Cut off the protruding end of the plug approximately 1/8 in above the tread surface.



10. Remount the tire and check the repair for leaks by either immersing it in a water tank or applying soapy water to the punctured area.
11. Rebalance the tire.

**Note:** When repairing radial tires, use only patches or patch-plugs that are designated for radial tires.

- Installing a tire patch

**Note:** Repairing a tire with a patch is similar to repairing it with a patch-plug.

1. Buff the inner surface of the tire in the same manner as described in the patch-plug method. Clean the buffing dust from the tire.
2. Probe the tire to ensure nothing is still in the puncture.

**CAUTION:** Do not use a tungsten carbide rod as described in the patch-plug procedure; doing so enlarges the puncture.

3. Coat the buffed area with patching cement and allow it to dry.
4. Peel the protective backing from the patch and center it over the puncture. Bond the patch carefully to the tire.
5. Remount the tire and check the repair for leaks by either immersing it in a water tank or applying soapy water to the punctured area.
6. Rebalance the tire.



### Principles of Wheel Balance and Runout

**Measuring Tire Runout**



**Reading Tire Runout**

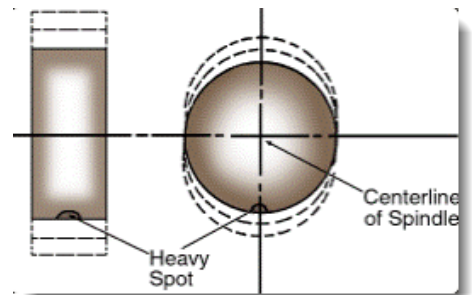


#### Static and dynamic balance

- If a wheel-and-tire assembly is heavier at one point than another, the assembly is said to be out of balance.
  1. Imbalanced wheel-and-tire assemblies result in a rough ride.
  2. Imbalanced wheel-and-tire assemblies also shorten the life of the tires and damage steering and suspension components.
  3. Tires can be balanced by using either the static method or the dynamic method.

#### Static balance

1. Static balance means the weight of the wheel-and-tire assembly is distributed equally around the axis of wheel rotation (the spindle).
  - a. If a wheel-and-tire assembly is in static balance, the wheel has no tendency to rotate on its own, regardless of its position.
  - b. If the wheel-and-tire assembly is not statically balanced, the assembly rolls on its own until the heavy spot is at the bottom.
2. A statically out-of-balance wheel-and-tire assembly tramps or hops as the car moves down the road.



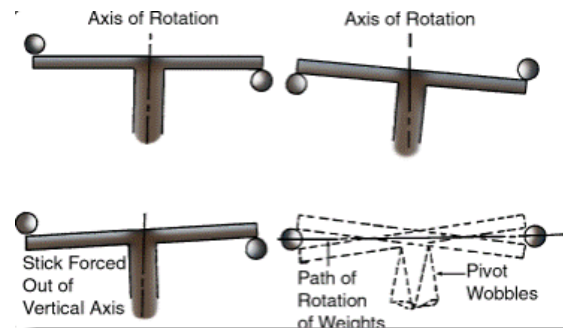
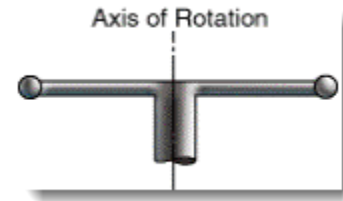
- a. The speed at which the tramp occurs depends upon the degree to which the wheel is out of balance.
- b. The greater the imbalance, the lower the speed at which the tramp is noticed.

#### Dynamic balance

1. Dynamic balance can be defined as balance in motion. If a wheel-and-tire assembly is in dynamic balance, it must also be in static balance. However, a wheel-and-tire assembly that is balanced statically is not necessarily balanced dynamically.

2. To achieve dynamic balance, weight must be distributed equally around the axis of rotation. Weight must also be distributed equally in regard to the centerline of the wheel-and-tire assembly. Listed below are some principles of dynamic balance.

- a. Imagine a stick with equal weights attached to each end. Imagine this same stick attached to a pivot, as shown in the illustration below. If the stick is spun around, the path of its rotation is at a right angle to the pivot (axis of rotation).
- b. If the weights are shifted, as shown in the illustration below, the stick remains in static balance. However, if the stick is spun with the weights in their shifted position, the stick is forced out of its axis of rotation due to dynamic imbalance. The stick tends to wobble each half revolution due to the heavy weights attempting to line up with the center of rotation.



- c. To compensate for this dynamic imbalance, weight must be placed equally around the centerline of the stick. In the case of an automobile wheel, the same is true: weights must be placed around the centerline of the tire, as indicated in the illustration below.



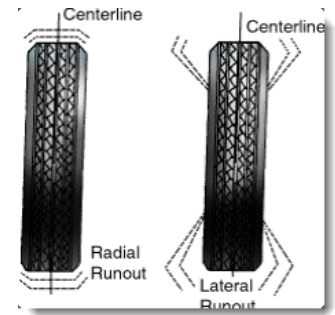
- d. Correcting the dynamic balance of the tire also corrects any static imbalance.

### Wheel Runout

- When wheel tramp or vibration is evident, the cause must be determined before corrective action can be taken. In addition to improper balance, radial or lateral wheel runout may be causing the tramp or vibration.

**Note:** When wheel tramp or vibration is evident, it is advisable to check runout before balancing a wheel.

- In a wheel-and-tire assembly with radial runout, the distance from the spindle to the ground changes as the assembly rotates, thus causing the assembly to hop or tramp. A wheel-and-tire assembly with excessive radial runout is commonly referred to as being out-of-round.
- Lateral runout is a sideways wobble of the wheel-and-tire assembly. The wobble occurs as the assembly rolls. Lateral runout is often referred to as shimmy. If the front wheels have lateral runout, the steering wheel may oscillate.



### Testing for and Correcting Runout

#### Procedure for testing a wheel-and-tire assembly for radial runout (out-of-round)

**Note:** Before testing runout, the vehicle should be driven. Driving the vehicle warms the tires and eliminates any irregularities that may have developed as a result of the vehicle being stationary.

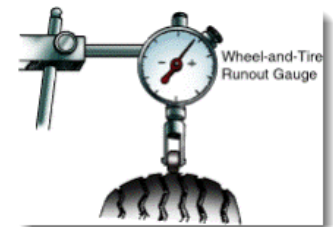
**CAUTION:** Drive the vehicle only with the instructor's approval.

**Note:** Check and, if necessary, correct wheel bearing adjustment.

- Raise and secure the vehicle. Make sure the tires are raised 3 in to 4 in off the floor.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

- Position the wheel-and-tire runout gauge (a dial indicator with a roller attached to the plunger) on the center rib of the tire.
- Rotate the wheel one full revolution and zero the runout gauge at the low spot of the wheel-and-tire assembly.
- Rotate the wheel again and mark the high spot on the tread. Also mark the wheel bolt nearest the high spot on the tire.



**Note:** The specification for radial runout is usually no more than .125 in. Check the proper service information for the vehicle to be serviced.

- If radial runout is within specifications, perform the lateral runout test. Refer to the information on lateral runout tests found later in this lesson.
- If radial runout is not within specifications, perform the following procedure.
  1. Unbolt the wheel and rotate it two studs on the hub. Repeat the steps on the previous page where you marked the wheel.



2. If, after performing the previous steps, you find that runout is still excessive, mark the location of the new high spot on the tire.

- a. If this second high spot mark is near the first high spot mark, either the wheel or the tire is causing the runout. Match mount the tire and wheel. (Refer to the match mounting information presented later in this lesson.)
- b. If the second high spot mark lines up with the first wheel stud mark, the hub or the hub assembly is defective. Replace the defective components.

Procedure for testing a wheel-and-tire assembly for lateral runout (wobble)

**Note:** Before testing runout, the vehicle should be driven. Driving the vehicle warms the tires and eliminates any irregularities that may have developed as a result of the vehicle being stationary.

**CAUTION:** Drive the vehicle only with the instructor's approval.

**Note:** Check and, if necessary, correct wheel bearing adjustment.

- Raise and secure the vehicle. Make sure the tires are raised 3 in to 4 in off the floor.

**CAUTION:** When lifting a vehicle, always use proper lifting equipment and observe all safety precautions.

- Position the wheel-and-tire runout gauge (a dial indicator with a roller attached to the plunger) on the tire sidewall. Make sure it is as close to the tire shoulder as possible without interference from the markings on the outside of the tire.



- Rotate the wheel one revolution. Mark the low spot on the tire and zero the gauge.
- Rotate the wheel again and mark the high spot on the tread. Also mark the wheel bolt nearest the high spot on the tire.

**Note:** The specification for lateral runout is usually no more than .060 in. Check the proper service information for the vehicle to be serviced.

- If lateral runout is within specifications, the lateral runout test is complete.

**Note:** If both radial and lateral runout are within specifications, the wheel-and-tire assembly should be balanced.

- If lateral runout is not within specifications, perform the procedure outlined below.
  1. Unbolt the wheel and align the low spot mark on the tire as closely as possible to the wheel bolt that was marked as the high spot.
  2. Repeat the steps above where you rotate the tire, marking the low and high spots.
  3. If, after marking the spots, you can tell that lateral runout is still excessive, mark the location of the new high spot on the tire.

- a. If this second high spot mark is near the first high spot mark, either the wheel or the tire is causing the runout. Match mount the tire and wheel. (Refer to the match mounting information presented later in this lesson.)
- b. If the second high spot mark is near the low spot marked in the first observation, the hub or hub assembly is defective. Replace the defective components.

#### Procedure for checking the wheel for lateral and radial runout

- A. Remove the wheel from the vehicle and dismount the tire.
- B. Reinstall the wheel on the vehicle and tighten wheel nuts evenly to the specified torque.
- C. Place the dial indicator on the vertical and horizontal bead seats and measure the lateral runout and then the radial runout while rotating the wheel.
- D. If the runout is excessive when compared to specifications, replace the wheel.

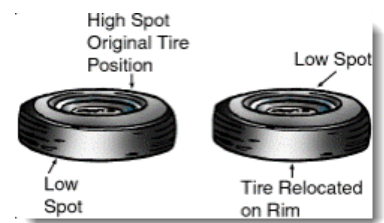
**Note:** The specification for wheel lateral and radial runout is usually half the wheel-and-tire assembly specified tolerance.

#### Procedures for match mounting a wheel-and-tire assembly

**Note:** The procedure for match mounting a wheel-and-tire assembly is the same for correcting both radial and lateral runout.

**Note:** Most new tires come with a yellow dot on the sidewall. Match the yellow dot with the valve stem hole.

- Mark the runout high spot on the wheel and tire.
- Using a tire changing machine (also called tire changer), deflate the tire and break the beads loose.
- Measure the lateral and radial runout of the wheel as described earlier in this lesson. If the wheel is defective, replace it.
- Rotate the tire on the rim 180° from its original position. Inflate the tire to the specified pressure.
- Install the wheel on the vehicle and recheck the runout. If runout is within specifications, proceed with balancing the tire. If runout is still excessive, the tire must be replaced.



### **Correcting Imbalance**

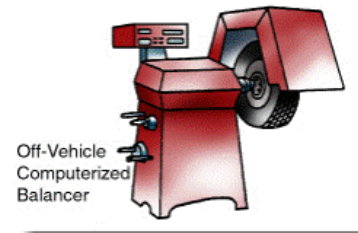
#### Balancing a wheel-and-tire assembly

- Wheel imbalance is corrected by determining the location of the imbalance and then determining where to place weights to correct the imbalance.
- Two types of wheel balancers are the bubble balancer and the off-vehicle computerized balancer.
  1. A bubble balancer can achieve only a static balance. It works much like a carpenter's level.

- a. If the tire has a heavy spot, the balancer tilts and throws the bubble off center. (The bubble moving out of a circle on the balancer indicates off center.)
- b. Weight is then applied at various positions on the tire. When the proper amount of weight is added at the proper locations, the bubble moves back into the center of the circle.



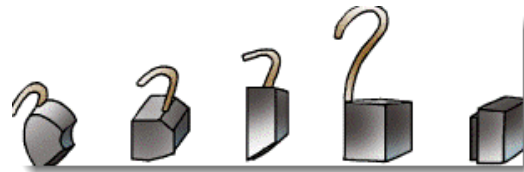
2. An off-vehicle computerized balancer is the most commonly used balancer today.
  - a. This type of balancer corrects both static and dynamic imbalance.
  - b. The computerized balancer is simple to operate and achieves a high degree of accuracy. After spinning the wheel-and-tire assembly, the balancer indicates how much weight is needed and where the weight should be placed.



### Wheel weights

1. Wheel weights are made of lead. Wheel weights range from 1/4 oz to several oz and are usually marked in both ounces and grams.
2. Wheel weights are usually attached to the rim by steel clips, which are molded into the lead weight. Stick-on weights are also available for custom wheels. The illustration below shows some of the various types of weights available.

**Note:** It is important to use the correct type of weights that correspond to the wheel design. Using incorrect types of weights may cause them to fall off the wheel after the vehicle is driven.



### Procedure for balancing wheels

1. Before balancing tires with any type of balancer, clean any foreign material from the tire tread and wheel assembly. Even small pebbles can affect wheel balance.
2. Inspect the tire condition. Discard tires with tread worn to 1/16 in or less. Also discard tires with bulges, separations, or other obvious damage.
3. Remove all old wheel weights.
4. Balance the wheel according to the directions provided by the manufacturer of the balancer.
5. Install weights securely on the wheel. Loose weights can fly off while the car is moving.
6. Recheck wheel balance after weights are installed.