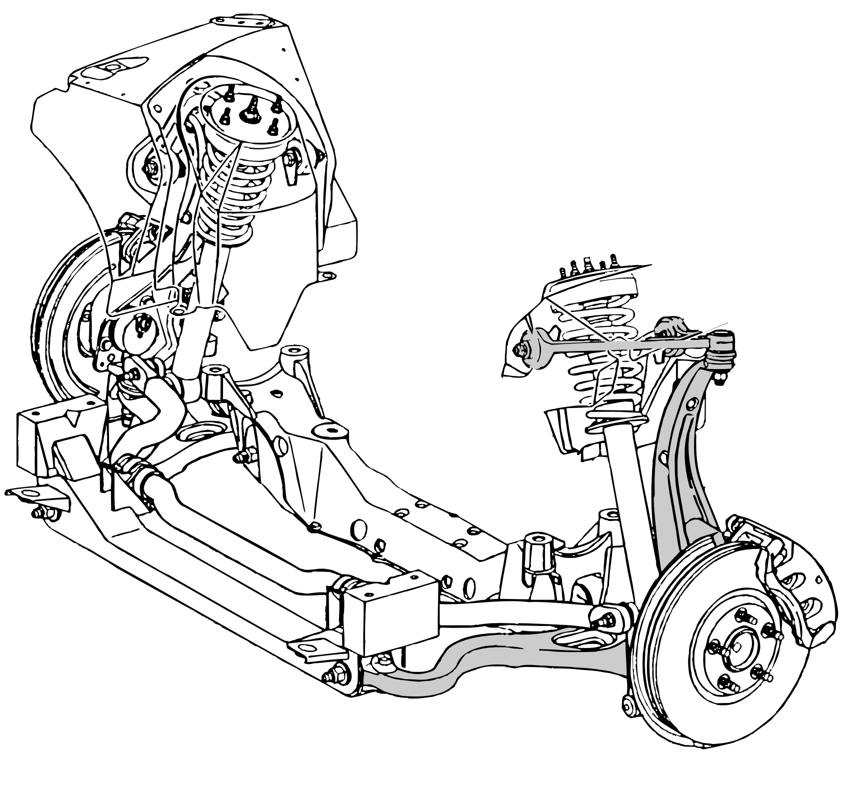
Technical Service Training

Global Fundamentals

Curriculum Training – TF1010010S

Steering and Suspension Systems



Student Information

Ford Motor Company

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FCS-13196-REF CG7966/S 05/2001

Global fundamentals training overview

The goal of the Global Fundamentals Training is to provide students with a common knowledge base of the theory and operation of automotive systems and components. The Global Fundamentals Training Curriculum (FCS-13203-REF) consists of nine self-study books. A brief listing of the topics covered in each of the self-study books appears below.

- Shop Practices (FCS-13202-REF) explains how to prepare for work and describes procedures for lifting materials and vehicles, handling substances safely, and performing potentially hazardous activities (such as welding). Understanding hazard labels, using protective equipment, the importance of environmental policy, and using technical resources are also covered.
- Brake Systems (FCS-13201-REF) describes the function and operation of drum brakes, disc brakes, master cylinder and brake lines, power-assist brakes, and anti-lock braking systems.
- Steering and Suspension Systems (FCS-13196-REF) describes the function and operation of the power-assisted steering system, tires and wheels, the suspension system, and steering alignment.
- Climate Control (FCS-13198-REF) explains the theories behind climate control systems, such as heat transfer and the relationship of temperature to pressure. The self-study also describes the function and operation of the refrigeration systems, the air distribution system, the ventilation system, and the electrical control system.
- Electrical Systems (FCS-13197-REF) explains the theories related to electricity, including the characteristics of electricity and basic circuits. The self-study also describes the function and operation of common automotive electrical and electronic devices.
- Manual Transmission and Drivetrain (FCS-13199-REF) explains the theory and operation of gears. The self-study also describes the function and operation of the drivetrain, the clutch, manual transmissions and transaxles, the driveshaft, the rear axle and differential, the transfer case, and the 4x4 system.
- Automatic Transmissions (FCS-13200-REF) explains the function and operation of the transmission and transaxle, the mechanical system, the hydraulic control system, the electronic control system, and the transaxle final drive. The self-study also describes the theory behind automatic transmissions including mechanical powerflow and electro-hydraulic operation.
- Engine Operation (FCS-13195-REF) explains the four-stroke process and the function and operation of the engine block assembly and the valve train. Also described are the lubrication system, the intake air system, the exhaust system, and the cooling system. Diesel engine function and operation are covered also.
- Engine Performance (FCS-13194-REF) explains the combustion process and the resulting emissions. The self-study book also describes the function and operation of the powertrain control system, the fuel injection system, the ignition system, emissions control devices, the forced induction systems, and diesel engine fuel injection. Read Engine Operation before completing Engine Performance.

To order curriculum or individual self-study books, contact Helm Inc.
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Mail: 14310 Hamilton Ave., Highland Park, MI 48203 USA
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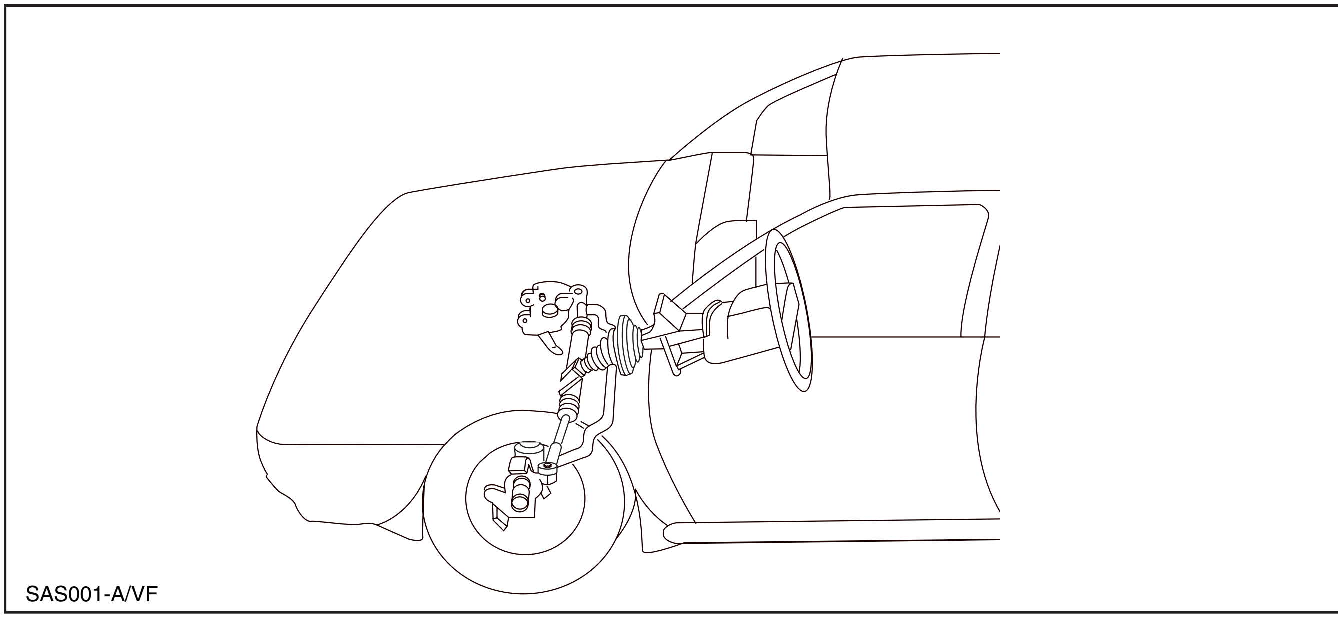
Objectives

Upon completion of this lesson, you will be able to:

- Describe the purpose and function of the steering system.
- Describe the steering system and identify the types of steering systems.
- Identify steering system components.
- Explain the theory and operation of the steering system.

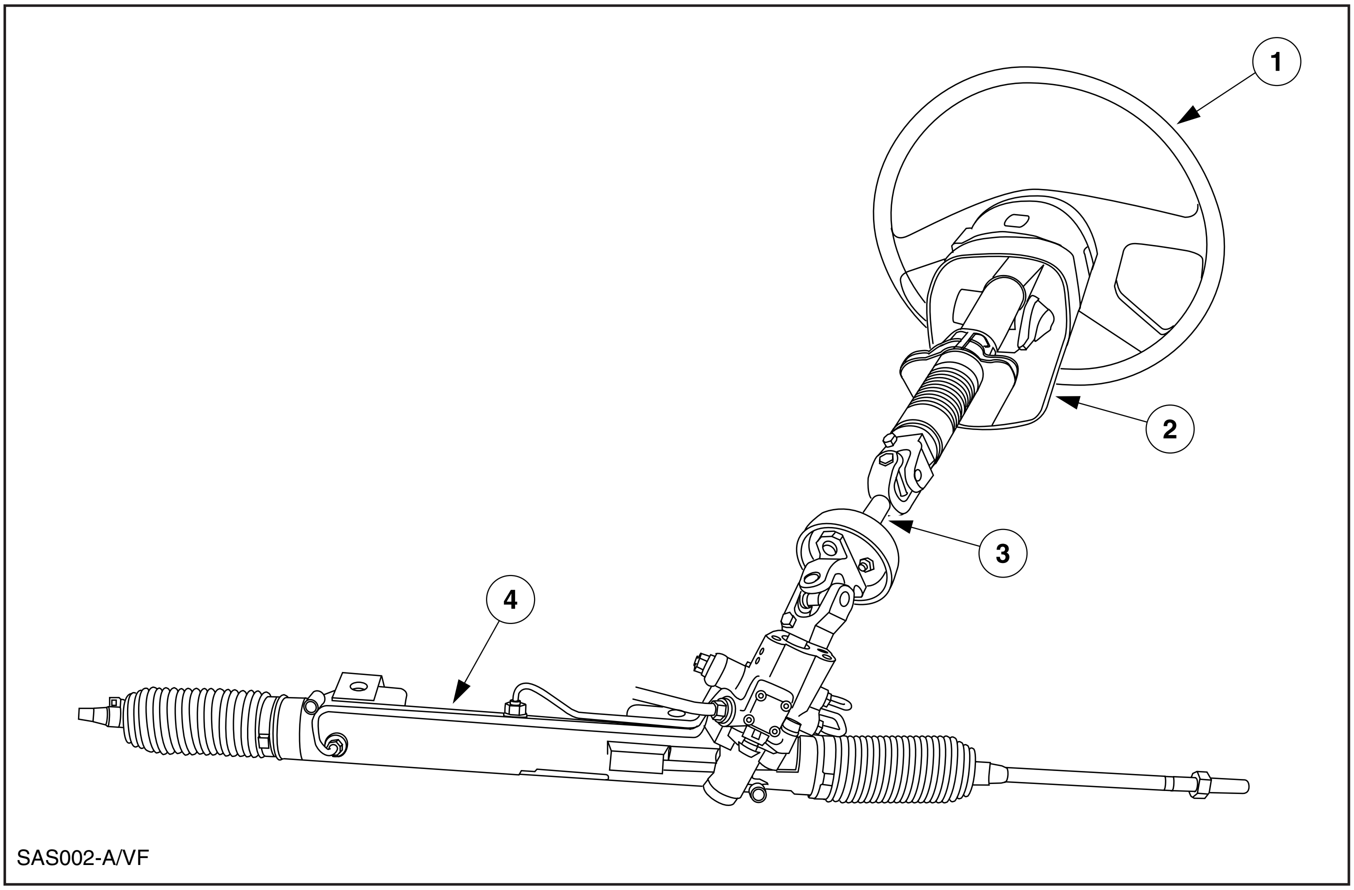
The steering system



Steering system location

The steering system allows the driver to control the direction of the vehicle. A series of linkages connect the steering wheel to the wheels and tires.

Steering system operation



Steering system

1 Steering wheel
2 Steering column
3 Steering column shaft
4 Steering gear

When the driver turns the steering wheel, the steering column shaft rotates the input shaft of the steering gear. The steering gear passes the motion of the steering wheel through the steering linkage to the front wheels. Vehicle direction changes when the driver turns the steering wheel.

To make steering easier for the driver, most new vehicles have power steering. Power steering uses hydraulics or fluid pressure to assist the steering system. Power steering is very helpful when parking or making quick turns. Power steering is used on the two most common steering systems: rack and pinion and recirculating ball type.

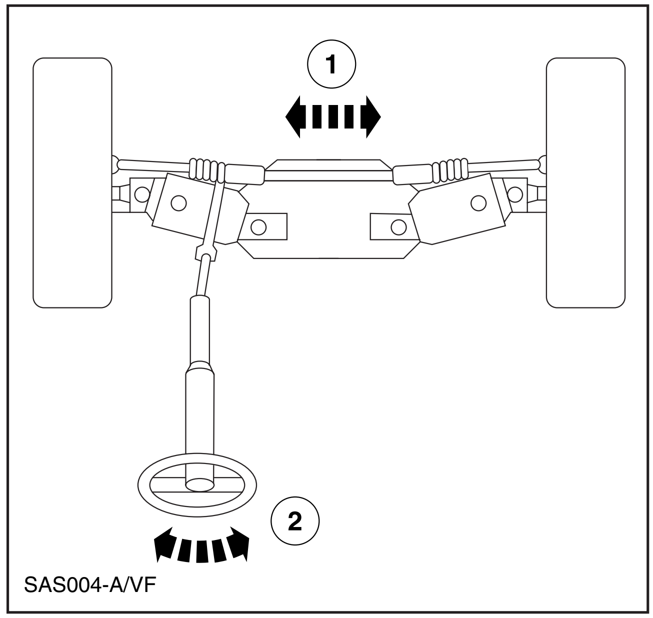
Steering wheel

As the driver turns the steering wheel, two things happen in both a rack and pinion and gear box type steering system.

1. The steering wheel is linked to the steering column shaft and both turn in a circular motion when the driver rotates the steering wheel.

2. This circular motion is changed to a back and forth or linear motion by the rack and pinion or gear box. The linear motion pushes or pulls the steering linkage to turn the wheels.

The steering wheel is the driver's link to the entire system. The steering wheel is formed from a strong material shaped into a circle. Spokes extend from the steering wheel to the inner steering wheel hub, which is fastened securely at the top of the steering column.



Circular to linear motion transfer

1 Linear motion
2 Rotary motion

Steering column

The steering column assembly supports the steering wheel and has three major components:

- Cover assembly
- Bearing assemblies
- Steering column shaft and wiring assemblies for electric functions on the steering column and steering wheel

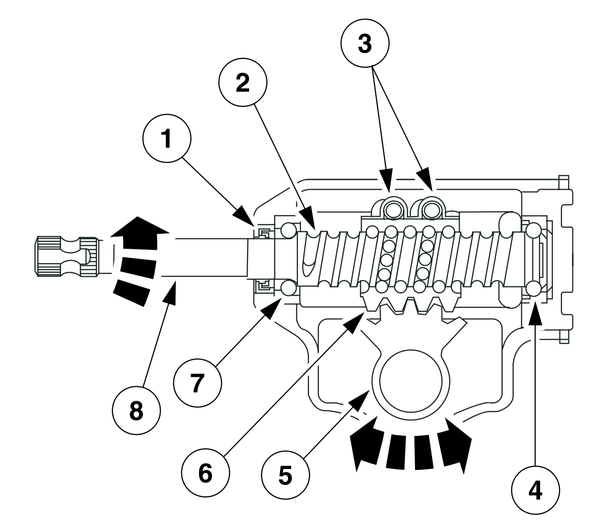
Steering gear

The steering gear transfers the circular motion of the steering wheel to a back and forth motion that controls the front wheels. The steering gear also increases the driver's force from the steering wheel to turn the front wheels using hydraulics or power steering. Gear ratios in the gear box determine how quickly the wheels turn in relationship to driver steering wheel input. The two most common steering gear types are the recirculating ball gear box and rack and pinion steering.

Recirculating ball steering gear

The recirculating ball type of steering gear converts circular motion into linear motion. Inside the worm gear shaft is a hollowed-out spiral thread, much like a screw thread. Inside the threads are several steel balls, trapped between the worm gear shaft and the ball nut. As the steering wheel is turned, the recirculating steel balls roll up or down on the worm gear shaft, moving the ball nut up or down the shaft. Teeth on the ball nut mate with the sector shaft, turning the shaft to the left or right and steering the wheels.

An important benefit of the recirculating ball steering system is low steering effort. This system works well for heavy vehicles, like trucks, and because of low internal friction the system will last a long time. The design of the recirculating ball type steering system helps to keep the driver from feeling rough roads through the steering wheel.



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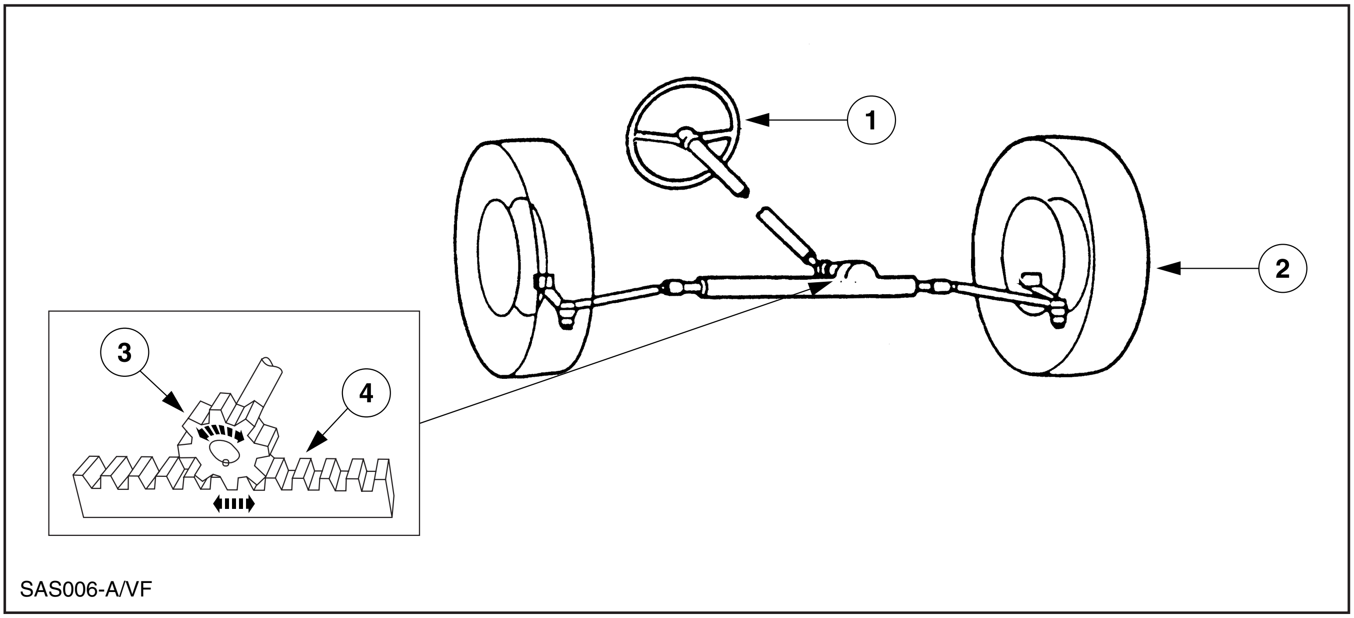
Recirculating ball gear box components

1 Seal
2 Worm gear
3 Balls and guides
4 Rear bearing
5 Sector shaft
6 Ball nut
7 Front bearing
8 Input shaft

Rack and pinion steering system



Rack and pinion gear box components

1 Steering wheel
2 Tire
3 Pinion
4 Rack

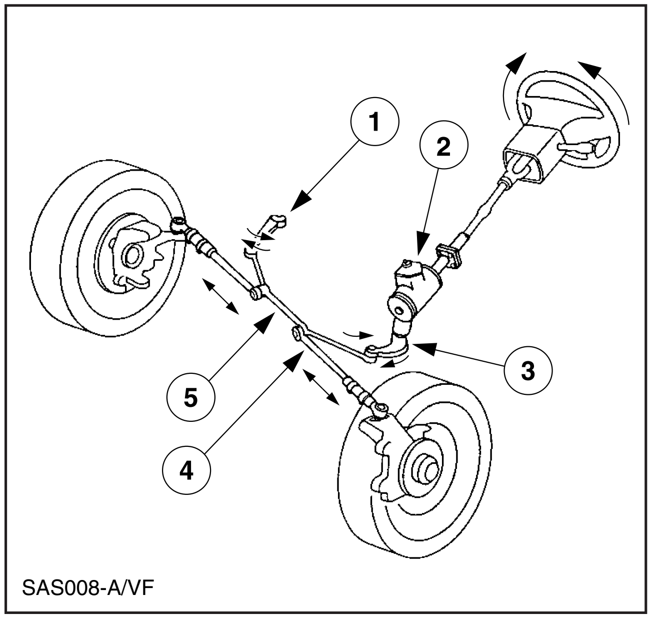
The rack and pinion gear box converts circular motion to a linear motion. The pinion is a round gear that when turned by the driver with the steering wheel the steering column shaft pushes or pulls a flat gear, called a rack, back and forth. When the rack travels from side to side, the linkage moves the front wheels to the desired steered position. The rack and pinion steering system is compact, simple and is very popular on today's vehicles.

Steering linkage

The steering linkage makes the connection between the steering gear box and the vehicle's wheels. The steering linkage is normally made from steel, making it strong. The linkage allows the linear motion from the gear box to be passed to the wheels. Steering linkages are formed with angles and bends so that they can work around engines or other underhood parts in a small area.

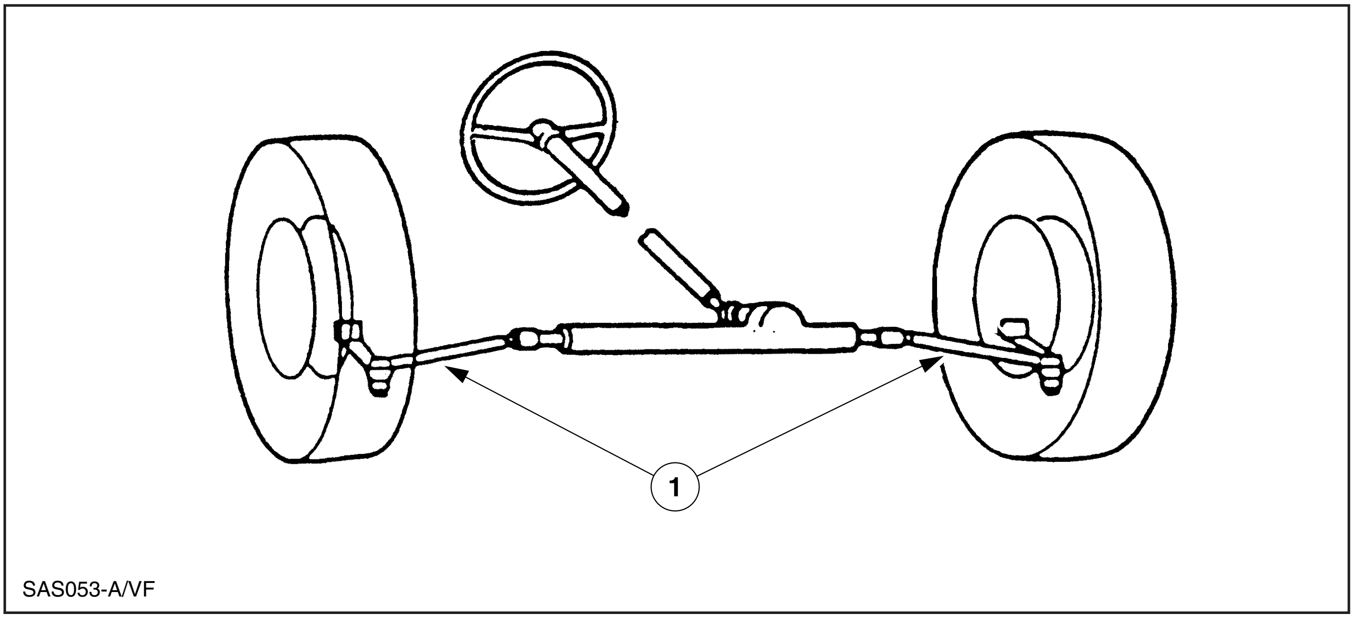
The idler arm helps to level the steering linkage and provide a pivot point. The idler arm is normally attached on the opposite side of the center link from the pitman arm. Idler arms are mounted to a point along the frame of the vehicle, supporting the center link at the correct height. A pivot or ball and socket device built into the arm allows sideways movement of the linkage, but controls any up and down movement.

The pitman arm is splined or keyed to the steering gear sector shaft. When the sector shaft in the gear box shaft turns, the pitman arm swings in an arc and moves the drag link. The drag link transfers the swinging motion of the pitman arm to a linear motion.



Recirculating ball steering linkage components

1 Idler arm
2 Recirculating ball gear box
3 Pitman arm and drag link assembly
4 Tie rod
5 Center link



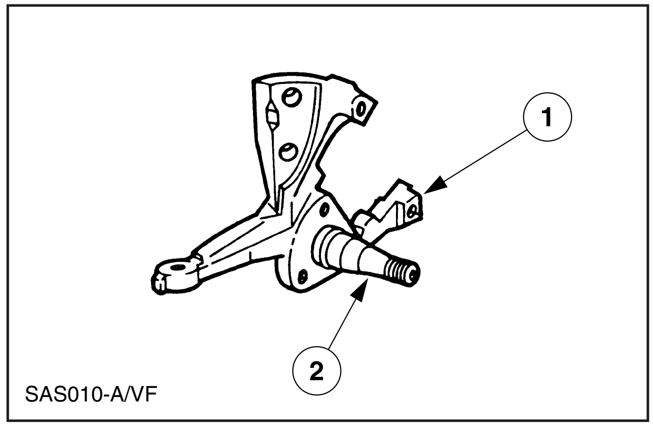
1 Tie rods

The linear motion from the drag link is then transferred to the center link. The center link is moved left to right by the drag link. Center links are used to transfer the linear motion to the tie rods. Tie rods are assemblies that make the final connection between the steering gear box and the wheel assembly.

The rack and pinion steering system also uses tie rods to connect the gear box to the wheel assembly.

Steering spindle

The spindle is a hardened steel shaft that is attached to, or part of, the steering knuckle. The spindle allows the wheel assembly to rotate freely while controlling any up and down movement. The steering knuckle is attached to the tie rods and the steering linkage. When the linkage moves, the steering knuckle moves also and the vehicle is steered in the correct direction.



Steering spindle components

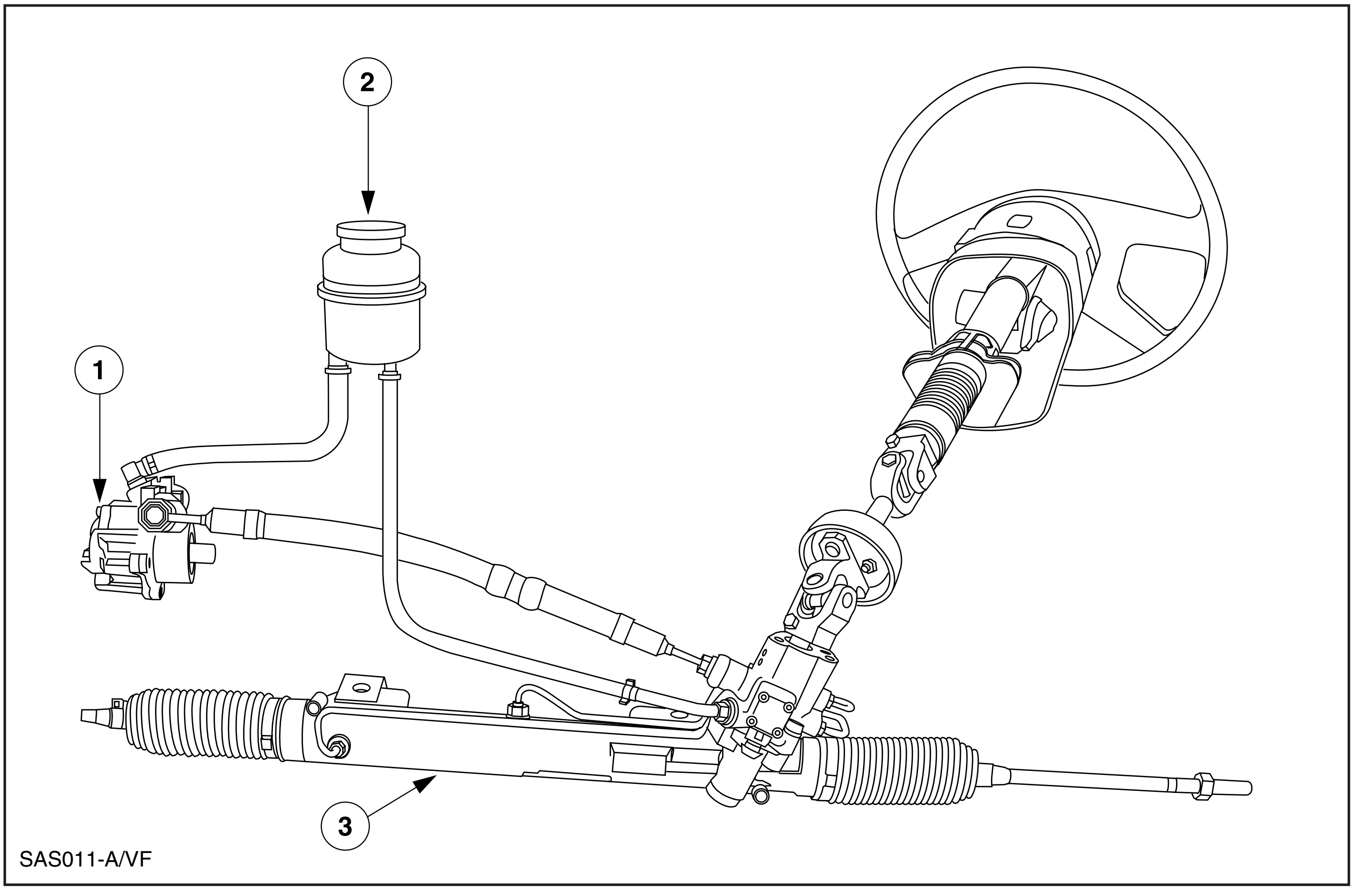
1 Steering knuckle
2 Spindle

Objectives

Upon completion of this lesson, you will be able to:

- Describe the purpose and function of the power-assisted steering system.
- Describe the power-assisted steering systems and identify the types.
- Identify the power-assisted steering system components.
- Describe the theory and operation of the power-assisted steering system.

Power steering systems



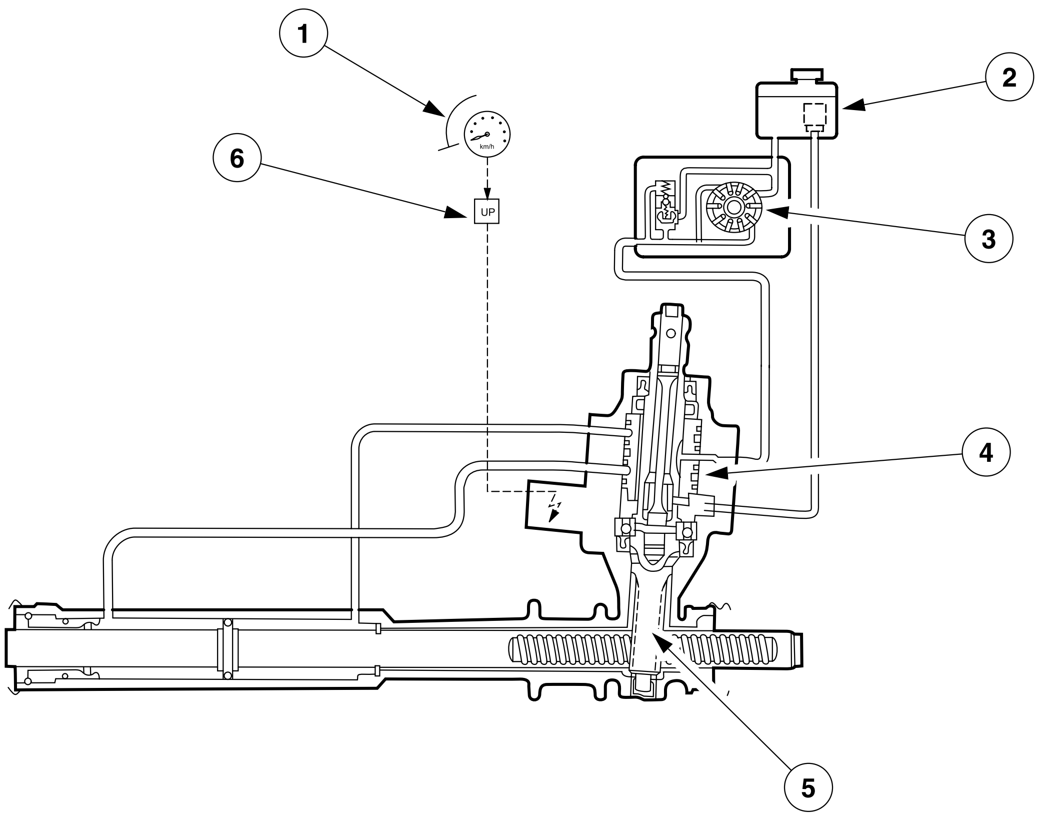
Power steering components

1 Power steering pump
2 Power steering fluid reservoir
3 Steering gear box

As modern vehicles became larger, heavier and faster, the need for power steering became apparent. Power steering makes tight turns and vehicle control easier. The hydraulic power steering system was made to help the driver turn a vehicle. Both the rack and pinion and recirculating ball type steering systems can be power assisted.

Hydraulic fluid pumped to the steering gear assembly uses fluid pressure to aid the driver in steering the vehicle. The hydraulic steering system requires a hydraulic pump, a series of lines, hoses, and a gear box assembly that is equipped to use hydraulic pressure.

Variable assist power steering



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Variable assist power steering components

1 Vehicle speed sensor
2 Hydraulic reservoir
3 Hydraulic pump
4 Variable assist control valve
5 Rack and pinion assembly
6 Control module

Variable assist power steering controls the amount of hydraulic pressure delivered to the gear box. At low vehicle speeds such as when parking, the amount of hydraulic pressure going from the pump to the gear box is high, allowing the driver to steer easily. At high speeds, the pressure delivered to the gear box is decreased so more force is needed from the driver to steer, making the vehicle less prone to high speed steering over corrections.

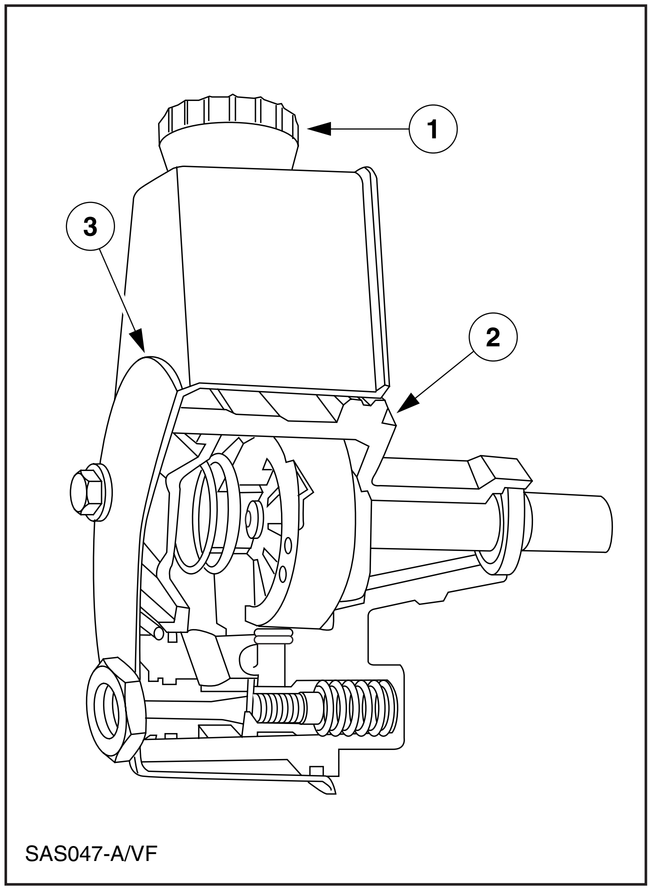
Variable assist power steering uses an electronic vehicle speed sensor to send an electrical signal to the electronic control module. The control module moves a valve in the control valve assembly, sending the correct pump pressure to the rack and pinion gear box assembly.

Power steering pump

The power steering pump uses engine power to rotate the pump and produce hydraulic fluid pressure and flow through the power steering system. Most often, power steering pumps are belt driven from the engine. Some power steering pumps are driven by an electric motor

The power steering pump reservoir stores hydraulic fluid that flows through the power steering system. The power steering pump draws the fluid from the reservoir, pressurizes it, and creates flow. The fluid, after flowing through the system, is returned to the reservoir.

If fluid level is low due to leakage, determine the cause of the leak. Fluid can be added to the reservoir through the filler cap.



Power steering pump components

1 Filler cap
2 Pump
3 Reservoir

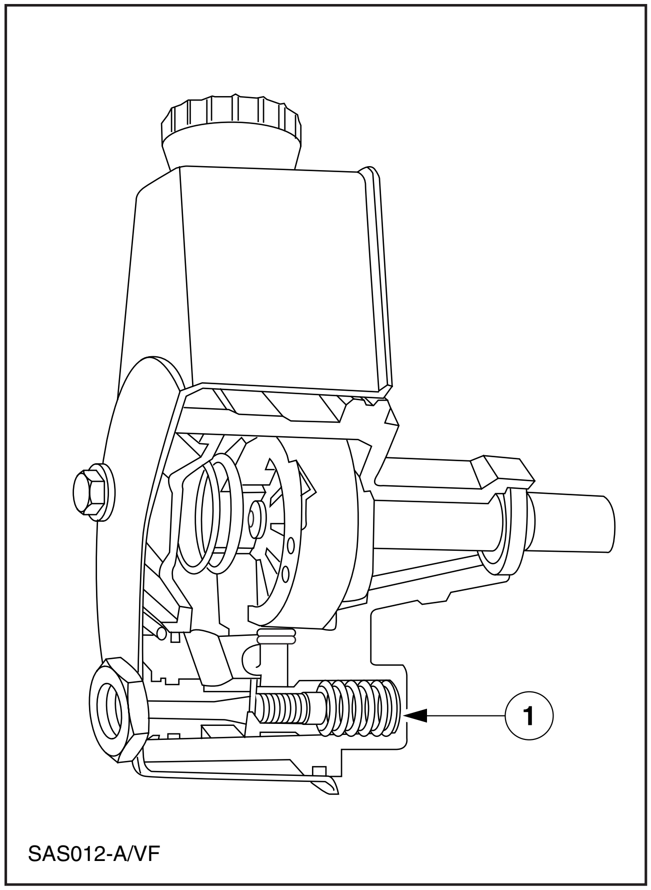
Pressure relief/flow control valve

The pressure relief/flow control valve assembly is located in the rear of the pump at the outlet. The valve assembly controls flow from the pump. The pressure relief valve controls the amount of pressure. As fluid within the pump assembly is forced into the flow control area, the fluid pushes the flow control valve against a spring. If fluid flow is too high, the flow control valve shifts position and opens a bypass port.

The bypass port allows extra fluid flow to be pushed back into the fluid reservoir. The valve allows the pump to keep a steady flow rate to the power steering gear assembly. In the center of the flow control valve is the pressure relief valve. If fluid pressure in the system becomes too great, the pressure relief valve allows the extra pressure to be pushed back to the reservoir.

These valves help control system pressure to extend the life of the hoses, gear seals and valve seals and prevent the pump from overheating fluid in the system. The main internal components of the gear box remain the same for both a manual and power steering gear box.

Power steering systems use hydraulic valves, pistons and other parts that are moved by hydraulic fluid pressure from the power steering system. These parts, when used as a complete hydraulic system, make up a power steering system.



1 Pressure relief/flow control valve

Objectives

Upon completion of this lesson, you will be able to:

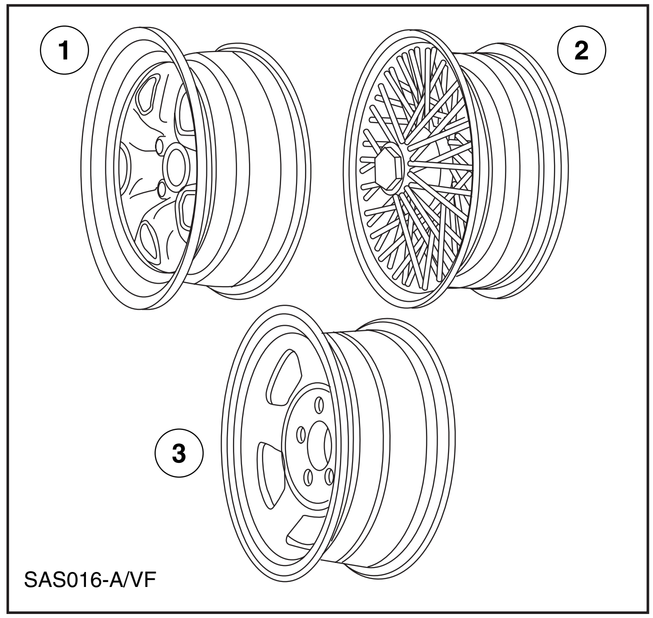
- Explain the purpose and function of tires and wheels.
- Describe tires and wheels and identify the types of tires and wheels.
- Identify the components of tires and wheels.
- Explain the theory and operation of tires and wheels.

Tires and wheels

A vehicle's tires and wheels support the vehicle's weight and absorb minor road shocks. The tires are the vehicle's only point of contact with the road. The tires are mounted to the wheels, providing the vehicle with traction to transmit acceleration, braking and cornering forces.

Tires are made from rubber compounds and fiber or steel cords. Radial tires are used on most new vehicles. Radial tires offer superior ride, performance and are very tough. Radial tires are made with steel plies woven into the rubber across the width of the tire. The tires are mounted on a wheel or rim. The wheel can then be mounted to the vehicle.

Wheels are made in different sizes to accept different size tires and vehicle loads. All wheels have holes to fasten the wheel to the axle. Some wheels use studs with wheel nuts. Others use bolts to fasten the wheel to the axle. Wheels are made from steel or aluminum. Some wheels may have plastic or polished steel covers to improve their appearance.

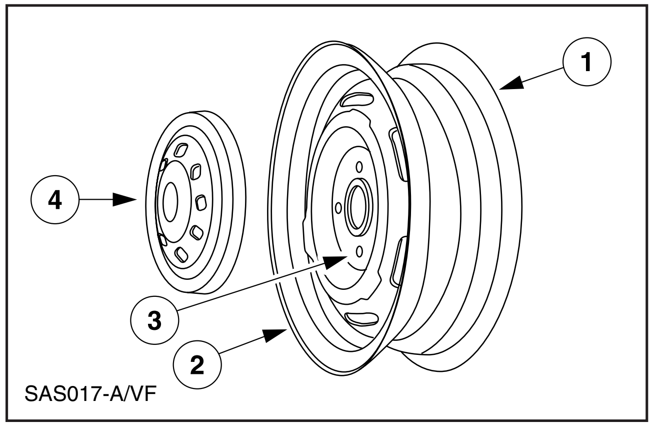


Wheel types

1 Steel wheel
2 Steel wheel with cover
3 Aluminum wheel

Wheels

Wheels are made of either stamped or pressed steel discs riveted or welded together. Aluminum wheels are lighter than steel wheels and are made in a variety of types. Single one-piece aluminum wheels and multipiece aluminum wheels bolted together are common types of aluminum wheels.



Wheel components

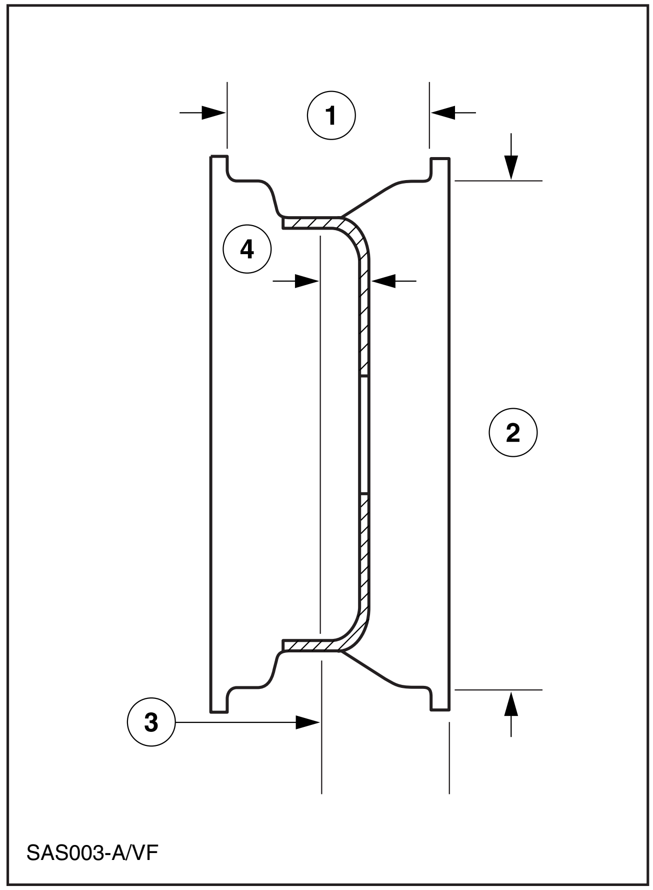
1 Wheel rim
2 Rim flange
3 Stud hole
4 Wheel cover

Wheel size

Wheel size is determined by rim width and rim diameter. Rim width is determined by measuring across the rim between the flanges. Rim diameter is measured across the bead seating areas from the top to the bottom of the wheel. Some rims have safety ridges near their lips. In case of a tire blowout, these ridges tend to keep the tire from moving into the dropped center and from coming off the wheel.

Replacement wheels must be equal to the original equipment wheels in load capacity, diameter, width, offset, and mounting types. An incorrect wheel can affect wheel life, ground and tire clearance, and the vehicle's speedometer and odometer calibrations.

Wheel offset is the distance between the centerline of the rim and the mounting face of the disc. The offset is positive if the centerline of the rim is inboard of the mounting face. The amount and type of offset is important because changing the wheel offset changes the loading on the front suspension and alignment.

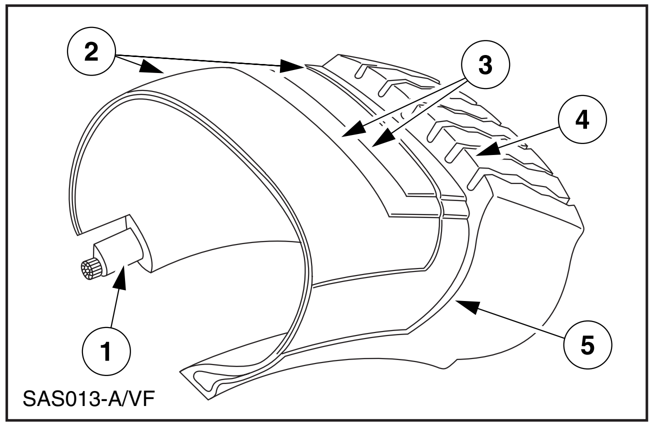


Wheel measurement locations

1 Rim width
2 Rim diameter
3 Center line
4 Offset

Tires

The basic parts of a normal tire are as follows: the cord body or casing consists of layers of rubber impregnated cords, called plies, that are bonded into a solid unit. Normal tires are made with 1, 2, 4, or 8 plies. The plies determine a tire's strength, handling, ride, and ability to hold up to fatigue, heat, and bruises.



Tire construction

1 Tire bead
2 Plies
3 Belts
4 Tread
5 Sidewall

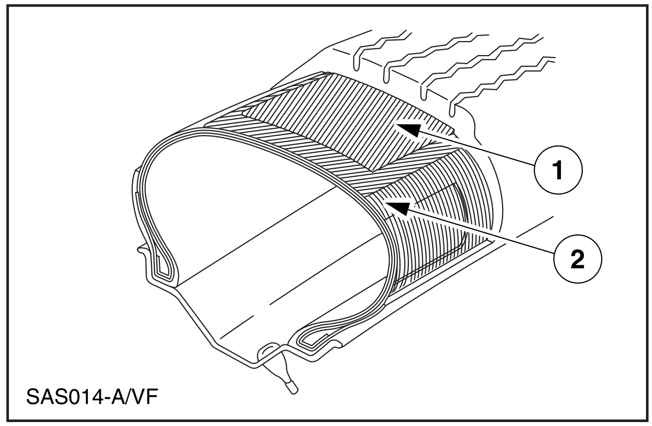
The bead is the portion of the tire that contacts the rim of the wheel. The bead also provides the air seal between the rim and the tire. The bead is made from a heavy band of steel wire wrapped into the inner circle of the tire's ply.

The tread is the part of the tire that meets the road surface. The tread is a pattern of grooves that provides the tire with traction, and provides a channel to drain off water between the road and the tire. It is designed with a raised molded pattern to grip the road. Various tread designs such as mud, snow, and all season tires have been developed to meet specific road conditions. Tread thickness varies with tire quality. On some tires, small cuts called sipes open as the tire flexes on the road, giving the tread better grip.

The sidewalls are the sides of the tire body. Sidewalls are made of a thinner material than the tread to offer greater flexibility. The tire body and belt material can be made of rayon, nylon, polyester, fiberglass, steel, or the newest synthetics: marid or kevlar.

Radial-ply tires

Radial-ply tires have body cords that extend from tire bead to tire bead at an angle of about 90 degrees or radial to the tire centerline, plus two or more layers of stiff belts under the tread. The construction of many combinations of rayon, nylon, fiberglass, and steel gives greater strength to the tread area and flexibility to the sidewall. The belts help to stop tread motion during contact with the road surface, and improve tread life and traction. Radial-ply tires also offer greater fuel economy, increased skid resistance, and more positive braking than non-radial tire designs.



Radial-ply tire detail

1 Belts
2 Radial cord body plies

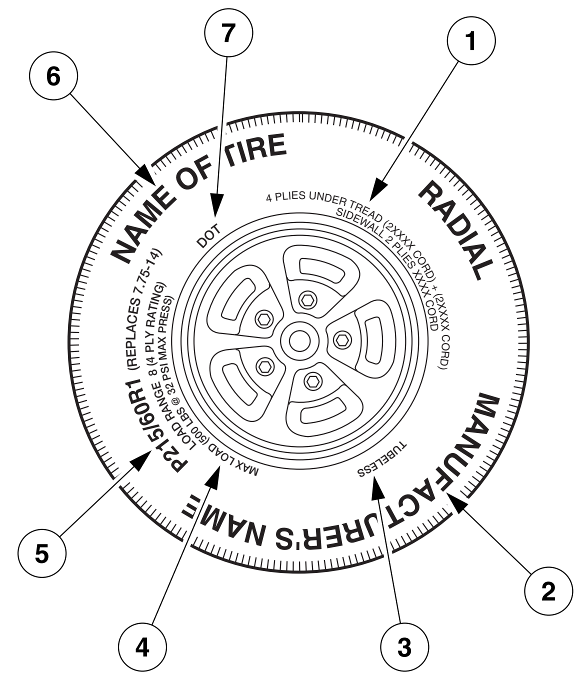
Tires (continued)

Tire sidewall information

Tire makers put important information on the sidewalls of all tires. The information on the tire gives the vehicle owner and the technician information on a tire's size and capabilities. When replacing tires, the correct tire must be used. If a different type of tire is installed on the vehicle, steering, braking, and handling abilities could be different and unsafe.

The United States Department of Transportation and other countries require sidewall information that may include:

- Number of plies
- Manufacturer’s name
- Tire type
- Load range
- Size of tire
- Name of tire
- DOT number
- Maximum tire load
- Maximum tire inflation pressure in kPa and psi
- Speed rating or maximum tire speed
- Date of manufacture
- Tire direction of rotation
- Producing country



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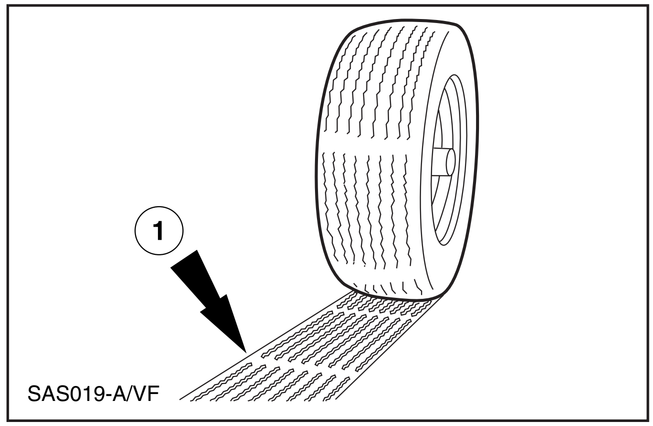
Tire sidewall information

1 Number of plies
2 Manufacturer’s name
3 Tire type
4 Load range
5 Size of tire
6 Name of tire
7 DOT number

Wear bar indicators

Wear bar indicators show how much tread wear has taken place. When too much tread has worn off, solid bars of rubber show up across the tread. The wear bars tell the customer and technician that tire replacement is needed. Tire wear bars will show when tread depth reaches 1.6 mm (2/32 inch) or less. The tread is made to pump water, mud, snow and other debris away from the road to tire contact area to prevent the tire from losing grip with the road. If the tread depth is not deep enough, the tread can not channel the water away from the road to tire contact area. Once contact is lost, the vehicle aquaplanes. Aquaplaning is a condition when the tire loses contact with the road and traction is lost. Tread depth plays an important role in keeping the tire on the surface of the road.

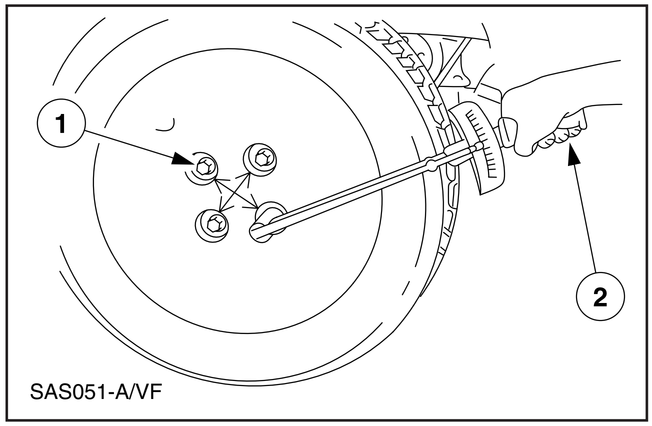


Tire wear indicator

1 Tread depth indicator

Wheel mounting procedure

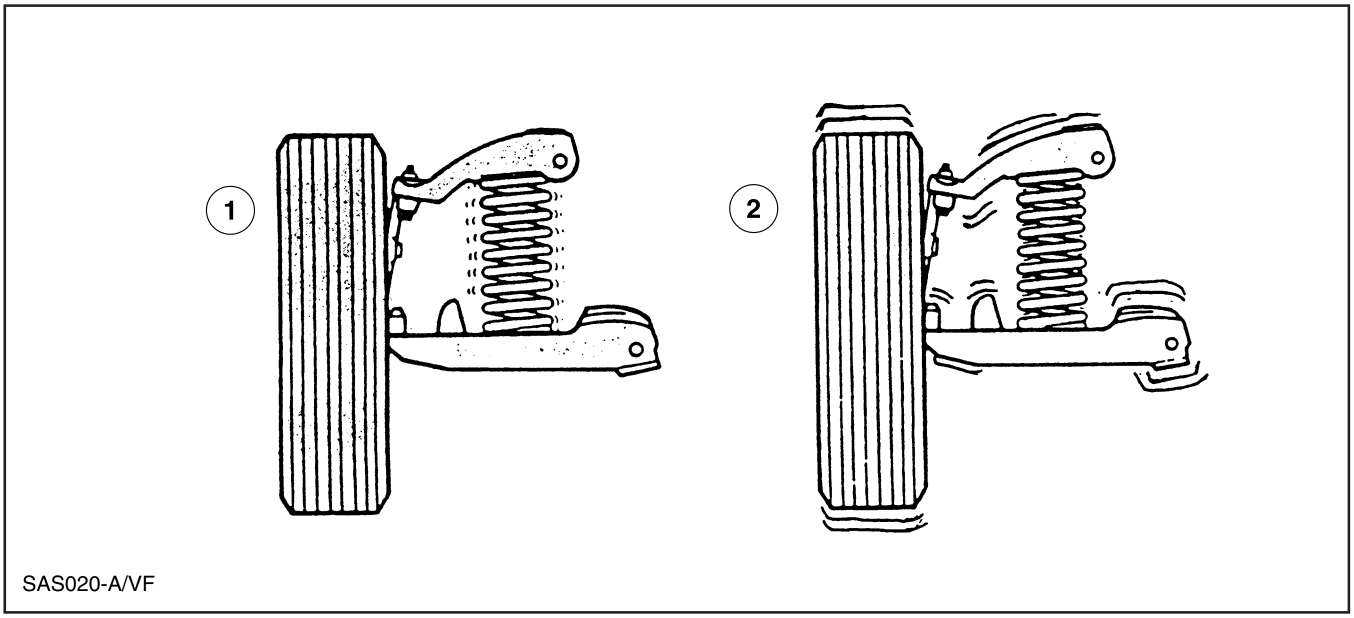
For radial tires, an airtight connection between the wheel rim and the tire is important. Properly mounting the correct size tires on the correct size wheels makes a good airtight and safe seal between the tire and rim. Modern, lightweight wheels can be damaged by improperly tightening the wheel nuts. Always use a torque wrench. Always follow the manufacturer's tightening sequence to properly seat the wheel to avoid wheel and brake component damage. Never use lubricants on wheel fasteners.



Tightening wheel fasteners

1 Wheel fasteners
2 Torque wrench

Wheel balancing procedure



Wheel balance

1 Balanced wheel and tire assembly
2 Unbalanced wheel and tire assembly

Wheel balance describes the placement of lead weights around both the up-and-down and side-to side-planes of the tire and wheel. Balancing places weights around the wheel rim to equalize any heavy spots on the tire and wheel assembly. Balancing allows the wheel assembly to roll without excess tread wear. A tire may look perfectly round, but there are usually small differences in weight, sidewall stiffness, and roundness.

Wheel imbalance is either static or dynamic. Static imbalance makes the tires move in an up and down motion. Dynamic imbalance makes the tire move in a side to side motion. Basically, one point of the tire assembly is heavier than the same point on the other side of the tire assembly. When the wheel rotates, the heavy spot in the wheel creates an unbalanced force. These forces can cause a vibration or wheel hop. Wheel hop can cause tire wear, increased suspension wear and poor vehicle control. Professional balancing equipment is used to balance wheels correctly.

Objectives

Upon completion of this lesson, you will be able to:

- Identify the purpose and function of the suspension system.
- Describe the suspension system and identify the types of suspension systems.
- Identify the suspension components.
- Explain the theory and operation of the suspension system.

Suspension systems

There are many types of suspensions in use today and they all are designed to improve vehicle performance. The typical suspension system uses coil springs, leaf springs, torsion bars or struts to keep the vehicle's wheels in firm contact with the road. The suspension system must support the weight of the vehicle and is the link between the tires and the body of the vehicle.

As the tires move across a rough surface, they are moving up and down following the rough surface of the road. The upward and downward motion of the tires is dampened by the suspension system. As the tires move upward or downward the springs or struts are squeezed, or released. The squeezing or compressing of the springs or struts takes out the harsh bumps that would have been felt by the passengers in the vehicle.

A vehicle's suspension system must balance the twin tasks of carrying the weight of the vehicle and distributing the load to each tire, while providing a smooth comfortable ride. The suspension plays an important role in making the vehicle more comfortable for the passengers. There are two commonly used types of suspension systems:

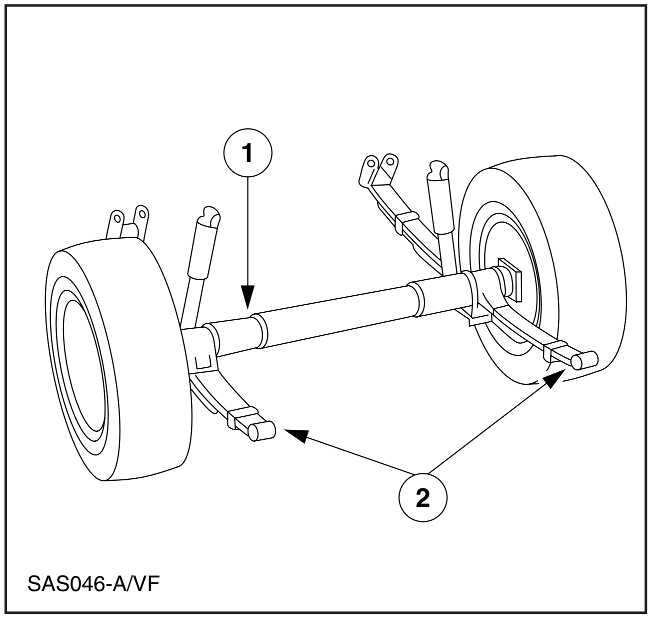
- Non-independent suspensions
- Independent suspensions

Suspension systems (continued)

Non-independent suspension systems

Non-independent suspension systems are sometimes called solid or rigid axles and mount the vehicle's wheels on a solid axle suspended by leaf or coil spring at each end. Non-independent suspension is long lasting, rugged, and can carry heavy loads. Many sport utility vehicles and trucks use non-independent rear suspension systems.

Non-independent suspensions contain fewer parts, and are easier to build and install than independent suspensions. Non-independent suspensions also provide more consistent wheel alignment. With both wheels solidly connected by a rigid axle, the distance between the wheels stays almost the same as the suspension moves up and down. Non-independent suspension may be used in both the front and rear of the vehicle.

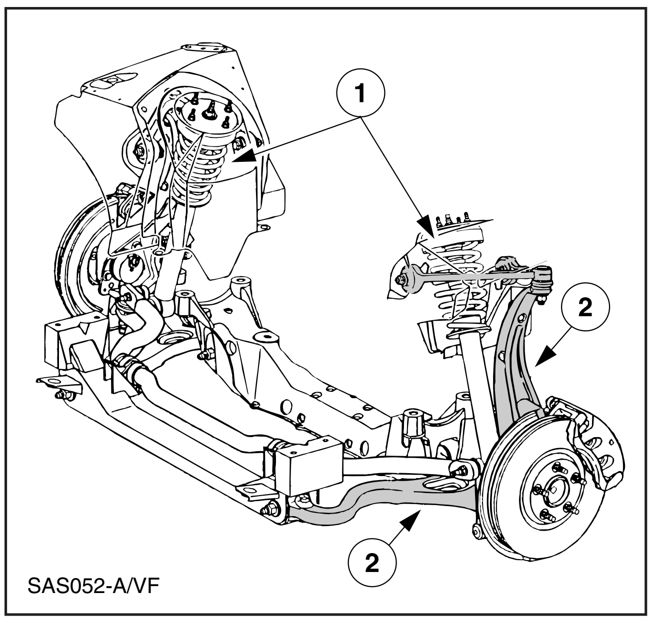


Non-independent suspension

1 Axle
2 Leaf spring

Independent suspension

Independent suspension systems allow each wheel on an axle to move independently of the other wheel. Independent suspensions provide support for each wheel individually, preventing bumps and shocks felt by one wheel from being passed on to the other wheel. Independent suspensions are lighter than non-independent systems and more of their weight is carried on the springs, greatly improving ride quality. Independent wheel action also improves handling and cornering performance. Independent suspensions are used in both the front and rear of the vehicle.

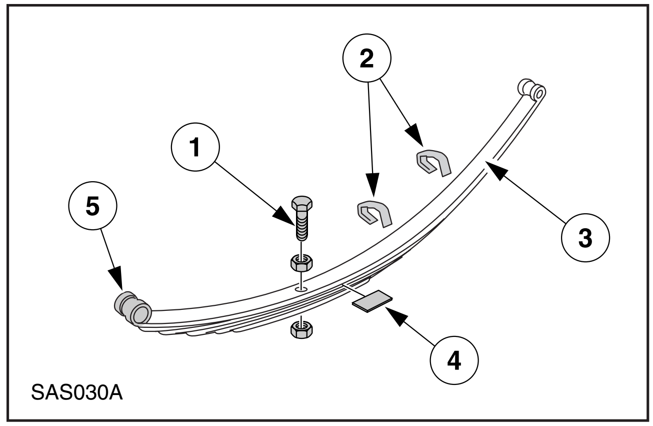


Independent suspension components

1 Coil springs
2 Independent suspension arm

Leaf springs

Leaf springs were the first automotive springs used. Today they are usually found in non-independent suspensions on vehicles that carry a lot of weight, including trucks. Most of the time, they are made by forming spring steel into several flat, curved bands that progressively increase in length or get shorter at the bottom of the stack than at the top. Leaf springs may also use a tapered single leaf that is thickest in the middle. Lightweight fiberglass-like material may also be used. The leaves are held together by clamps and a center bolt. The axle is held to the springs with U-bolts.



Leaf spring components

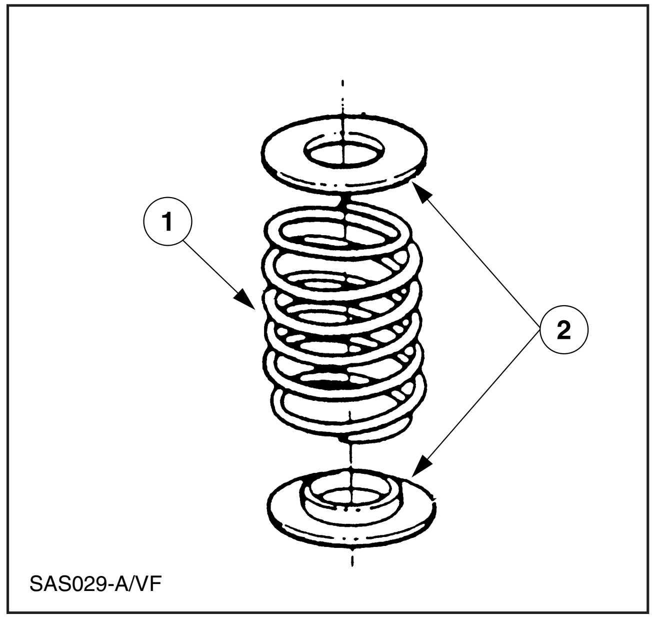
1 Center bolt
2 Spring clamps
3 Main leaf
4 Silencer pad
5 Leaf eye

To increase the spring rate, the vehicle's rear axle is attached to the leaf springs slightly ahead of their center. The top leaf is curled at both ends, to form eyes. These eyes are used to attach the spring to the vehicle's frame. To avoid abrasive, noisy, metal-to-metal contact between the spring eyes and the frame, rubber bushings are inserted into the eyes. Silencer pads are inserted between each leaf to reduce leaf-to-leaf friction.

Leaf springs do not intrude upwards into the vehicle's load carrying space like independent suspensions do. The load carrying ability of leaf springs is especially important for vehicles that carry a lot of weight such as pickup trucks and sport utility vehicles.

Coil springs

Coil springs are formed by winding spring steel to form a coil. The coil spring provides good ride, comfort and handling. Plastic or rubber insulators are usually used to separate coil springs from the frame and the suspension in order to stop spring noise from metal to metal contact. Coil springs also weigh less than leaf springs, and take up less space.

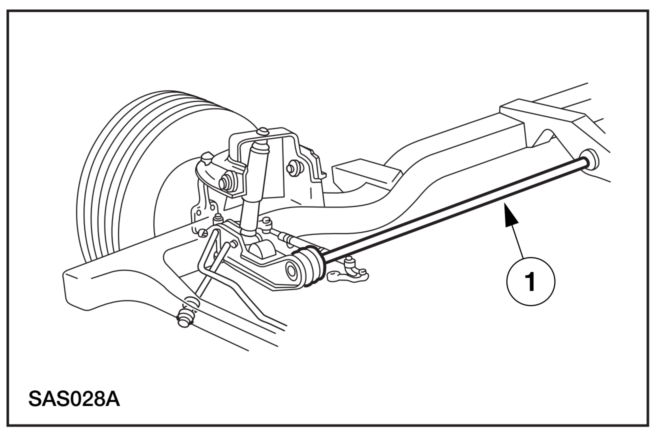


Coil spring components

1 Coil spring
2 Coil spring insulators

Torsion bar

Torsion bars get their spring effect through their ability to twist as loads caused by bumps, cornering, braking and acceleration are applied. Torsion bars are anchored to the vehicle's frame at one end, and to a suspension component at the other. They are formed from spring steel. The length and thickness of a torsion bar determine the spring rate. The shorter or thicker the bar is, the higher the spring rate. Torsion bars are directional. They may only be installed one way, and are weak if installed in the wrong direction. The correct direction should be clearly marked on each torsion bar. Depending upon the vehicle, torsion bars may be mounted across the width of the vehicle or lengthwise. As they weaken with age, adjustments can be made to restore ride height. Torsion bars take up very little space and are popular in many four-wheel drive trucks.

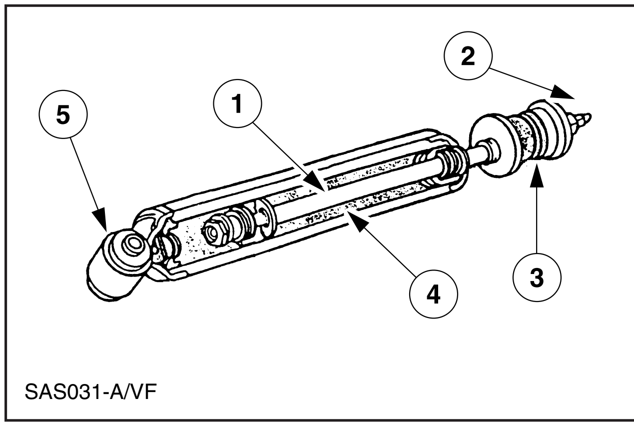


Location of torsion bar

1 Torsion bar

Shock absorbers

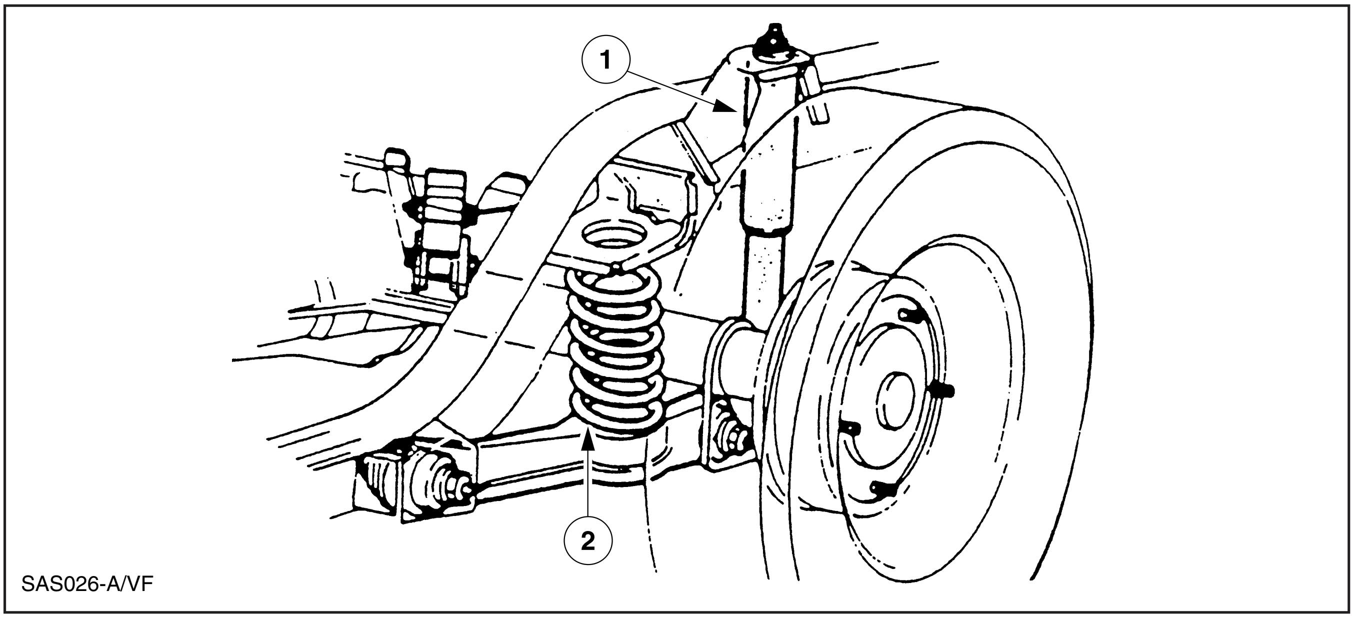
The purpose of the shock absorber is to dampen or stop the movement of the suspension system. Without a shock absorber, the system would continue to move after absorbing a bump. With a shock absorber in place, the motion is quickly reduced. The shock absorber allows the spring to recover and prepare for the next bump. The top portion of the shock absorber is mounted to the vehicle body or chassis and the bottom is mounted to a suspension component that moves with the wheel. The shock absorber acts in parallel with the movement of the spring.



Shock absorber components

1 Hydraulic cylinder
2 Top
3 Insulators
4 Fluid reservoir
5 Bottom

Shock absorbers (continued)



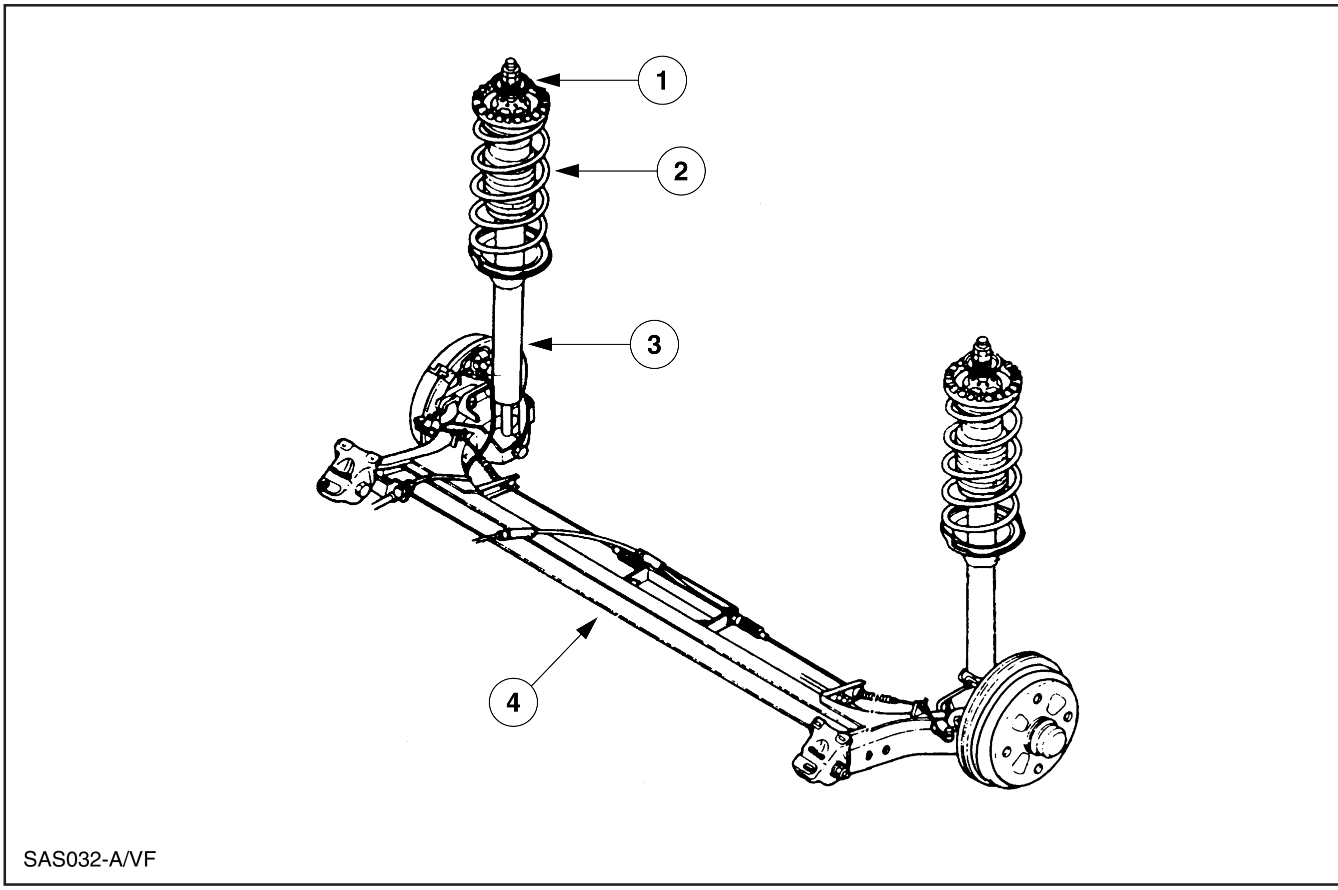
Shock absorber location

1 Shock absorber
2 Coil spring

Shock absorbers use hydraulics to dampen spring oscillations. As the suspension moves, the shock absorber must be extended or compressed. Opposing the spring oscillations is hydraulic fluid in the shock absorber that must be forced through orifices in the piston. As the fluid is forced past the orifices, the piston can move. When the piston moves, the shock absorber can shorten or extend. The controlled extension and compression of the shock absorber limits the rate at which the spring can move up or down.

Some shock absorbers use pressurized gas to keep the hydraulic fluid from foaming during rapid shock absorber fluid movement. Rubber insulators between the body and the suspension help to prevent noise and vibration between the shock absorber and the vehicle body.

Struts



Strut components

1 Upper body mount
2 Coil spring
3 MacPherson strut assembly
4 Axle

The MacPherson strut uses a tube type shock absorber and a coil suspension spring that is made into one unit. In some designs, the shock absorber piece is a replaceable part or cartridge. In other designs, the entire strut must be replaced. The MacPherson strut has two points of contact with the vehicle, creating an efficient, compact design. By reducing space normally needed for the coil or leaf spring and shock absorbers and the necessary linkage in the suspension system, the MacPherson strut design leaves more underhood area available for other purposes. The MacPherson strut is used on many different types of vehicles.

Objectives

Upon completion of this lesson, you will be able to:

- Describe the purpose and function of steering system alignment.
- Describe front end alignment.
- Identify nine alignment angles.
- Explain the theory and operation of steering system alignment.

Alignment overview

Proper vehicle alignment allows the driver to move down the highway with small steering corrections and minimum tire wear. Adjustments to the vehicle's suspension make alignment possible. Improper wheel alignment can be the main cause of nearly every kind of vehicle handling complaint. Correct front wheel alignment allows the tires to roll straight down the road. Incorrect front wheel alignment causes the front tires to have a slight sliding, scuffing, or dragging movement. Correct wheel alignment removes the dragging condition and increases tire life. Front end alignment is a series of measurements and adjustments that will allow a vehicle to track in a straight line down the road. The steering system, suspension, wheels, and tires all help to prevent the vehicle from shaking, wobbling, or pulling from side to side as it moves down the highway. Any looseness in the steering linkage or suspension will cause the vehicle to handle erratically.

There are nine alignment measurements used to determine proper alignment. Some of these alignment measurements are directly adjustable, while others are not. Each angle or measurement provides valuable information that can be used to diagnose the cause of steering and handling complaints, and tire wear:

- Caster
- Camber
- Toe
- Scrub radius
- Thrust angle
- Set back
- Steering axis inclination
- Included angle
- Ride height

Alignment measurements

Caster

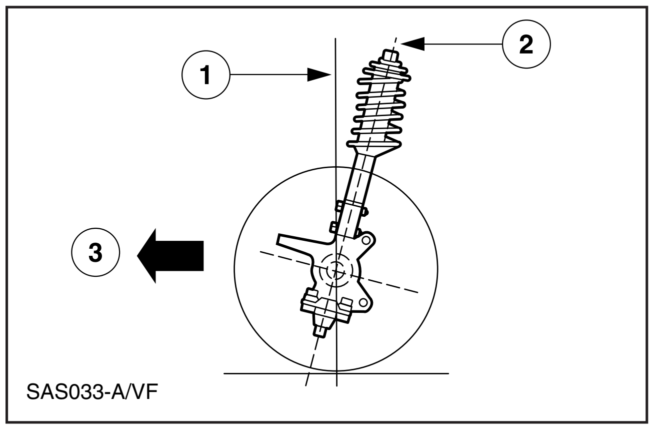
Caster is the forward or rearward tilt of the steering axis from true vertical, or straight up and down, as viewed from the side of the front wheel. The steering axis is an imaginary line through the center of the steering component and the wheel. There are three possible caster angles:

- Positive caster
- Negative caster
- Zero caster

Positive caster

Positive caster is when the steering axis or vehicle centerline is in front of the tire's road contact point. Positive caster causes friction or drag in the rearward portion of the tire. The dragging effect, called caster trail, tends to force the tire to travel in a straight line or to return to the straight-ahead position. Most vehicles use positive caster so that the vehicle steers itself in a straight-ahead direction. Although positive caster helps maintain directional stability, too much positive caster can cause:

- Hard steering and low speed shimmy
- Wandering at high speeds



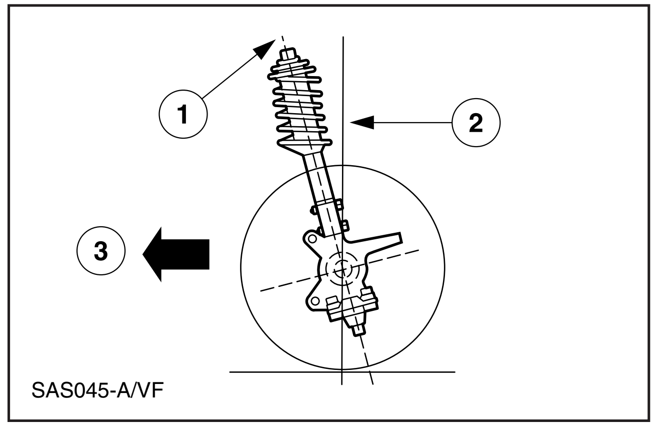
Positive caster angles

1 True vertical
2 Positive caster steering axis
3 Front of vehicle

Negative caster

Negative caster tends to make a vehicle easier to turn. With negative caster, the steering axis centerline is behind the tire's road contact point. Negative caster tends to push the tire away from the straight-ahead position and make steering easier. The downside of negative caster is that straight-ahead driving becomes more difficult because the vehicle wants to move to the right or left, and not in a straight position like positive caster. Unlike a shopping cart, where the wheel is behind the cart's axle centerline, this wheel is ahead of the centerline and drifts to the right or left. Although negative caster tends to make steering easier, too much negative caster can cause:

- Vehicle wandering
- Decreased steering return-to-center
- Decreased stability during braking

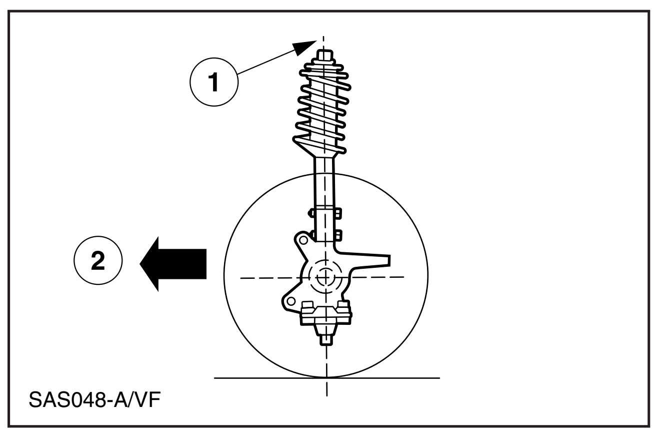


Negative caster angle

1 Negative caster steering axis
2 True vertical
3 Front of vehicle

Zero caster

When the steering axis is at true vertical, the caster angle is zero. Zero caster tends to have a neutral effect on directional stability and steering. With zero caster, the extended centerline of the steering axis aligns with the exact center of the tire's road contact point. Therefore, the tire is not dragged in any direction. Without drag, no forces are present to turn the wheels either left or right. Most vehicles use some degree of positive caster angle.



Zero caster angle

1 True vertical/zero caster
2 Front of vehicle

Alignment measurements (continued)

Camber

Camber is the inward or outward tilt of the top of the tire compared to a true vertical line, as viewed from the front of the vehicle. Camber angle is measured in degrees or minutes or seconds. Like caster, camber has three possible angles:

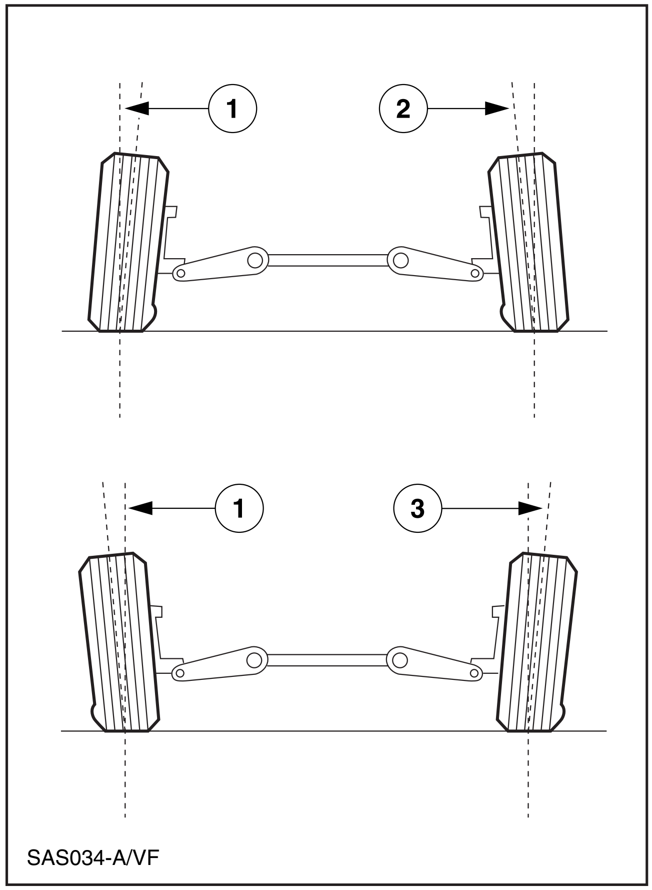
Negative: Top of the tire tilts inward

Positive: Top of the tire tilts outward

Zero: Tire has no tilt

Positive camber tends to cause a vehicle's tire to roll away from the center of the vehicle. Too much positive camber pulls the vehicle in the direction of the side with most camber. Too much positive camber leans the top of the tire out, placing the vehicle load on the outside edge of the tire and causing uneven wear.

Negative camber tends to cause the tire to roll toward the center of the vehicle. A vehicle tends to drift toward the side that has greater negative camber. Too much negative camber leans the top of the tire in, placing the load on the inside edge of the tire and causing uneven wear.



Camber angle

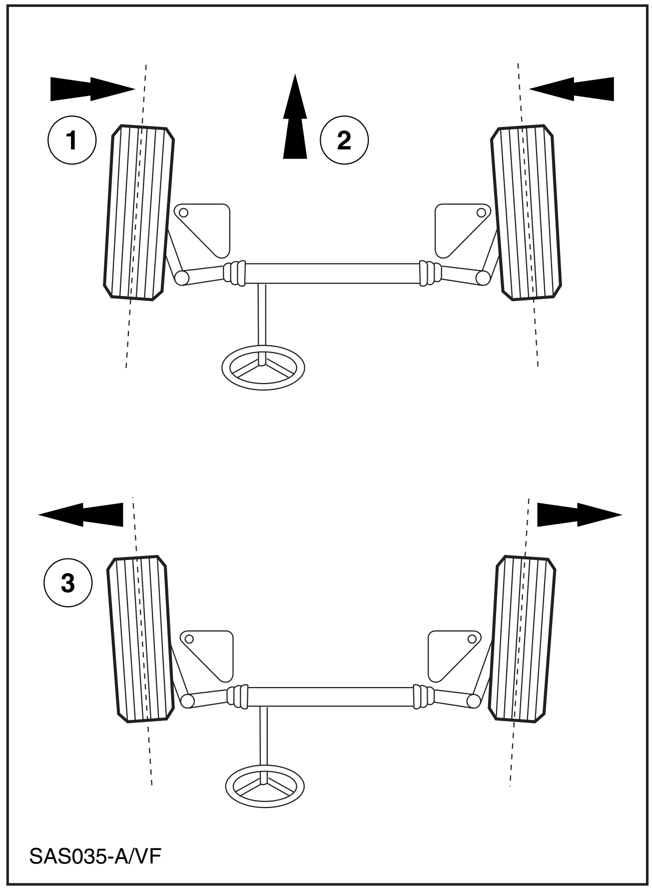
1 True vertical
2 Negative camber
3 Positive camber

Toe

Toe measures the difference in distance between the front of the two front tires and the rear of both front tires. Toe can be measured in millimeters, inches, degrees or minutes or seconds. There are three possible toe settings:

- Positive toe is when the front of the tires are closer together than the rear of the tires.
- Negative toe is when the front of the tires are farther apart than the rear of the tires.
- Neutral toe is when the front and rear of the tires are the same distance apart.

The purpose of toe is to keep the tires in a straight line with each other as they roll down the road. Toe helps to control the vehicle and get more life from the tires. Camber and caster adjustments and other driving forces tend to turn the tires outward when the vehicle is moving. Toe-in or toe-out adjusts for these forces.



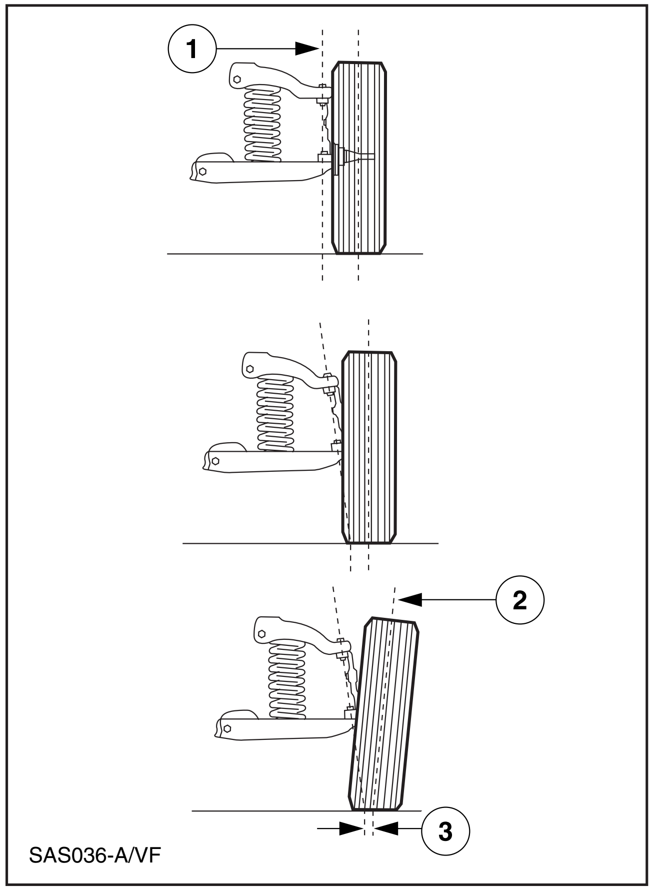
Toe angle

1 Positive toe
2 Direcion of vehicle travel
3 Negative toe

Alignment measurements (continued)

Scrub radius

Scrub radius is the distance between the steering axis centerline and the tire centerline. Scrub radius affects ease of steering and the amount of road shock felt by the driver through the steering wheel. As the vehicle turns right or left, the tires tilt outward on a right-hand turn and inward during a left-hand turn. Correct tire scrub reduces the amount of sideways drag on the front tires when going around corners.

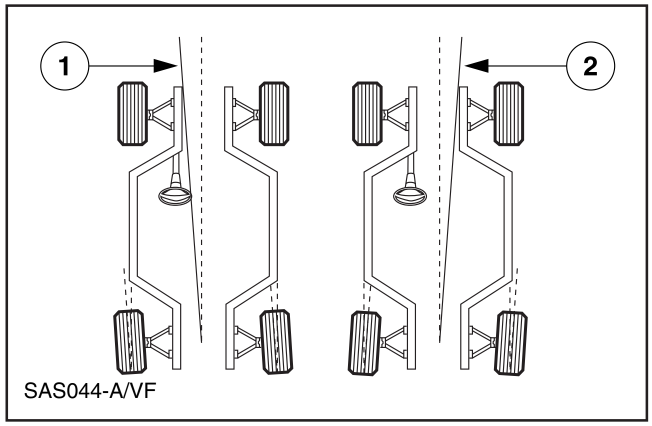


Scrub angle location

1 Steering axis inclination
2 Camber
3 Scrub radius

Thrust angle

Thrust angle is the angle between the vehicle's centerline, a line that goes through the exact center of the front and rear axles, and the vehicle's thrust line. The thrust line is the direction the rear axle would travel if the front wheels did not adjust. A properly aligned vehicle will travel straight down the road, with the rear wheels following or tracking directly behind the front wheels. Improperly aligned rear wheels cause thrust angle error and can make the vehicle appear to be traveling sideways, while moving straight down the road. In an ideal alignment, both sides of the vehicle's wheels are moving in a straight line with the vehicle centerline. Rear-wheel drive vehicles rarely need adjustment unless they have been in an accident or driven very hard.



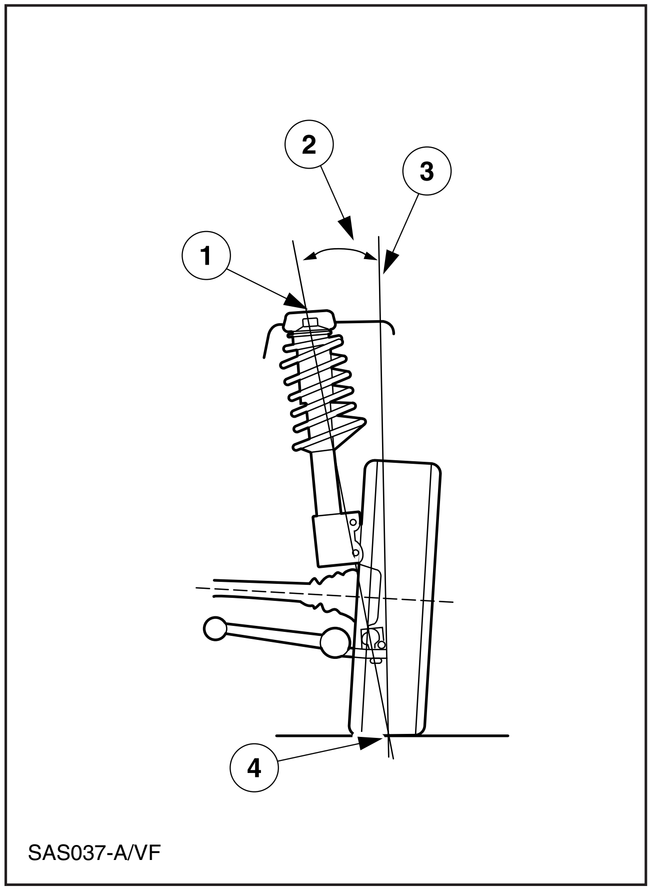
Thrust angle location

1 Left thrust angle
2 Right thrust angle

Alignment measurements (continued)

Steering axis inclination (SAI)

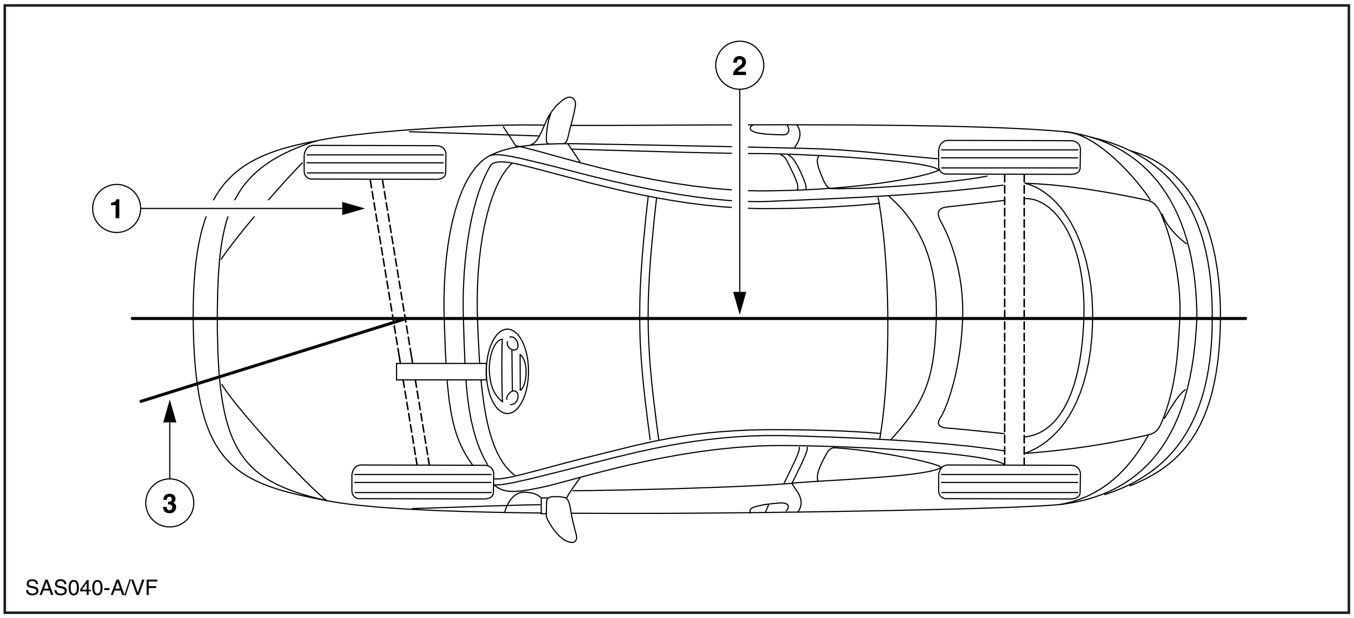
Steering Axis Inclination (SAI), sometimes called ball-joint or kingpin inclination, is the tilt of the steering axis when viewed from the front of the vehicle. To determine the SAI, draw an imaginary line through the center of the steering component. The angle between this line and true vertical is the SAI. Steering axis inclination is similar to caster angle in that both are concerned with steering axis angle. Unlike caster, steering axis inclination is not adjustable, except by replacing steering linkage components. As with caster, the vehicle's weight on the steering axis helps the wheels stay in the straight-ahead position and return to center when coming out of a turn. Because SAI is greater than caster angle, it has an even greater effect on direction control. When the SAI is correct, the steering axis centerline extends down to a point near the center of the tire's road contact area. Correct SAI causes less tire scrubbing on turns, reducing tire wear and the amount of effort needed to steer.



Steering axis inclination (SAI) location

1 Steering axis centerline
2 Steering axis inclination
3 True vertical
4 Pivot point

Setback



Setback location

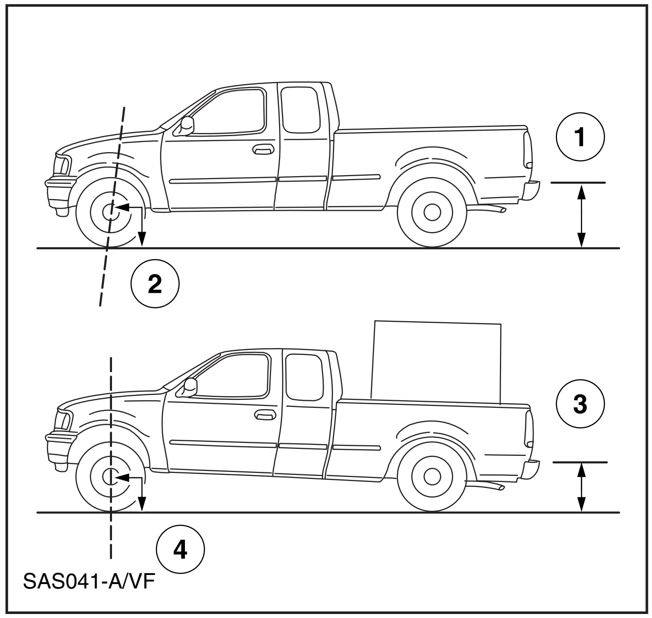
1 Front axle centerline
2 Vehicle centerline
3 Setback angle

Setback is the measurement between the right front and right rear tires compared to the measurement from the left front and left rear tires. The difference between these measurements is the setback. Incorrect setback will cause quick tire wear and poor steering.

Alignment measurements (continued)

Ride height

Ride height is the distance between the upper surface of the front axle and the rear axle at a specified point directly above the axles. Differences in ride height from front to rear affect caster angle, while differences in ride height from side to side affect camber angle. Ride height is an especially important factor when aligning light trucks. Most alignment specifications for light trucks are based on a range of ride heights. Always measure ride height and compare the measurements to specifications before making caster, camber and toe adjustments.

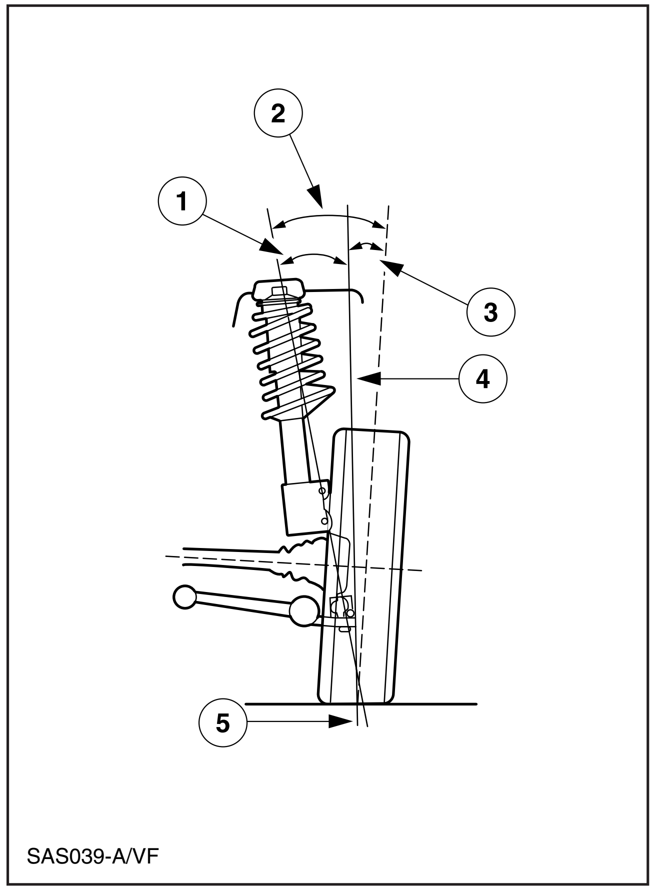


Vehicle weight and the effect on caster

1 No load height
2 Unloaded vehicle caster angle
3 Loaded height
4 Loaded vehicle caster angle

Included angle

The included angle is found by adding the camber angle and the steering axis inclination (SAI) angle. The included angle shows the relationship between the steering axis position and the spindle. If the camber angle is negative, the included angle is smaller than the SAI. If the camber angle is positive, the included angle is larger than the SAI. Understanding this relationship can help you determine if a vehicle has a bent spindle or strut.



Included angle location

1 Steering axis inclination
2 Included angle
3 Positive camber angle
4 True vertical
5 Scrub radius

Objective

Upon completion of this lesson, you will be able to:

- Explain the Symptom-to-System-to-Component-to-Cause diagnostic procedure and provide an example.

Symptom-to-system-to-component-to-cause diagnostic procedure diagnosis

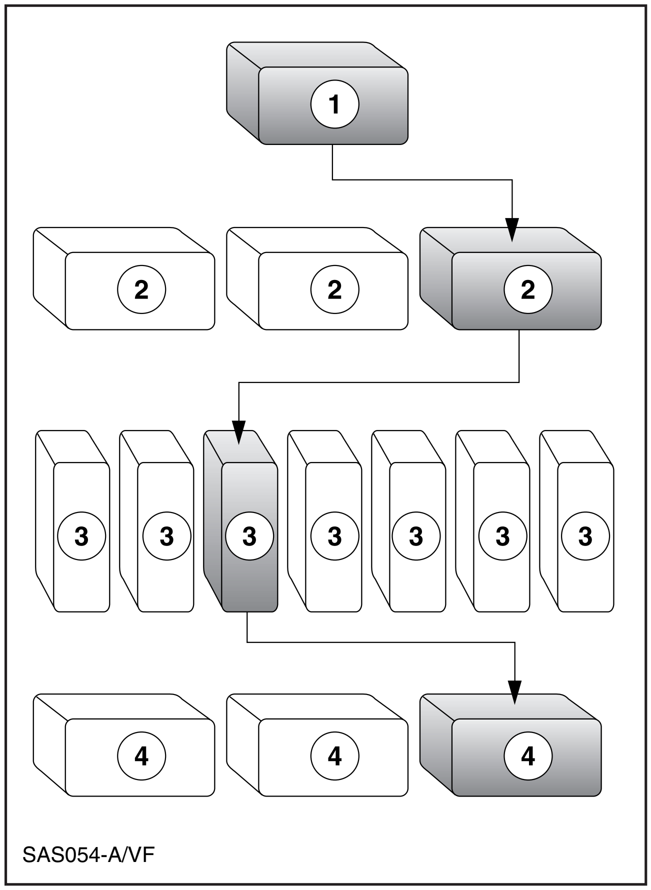
Diagnosis requires a complete knowledge of the system operation. As with all diagnosis, a technician must use symptoms and clues to determine the cause of a vehicle concern. To aid the technician when diagnosing vehicles, the strategies of many successful technicians have been analyzed and incorporated into a diagnostic strategy and into many service publications.

Symptom-to-system-to-component-to-cause diagnostic method

Using the "Symptom-to-System-to-Component-to Cause" diagnostic routine provides you with a logical method for correcting customer concerns:

- First, confirm the "Symptom" of the customer's concern.
- Next, you want to determine which "System" on the vehicle could be causing the symptom.
- Once you identify the particular system, you then want to determine which "Component(s)" within that system could be the cause for the customer concern.
- After determining the faulty component(s) you should always try to identify the cause of the failure. In some cases parts just wear out. However, in other instances something other than the failed component is responsible for the problem.

For example, the vehicle complaint or symptom is excessive front axle tire wear. If the technician replaces the front tires the problem may disappear for a short time. By finding the system (such as the suspension system) and repairing the faulty components in the system which are causing premature tire wear (like worn shock absorbers), the problem is permanently corrected the first time.



1 Symptom
2 Vehicle systems
3 Components
4 Causes

Workshop manual

The vehicle Workshop Manual contains information for the following diagnostic steps and checks such as: preliminary checks, verification of customer concern, special driving conditions, road test, and diagnostic pinpoint tests

Aquaplane	Hydroplane
DOT	**D**epartment **o**f **T**ransportation
Gear box	Steering gear
Hydroplane	Aquaplane
Positive toe	Toe-in
Negative toe	Toe-out
SAI	**S**teering **A**xis **I**nclination
SSCC	**S**ymptom-to-**S**ystem-to-**C**ause-to-**C**omponent